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Number of Papers Included in these Proceedings per Country

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Country	# Papers	%
TOTAL	213	100%
United States	42	19,72%
Japan	11	5,16%
Latvia	11	5,16%
South Korea	11	5,16%
Germany	10	4,69%
China	8	3,76%
India	8	3,76%
Taiwan	8	3,76%
Canada	7	3,29%
Czech Republic	7	3,29%
Turkey	7	3,29%
France	6	2,82%
Italy	6	2,82%
Mexico	6	2,82%
Spain	6	2,82%
Australia	5	2,35%
Brazil	5	2,35%
Israel	5	2,35%
United Kingdom	5	2,35%
Lithuania	4	1,88%
Croatia	3	1,41%
Denmark	3	1,41%
Egypt	3	1,41%
Poland	3	1,41%
Finland	2	0,94%
Greece	2	0,94%
Iran	2	0,94%
Malaysia	2	0,94%
Slovakia	2	0,94%
Austria	1	0,47%
Belgium	1	0,47%
Colombia	1	0,47%
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Foreword

Our purpose in the 15th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2011) is to provide, in these increasingly related areas, a multi-disciplinary forum, to foster interdisciplinary communication among the participants, and to support the sharing process of diverse perspectives of the same transdisciplinary concepts and principles.

Systemics, Cybernetics and Informatics (SCI) are being increasingly related to each other in almost every scientific discipline and human activity. Their common transdisciplinarity characterizes and communicates them, generating strong relations among them and with other disciplines. They work together to create a whole new way of thinking and practice. This phenomenon persuaded the Organizing Committee to structure WMSCI 2011 as a multi-conference where participants may focus on one area, or on one discipline, while allowing them the possibility of attending conferences from other areas or disciplines. This systemic approach stimulates cross-fertilization among different disciplines, inspiring scholars, originating new hypothesis, supporting production of innovations and generating analogies; which is, after all, one of the very basic principles of the systems' movement and a fundamental aim in cybernetics.

WMSCI 2011 was organized and sponsored by the International Institute of Informatics and Systemics (IIIS), member of the International Federation for Systems Research (IFSR). IIIS is an organization dedicated to contribute to the development of the Systems Approach, Cybernetics, and Informatics potential, using both: knowledge and experience, thinking and action, for the:

a) identification of synergetic relationships among Systemics, Cybernetics and Informatics, and between them and society;
b) promotion of contacts among the different academic areas, through the transdisciplinarity of the systems approach;
c) identification and implementation of communication channels among the different professions;
d) supply of communication links between the academic and professional worlds, as well as between them and the business world, both public and private, political and cultural;
e) stimulus for the creation of integrative arrangements at different levels of society, as well as at the family and personal levels;
f) promotion of transdisciplinary research, both on theoretical issues and on applications to concrete problems.

These IIIS objectives have directed the organizational efforts of yearly WMSCI/ISAS conferences since 1995.

On behalf of the Organizing Committee, I extend our heartfelt thanks to:

1. the 496 members of the Program Committee from 69 countries;
2. the 821 additional reviewers, from 86 countries, for their **double-blind peer reviews**;
3. the 529 reviewers, from 68 countries, for their efforts in making the **non-blind peer reviews**. (Some reviewers supported both: non-blind and double-blind reviewing for different submissions).

A total of 2461 reviews made by 1350 reviewers (who made at least one review) contributed to the quality achieved in WMSCI 2011. This means an average of 6.29 reviews per submission (391 submissions were received). *Each registered author had access, via the conference web site, to the reviews that recommended the acceptance of their respective submissions.* Each registered author could also get information about: 1) the average of the reviewers evaluations according to 8 criteria, and the average of a global evaluation of his/her submission; and 2) the comments and the constructive feedback made by the reviewers, who recommended the acceptance of his/her submission, so the author would be able to improve the final version of the paper.

In the organizational process of WMSCI 2011, about 391 papers/abstracts were submitted. These pre-conference proceedings include about 193 papers that were accepted for presentation from 40 countries. I extend our thanks to the invited sessions' organizers for collecting, reviewing, and selecting the papers that will be presented in their respective sessions. The submissions were reviewed as carefully as time permitted; it is expected that most of them will appear in a more polished and complete form in scientific journals.

This information about WMSCI 2011 is summarized in the following table, along with the other collocated conferences:

Conference	# of submissions received	# of reviewers that made at least one review	# of reviews made	Average of reviews per reviewer	Average of reviews per submission	# of papers included in the proceedings	% of submissions included in the proceedings
WMSCI 2011	**391**	**1350**	**2461**	**1.82**	**6.29**	**193**	**49.36%**
IMETI 2011	**212**	**679**	**1431**	**2.11**	**6.75**	**88**	**41.51%**
IMSCI 2011	**276**	**856**	**2104**	**2.46**	**7.62**	**124**	**44.93%**
CISCI 2011	**388**	**973**	**2359**	**2.42**	**6.08**	**173**	**44.59%**
TOTAL	**1267**	**3858**	**8355**	**2.17**	**6.59**	**578**	**45.62%**

We also extend our gratitude to the focus symposia organizers, as well as to the co-editors of these proceedings, for the hard work, energy and eagerness they displayed preparing their respective sessions. We express our intense gratitude to Professor William Lesso for his wise and opportune tutoring, for his eternal energy, integrity, and continuous support and advice, as the Program Committee Chair of past conferences, and as Honorary President of WMSCI 2011, as well as for being a very caring old friend and intellectual father to many of us. We also extend our gratitude to Professor Belkis Sanchez, who brilliantly managed the organizing process.

Our gratitude to Professors Bela H. Banathy, Stafford Beer, George Klir, Karl Pribram, Paul A. Jensen, and Gheorghe Benga who dignified our past WMSCI conferences by being their Honorary Presidents. Special thanks to Dr. C. Dale Zinn and Professor Jorge Baralt for co-chairing WMSCI 2011 Program Committee and to professors Andrés Tremante and Belkis Sánchez for co-chairing the Organizing Committee. We also extend our gratitude to Drs., Louis H. Kauffman, Leonid Perlovsky**,** Stuart A. Umpleby, Thomas Marlowe**,** Ranulph Glanville, Karl H. Müller, Shigehiro Hashimoto, T. Grandon Gill, Alec Yasinsac, Marta White Szabo**,** Jeremy Horne, Mario Norbis, Ham Chan, Felix Soto-Toro, Susu Nousala, and Dipl.-Math Norbert Jastroch**,** for accepting to address the audience of the General Joint Plenary Sessions with keynote conferences.

Many thanks to Drs. Dale Zinn, Jorge Baralt, Hsing-Wei Chu, Andrés Tremante, Friedrich Welsch, Thierry Lefevre, José Vicente Carrasquero, Angel Oropeza, and Freddy Malpica for chairing and supporting the organization of the focus symposia and conferences in the context of, or collocated with, WMSCI 2011. We also wish to thank all the authors for the quality of their papers.

We extend our gratitude as well to Maria Sanchez, Juan Manuel Pineda, Leonisol Callaos, Dalia Sánchez, Keyla Guedez, Nidimar Díaz, Marcela Briceño, Cindi Padilla Louis Barnes, Sean Barnes, Marisela Jiménez, Noraima Castellano, Abrahan Marin, and Freddy Callaos for their knowledgeable effort in supporting the organizational process producing the hard copy and CD versions of the proceedings, developing and maintaining the software supporting the interactions of the authors with the reviewing process and the Organizing Committee, as well as for their support in the help desk and in the promotional process.

Professor Nagib C. Callaos
WMSCI 2011 General Chair

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International Symposium on Models and Modeling Methodologies in Science and Engineering: MMMse 2011
The 2nd International Symposium on Design and Research In Artificial and Natural Sciences: DRANS 2011
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Optimal development of textile products using Genetic Algorithms

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ABSTRACT

This paper talks about the design new textile products from technical features proposed by the customer. It is an optimization case where the objective function is to minimize the overall costs subject to restrictions on the technical specifications like the raw material, the stress of the warm and/or the fill of the woven or the minimal or maximal weight per unit of the product. The decision variables are the technical parameters with which the product will be developed such as the yarn specifications, the density of the woven, and the percentile of the finishing substances. First, the mathematical model is presented and then it is applied to the requirements of a technical textile factory. The problem is solved by a genetic algorithm whose initial population is obtained from existing similar products, relaxing the specifications. The population is updated only with the new solutions with better objective function value than the best one of the previous population. One concludes that the problem is a nonlinear mixed integer programming case, that the genetic algorithm is a low computational way to solve it and that the further jobs can apply other meta-heuristics or exact methods to solve the problem.

Keywords: Product Design, Nonlinear Programming, Evolutionary Algorithms, Meta-heuristics, Textile Industry.

1. INTRODUCTION

The competitive conditions of the market and the quick changes of the business environment make necessary to be productive and effective in the process of design of new products and to answer to the customer needs as soon as possible. The traditional ways of develop new products by proof and error and the prototype construction with high costs and long answer times, are revaluated in order to be fast and efficient in the responses to the requests of the market. This research is about a procedure to develop new textile products based on technical customer requirements. The problem is a combinatorial nonlinear programming case. The costumer gives the upper and lower bounds to the physical attributes of the fabric to be produced.

The objective function is a function of minimization of production costs (or any related variable). The constraints are given by the specific needs of the costumer about the specific features of the desired product. The mathematical expressions match with the way to put together the raw material, the technical conditions, the conditions of the factory and the available production resources.

2. STATE OF THE ART

The optimal product design problem has been treated recently (in the last fifteen years) by different optimization technics. Hsiao (1998) [3] and Liu (2011) [6] worked in fuzzy logic. Alexouda & Paparrizos (2001) [2] made a computational comparative study and proposed a genetic algorithm to solve the problem. Tarasewich & McMullen (2001) [7] boarded the theme by a heuristic method. Lai et al (2006) [5] worked in a neural network approach. Albritton & Mcmullen (2007) [1] proposed an ant colony algorithm. Wang et al (2009) [8] developed agent-based collaborative system. All these works are focused in the marketing conditions and the commercial features of the products. Their scope was to design products for the final customer and the main requirements were related to the esthetic properties and the perception of the customer about the product. This work, instead, is about the optimization of the physical features and the technical conditions of textile products for industrial use with minimal overall costs.

3. CONTRIBUTION OF THIS WORK

This work presents an optimal product design case of intermediate textile products with quantitative conditions. The theoretical contributions are the development of the mathematical model for the textile industry and the application of the optimal design to industrial use products. The practical contribution of this research is the use of the model to the technical textiles production and the development of the genetic algorithm to solve this problem.

4. MATHEMATICAL MODEL

In the technical textile industry, the products are fabrics whose characteristics most relevant to the customer are the weight and tensile strength in both: warp (lengthwise) and weft (widthwise). In some cases, the customer may specify a particular textile fiber as raw material for the weft, the warp or the whole product. There may also be constraints about the finishes applied to the finished product. In the other hand, the company has a specific set of production capacity with different efficiency levels according to the products.

Because in the technical textile industry, the costs, most of the times, are directly related to the overall weight of the product, the objective function is about the overall costs of the raw material to be minimized. The raw material and the production process are generally cheaper when the fabric is lighter. The constraints are given by the customer needs for the industrial use of the product.

The overall model is the following:

$$\text{Minimize Overall Cost } z = \sum_{i=1}^{5} Cm_i x_i \quad (1)$$

Subject to:

$$r_1 * x_1 \geq l_1 \quad (2)$$

$$r_2 * x_2 \geq l_2 \quad (3)$$

$$100 * \big((x_4 * x_2) + (x_3 * x_1)\big) * (1 + x_5) \leq h_3 \quad (4)$$

Where:

Cm_i: Unit cost of the i resource

x_1: Feature of resource 1 (discrete)

x_2: Feature of resource 2 (discrete)

x_3: Use rate of resource 1 (discrete)

x_4: Use rate of resource 2 (discrete)

x_5: Adding factor of resource 5 (between 0 and 1). (continue)

r_1: Unit property of resource 1.

r_2: Unit property of resource 2.

l_1: Client requirement for property 1 in resource 1.

l_2: Client requirement for property 2 in resource 2.

h_3: Client requirement for overall property of product.

r_1 values are in function of x_1.

r_2 values are in function of x_2.

Although the objective function is a linear expression, the model is a nonlinear programming problem because the mathematical form of the constraints. The encoding is mixed between continuous and discrete variables. x_1, x_2, x_3, x_4 are discrete variables because the possible values of each one are limited to a finite set of numbers, given by the features of the raw materials and the technical bounds of the machinery.

The detailed actual meaning of x_1, x_2, x_3, x_4 variables and l_1, l_2, r_1, r_2 and h_3 parameters has been intentionality hide to preserve the confidentiality of the internal know-how of the company where the research was made.

The conditions of the model make necessary to find solution procedures of good performance, low computational costs and good quality results.

5. SOLUTION ALGORITHM

To solve this problem, we propose a genetic algorithm, to arrive at a solution of very good quality at a reasonable computational cost. The efficiency of the algorithm is very important because of their habitual use in the development of new products. One wants to minimize the answer time to the customer.

The following is the description of the steps of the proposed solution algorithm:

Initial population
The selection of the initial population starts with an exploration of the preexisting products with similar features to those required. In first place, the system will search the products with the features as the customer requested. If there are not products that match the costumer conditions, the system will relax the conditions by 10% in both sides (maximum and minimum). If there aren't at least 7 products, the system will relax another 10%, and the cycle is repeated until there is at least 7 individuals in the population or reaches 100% of relaxation (whichever comes first). Each member of the population will be a solution vector of n elements (n = variables of the model). Each item indicates the value that will take the corresponding variable.

Parent Selection
To make the fitness function to select parents, the objective function is evaluated at each solution vector components of the population. It also assesses compliance with the constraints. If it fails, it penalizes the objective function value by adding the value of default multiplied by the size of the population. Therefore, the individuals that not match the constraints will have less chance to be selected as parents.

For each solution is calculated as an indicator to 1 on the value of the objective function evaluated with the specified resource allocation. With the values of the indicators produced by the "wheel", the parents are selected. Roulette is proportional to the contribution of each indicator in the sum of all indicators. Then, the system generates two random numbers between 0 and 1, to select two parents from the existing solution vectors. It compares the value of each random number with the sum of the indicators from the first to the under consideration until the random be greatest than the cumulative. At that point, the individual is selected as the solution vector corresponding parent.

Recombination
With a reduced quantity of variables (only 5), there is only one crossing point. The system generates a random number between 2 and 4 to determine where the crossing will be located within the solution vector. According to the location of the crossing will be inserted the values of both parents in the two children generated, starting with the values of the first parent in the first child and second-parent values in the second child until the crossing point where continue with the values of the second parent in the first child and the values of the first parent in the second child. The results are two children with mixed features of their parents.

Mutation
After many tests with different values, the best results were obtained with a mutation rate of 0.8. It means that the 80% of the times, the mutation will occur.

The system generates a random number between 0 and 1. If the value is below the fixed rate of mutation (0.8), is chosen at random a position within the "child" generated in the crossing. For this position, the system again generates a random number assigned to a new random value between the values that can make that variable. It recalculates the value of the objective function in the "child" affected by the mutation. The mutation procedure is repeated in the second child.

Update population
Given the small size of the population and to avoid of the “cloning” of the best individuals and to increase the search of the final solution, in the tests it was found that the children only can belong to the population if they improve the best objective function value previously known.

The element of the population with best objective function value (minimum) is compared with the value of the first "child". If the child is better than the best, the child will replace the worst individual of the population. The operation is repeated for the second "child". The system returns to the selection of parents.

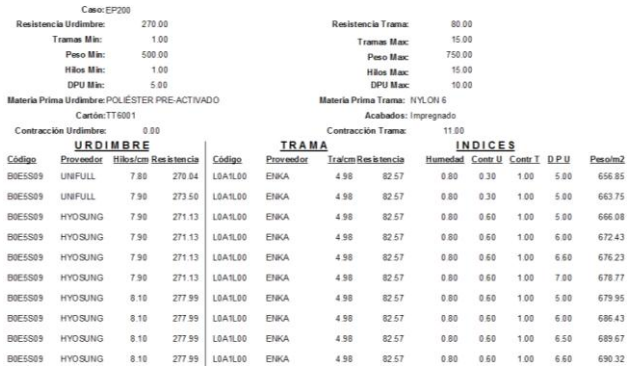
Stop Criterion
The process is repeated until after a number of generations equal to the product between the total sum of possible values for the variables of the warp and the sum of the possible values of variables of the weft. When completed the number of iterations will have a proposed list of settings to develop the new product. During the process, specifications are verified to consider avoiding incompatible resources in a single proposal.

The list of settings gives to the user a set of different possibilities to make the new product instead of a single solution. This can increase the effectiveness and consistency of the process.

6. RESULTS

The procedure was tested with real customer requests for a textile company. Figure 1 shows a sample of the input data and results. To test the algorithm, we used a computer program developed by the authors, integrated to the enterprise database of production scheduling, where the input came, fulfilling the desirable characteristics of optimization software, according to Johnson et al. (1992)

[4] . The average processing time was in the range of 4 to 5 minutes with about 100000 generations, 1 point crossover and a mutation factor of 0.8. In the textile company where the system was implemented, the algorithm complements the development activities involving trial and error before physically developing the product manuals or by taking multiple simulations in a spreadsheet. Detailed cost data are omitted intentionally, but it can be assumed that the total costs are proportional to Weight/m^2.



Caso: EP200

Resistencia Urdimbre:	270.00	Resistencia Trama:	80.00
Tramas Min:	1.00	Tramas Max:	15.00
Peso Min:	500.00	Peso Max:	750.00
Hilos Min:	1.00	Hilos Max:	15.00
DPU Min:	5.00	DPU Max:	10.00
Materia Prima Urdimbre:	POLIÉSTER PRE-ACTIVADO	Materia Prima Trama:	NYLON 6
Cartón:	TT6001	Acabados:	Impregnado
Contracción Urdimbre:	0.00	Contracción Trama:	11.00

URDIMBRE				TRAMA				INDICES				
Código	Proveedor	Hilos/cm	Resistencia	Código	Proveedor	Tra/cm	Resistencia	Humedad	Contr U	Contr T	D P U	Peso/m2
B0E5S09	UNIFULL	7.80	270.04	L0A1L00	ENKA	4.98	82.57	0.80	0.30	1.00	5.00	656.85
B0E5S09	UNIFULL	7.90	273.50	L0A1L00	ENKA	4.98	82.57	0.80	0.30	1.00	5.00	663.75
B0E5S09	HYOSUNG	7.90	271.13	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	5.00	666.08
B0E5S09	HYOSUNG	7.90	271.13	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	6.00	672.43
B0E5S09	HYOSUNG	7.90	271.13	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	6.60	676.23
B0E5S09	HYOSUNG	7.90	271.13	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	7.00	678.77
B0E5S09	HYOSUNG	8.10	277.99	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	5.00	679.95
B0E5S09	HYOSUNG	8.10	277.99	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	6.00	686.43
B0E5S09	HYOSUNG	8.10	277.99	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	6.50	689.67
B0E5S09	HYOSUNG	8.10	277.99	L0A1L00	ENKA	4.98	82.57	0.80	0.60	1.00	6.60	690.32

Fig. 1. Sample of requirements and results

7. CONCLUSIONS

This research work proposed the mathematical model and a solution algorithm to address the development of new textile products based on technical customer requirements. The model minimizes the overall cost subject to constraints on technical parameters and capacity.

The model was particularized for the specific case of design of technical textiles. This case is a mixed integer nonlinear model. The too many possible combinations of raw materials, production procedures and productive resources and limitations increase the complexity of the problem.

The genetic algorithm applied has mixed integer and real coding, initial population generated from features of pre-existing products, selection of parents by fitness function, random recombination for two children per generation, mutation by a factor of 0.8 on a variable in one or both children, Update population tournament between each child and the best member of the population, replacing the worst. The process is repeated until there are a number of generations equal to the product of the sums of the possible values for the variables of warp and weft.

Failure to comply with the constraints is penalized in the objective function multiplying the default by a factor equal to the size of the population.

The actual application of the model in a real textile factory is producing satisfactory results in appropriate computational times. Future studies can make comparisons of the results of the proposed algorithm with either exact or meta-heuristic methods such as those mentioned in the references.

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Remaining Life Evaluation of Power Plant Based on Strain Deformation Monitoring and Computational Diagnosis

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ABSTRACT

The present paper describes the development of a monitoring, analysis and diagnosis system of power plant equipments based on strain measurements. The objective is to help companies increase availability and reduce maintenance costs. The aim is the integrity evaluation of a main steam and a hot reheat steam piping through inspection, strain monitoring and computational diagnosis.

The benefits are, among others, reduction in the uncertainty of the remaining life prediction and reduction of work, through process automation and integration and real time monitoring (through the Internet) of the operational condition of the equipment. Thus, greater confidence and availability of the monitored generating unit is sought as well as cost reduction as a consequence of reduced frequency of unnecessary unit stops and greater speed in decision making due to more precise follow up of the operational condition of the target-equipment and of its remaining life.

Keywords: Integrity Evaluation, Strain, Monitoring and Diagnosis, Mathematical Modeling, Monkman Grant.

1. INTRODUCTION

Thermal plants all over the world are aging and their piping and components have a finite life due to long-term exposition to high temperatures, stresses and harsh environments. Aging and cyclic operation regime of thermal power plants point the necessity of life assessments of their components to ensure continued safe operation or recommend repairs and modifications that allow operation for a pre-determined period. These analyses have been recognized by the industry as extremely important since the assurance of safe operation, reduction of unnecessary shutdowns for inspection and maintenance, as well as reduction of the costs associated to the industrial power plants life-time extension have been highlighted as a world-wide trend.

Currently, the integrity evaluation is based on the analysis of temperature, and pressure data registered on a continuous data base over a period considered adequate by the station supervisor. Power generation in Brazil is mainly from hydroelectric stations, and the thermoelectric plants only operate in dry periods or at periods of maximum energy consumption. Considering the thermoelectric case, an estimation of its remaining life

based on non-automated reading of the records lead to high uncertainty due to the small number of points usually shown on the registers. Another problem is the fact that life calculation is made using averaged values of the data, particularly considering the cyclic nature of their operation.

In 2006, the materials and mechanical engineering teams at Electric Energy Research Center (CEPEL) joined their experiences to create a monitoring system for cycling operation thermal power plant [1]. The new applied methodology consists in on-line monitoring of temperature and pressure of those components more susceptible to creep failure and in which problems have been previously recorded. Based on data from measurements made by the implanted monitoring system and the inspections performed, prototype formulas were used to evaluate the remaining life of monitored components.

The intent was to attend the Brazilian electric companies demand for an automated monitoring system which could evaluate power plant component's remaining life based on pressure and temperature measurements collected by the monitoring system. The developed system is called Diaterm and was successfully concluded in 2008.

The remaining life of a component can also be calculated by strain measurements. In this case, the mathematical methodology is simpler and direct, reducing uncertainty, but strain measurements in the field are much more complex.

The damages that occur during creep are microstructural degradation, dislocation reordering and development of voids and microcracks which may lead to failure [2]. Monitoring and prognostic of damage accumulation rate are essential to elaborate life assessments.

The purpose of the project presented in this paper is to develop a computational tool for the measurement and diagnosis of operational conditions of components in thermoelectric stations, coupled to a structural integrity evaluation methodology based on strain measurements, in order to supply maintenance engineering with elements to help decision making.

2. REMAINING LIFE ESTIMATE METHODS

The principal degradation mechanism of steels in high temperature applications is creep, which is time-dependent, thermally assisted strain of components under stress. Creep of Cr-Mo ferritic steels initially involves the spheroidization and structural transformation of carbide precipitates and, at an advanced stage, results in the formation of voids and microcracks. Since life expectancy of components that work at high temperatures is, in most cases, based on the capacity of the material to maintain its creep resistance at high temperature for a period of at least twice the design life, methods to evaluate creep strength of the material based on physical changes taking place in it as well as robust methods for data extrapolation are necessary

In the first methodology developed by CEPEL in 2006 to estimate the remaining life of thermoelectric station components, the mechanical stress, operational temperature and time to rupture are related with the Larson-Miller Parameter (LMP) [3]. Each material has a master curve to estimate remaining life, represented by a plot of allowable (design) stress versus LMP. This curve is drawn using the ASME Code data [4] as shown in Figure 1.

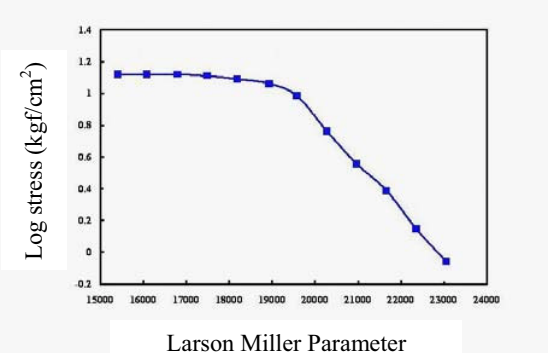


Figure 1: Master curve for SA-213 T22 steel (equivalent to DIN 10 CrMo910 steel).

The maximum permitted stress, σ, is calculated for actual operational conditions, according to the expression:

$$\sigma = (PD - 2Pye)/(2Ee) \quad (1)$$

where P is the actual working pressure, D is the actual pipe diameter, e is the actual wall thickness and y and E are parameters whose values depend on the material.

Once the maximum permitted stress is calculated, the LMP value is obtained from the master curve. With the known LMP value and considering that:

$$LMP = T[20 + \log(t_r)] \quad (2)$$

where T is the equipment working temperature (in Kelvin), then the time for rupture, t_r, is obtained. For a better estimation of the remaining life, this procedure should be repeated for each monitored condition of temperature and pressure. Robinson's rule [5] for accumulated damage is applied:

$$\sum_{i=1}^{n} t_i / t_{r_i} = \omega_1 \quad (3)$$

where n is the considered number of operational conditions, t_i is the working time in each condition and ω_1 is the spent life fraction. In this way, the remaining life can be calculated, assuming that the same proportion of different working temperatures is kept constant. Thus,

$$\left(\sum_{i=1}^{n} t_i / t_{r_i} \right) t = 1 - (\omega_1 + \omega_0) \quad (4)$$

where t is the remaining life time and ω_0 is the life fraction consumed at the beginning of monitoring. The value of ω_0 is obtained through inspection of the boiler at standstill, using metallographic techniques that allow a good estimation of spent life.

The techniques used for the estimation of ω_0 consider visual examination, microstructural evaluation through metallographic replicas, classification on this based on the Toft and Marsden criterion [6], hardness tests, and pipe thickness and diameter measurements.

In that methodology based on Larson and Miller Parameter, the monitoring system measures pressure and temperature.

A second methodology to evaluate high temperature components remaining life was developed by Monkman and Grant [7].

After several tests on different alloys, Monkman and Grant proposed an empirical relationship to predict the rupture time of materials exposed to creep conditions [7]:

$$\log(t_r) + m \log(\dot{\varepsilon}) = C \quad (5)$$

where t_r is the time for rupture, $\dot{\varepsilon}$ is the minimum creep rate measured in the secondary stage of creep, m and C are material constants obtained from experimental data fit from labaoratory creep tests. The relationship is obtained over a wide range of strength levels and test conditions. Figure 2 presents the Monkman-Grant relationship between minimum creep rate and time to rupture fot the 2.25Cr-1Mo steel.

Once a minimum creep rate has been determined in a low-stress test, rupture life can be estimated without running the test to failure. For materials where good fit is obtained to a single linear plot on the coordinates of log time versus log secondary creep rate, extrapolation of a known secondary creep rate to the corresponding rupture life appears to be good or better than by other extrapolation methods.

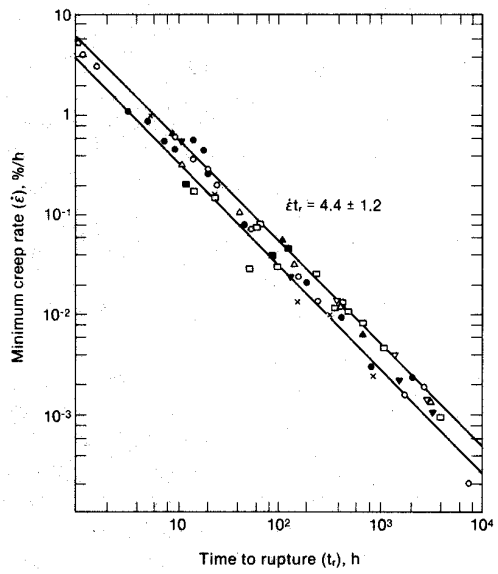


Figure 2: Monkman-Grant relationship between minimum creep rate and time to rupture for 2.25Cr-1Mo steel [8].

In field components where the creep rate may be obtained directly from installed strain gages, it is possible to estimate the rupture life using the Monkman-Grant relationship.

As the data can be collected in real time, all the operational changes can be analyzed. These changes lead to different creep rates, thus different levels of creep damage can be generated in the component. For a better estimate of remaining life, this procedure should be repeated for each monitored condition of temperature and creep rate. Robinson's rule [5] for accumulated damage is then applied, according to equation (4). The technique to estimate ω_0 is the same as before, involving visual examination, microstructural evaluation through metallographic replicas, hardness tests, pipe thickness and diameter measurements.

3. FIELD STRAIN MEASUREMENTS

Creep strain monitoring has been a non-destructive method to evaluate remaining life. Hence, strain gages must be robust in order to support the aggressive conditions and the high temperature of a thermal power plant (over 450°C). A great variety of strain gages of different specifications is available in the market. Some factors should be taken into consideration when selecting strain gages: temperature range, maximum current and

maximum strain limit; otherwise, inadequate choices may lead to erroneous measurements.

The ASTM E1319-98 [9] standard claims that capacitance strain gages are the most indicated to measure creep strain and are not affected by variations of temperature, oxidation, relaxation and phase transformations in materials susceptible to strain. Moreover, the standard suggests that these factors may cause variations in resistance strain gages, and then these models may not be indicated to long term measurements.

However, the literature disagrees on what model best suits the conditions of an industrial plant. Baumann e Schulz [10] stated that capsulated resistance strain gages can be successfully used at temperatures above 400º C in long term measurements. The authors also observe that the criteria to select of the most adequate strain gage are maximum temperature, time measurement and environment conditions. Tests with a capsulated resistance model have also been done by EPRI [11]. Several manufacturers, however, state that bonded weldable resistance strain gages respond better to creep conditions and can be employed to measure strains in aggressive conditions, such as the ones in thermal power plants and refineries.

In function of these doubts, a project to test three strain gage models was developed. The aim of the project was to compare and contrast the performance of two high temperature resistance strain gages and one capacitance strain gauge through creep and tensile tests. Based on the results, the sensor that presents the best characteristics related to strength, stability and precision in measurements would be installed on a steam piping of a thermal power plant. Based on the laboratory results, it could be concluded that the capsulated strain gage suits better the parameters chosen in the research such as precision, stability and strength. This strain gage was selected and installed in the field as part of the real-time monitoring system, which estimates the residual life of the components.

Another decision to be taken during the project, was to select the component that should be monitored. The selected component was sought to provide the necessary conditions to act as a field laboratory where the essential quantities needed to calculate remaining life could be monitored and software and methodologies developed during the project could be tested and adapted. This component should:

- operate at temperatures higher than 500ºC in order to guarantee typical degradation mechanisms of equipment working at high temperatures, such as creep, thermal fatigue and high temperature corrosion;
- be available (out of service) for at least 20 days in order to install measuring devices and the data collection system;
- be available once a year for non-destructive inspection (boiler open and cold) and for taking of metallographic replicas.

In order to meet the above conditions, the main steam and the hot reheat steam piping of Boiler 3 of Unit B from the Presidente Médici Thermoelectric Station, were selected as the field laboratory, through a partnership agreement between CEPEL, CGTEE, CHESF, Eletrobrás, Eletronorte and Furnas. Figure 3 shows the schematic drawings of the main steam and hot reheat steam piping which have been operating for 100,372 hours with a nominal pressure of 175.4 kgf/cm² and nominal temperature of 538ºC, and a nominal pressure of 7.4 kgf/cm² and nominal temperature of 536ºC, respectively. Both piping were manufactured in 2.25Cr-1Mo steel.

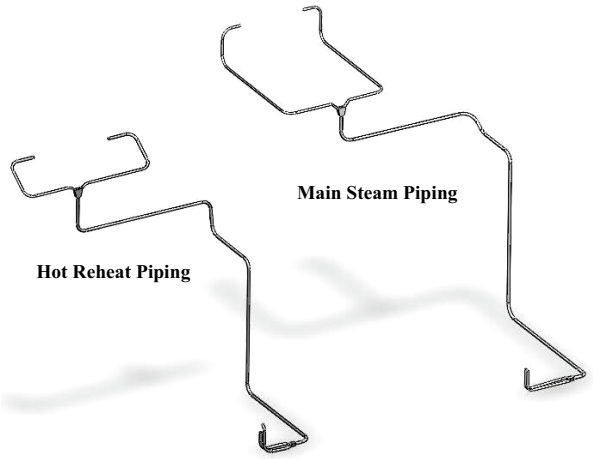


Figure 3: General view of main steam and reheat steam piping from Presidente Médici B Power Station.

The strain gages were installed directly in both piping in the positions of higher stresses, where higher strains are expected. Finite element analyses in both lines, turned possible the identification of the higher stress position in the components. Figure 4 shows a strain gauge couple welded in the steam piping.



Figure 4: Strain gages welded in main steam piping from Presidente Médici B station.

4. THE MONITORING SYSTEM

The process of calculating remaining life, when made manually, is difficult and slow, leading to error and imprecision. Therefore, an automated process becomes necessary, using a real time monitoring system tool.

The system used, named Monitermo, was developed at CEPEL, and is based on WEB technology, Postgres data bank and Field Point platform, from National Instruments, for data acquisition. The main steam piping has 65 temperature points and 18 strain gages welded in critical locations. The hot reheat steam piping has 43 temperature points and 16 strain gages welded in critical locations. Pressure data collected at the entry of both piping and turbine power generation are also monitored. Data are stored periodically in a data bank that can be accessed via internet. Real time data (on-line) can also be observed on the net, since they are renewed every minute.

In Figure 5, it is possible to see an example of the Monitermo system screen, where strain versus time have been monitored during 3 days. Figure 6 shows another screen example where is possible to see the temperature and strain in each monitored part of the piping. Temperatures lower than 530°C are shown in a green box, temperatures higher than 555°C are presented in a red box. Strains lower than 5,000με are shown in green, from 5,000 to 8,000με are shown in yellow and above 8,000με, red. The red box works as an alarm telling the engineering group that the piping is working in non secure conditions.

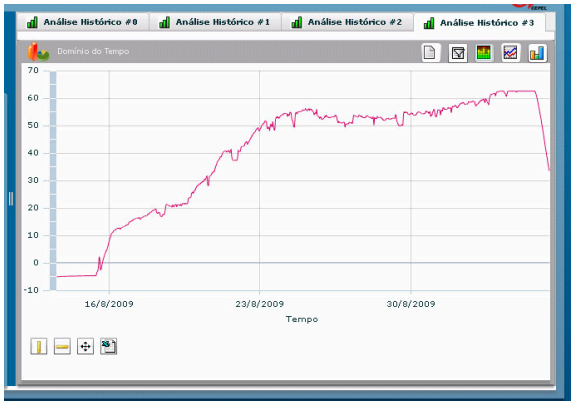


Figure 5: Screens of Monitermo monitoring system: Strain versus time (days)

Using the measurements recorded in the data bank, the remaining life of each monitored component is calculated by means of a prototype program developed using the methodology presented in Section 2 of the present work. The output screens with the remaining life results are shown in Figures 7 and 8 for the main steam piping and for the hot reheat steam piping, respectively.

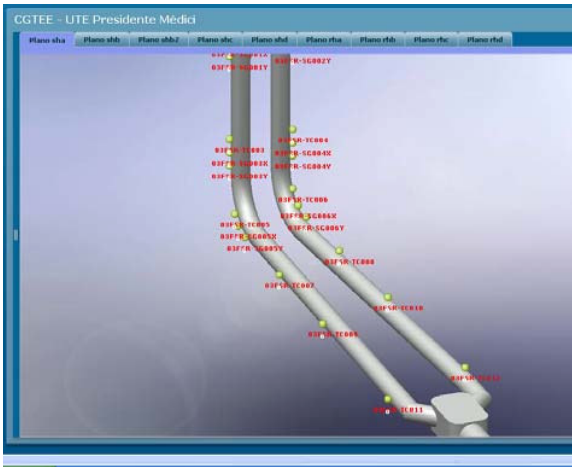


Figure 6: Screens of Monitermo monitoring system: strains and temperatures in a section of the main steam piping.

Both piping have been monitored since January 2009. It is possible to see that most part of the points which creep strain is being monitored by strain gages present different accumulated damages. Due to the geometrical arrangement of the piping and their supports in the plant, different stress levels can be generated in the component. It is also shown that some points in both piping have already reached an accumulative damage higher than 1, which implies in the end of the useful life in that part of the piping. These points must be carefully checked by the maintenance team at the power plant in order to guarantee a safe operation.

TAG	Accumulated Damage	Remaining Life (hours)	Remaining Life (%)	Calculation Method
03FSR-SG001X	0.59	1.00e+3	40.52	Monkman-Grant
03FSR-SG001Y	0.61	1.10e+3	38.96	Monkman-Grant
03FSR-SG002X	1.42	0.00e-16	0.00	Monkman-Grant
03FSR-SG002Y	0.60	1.30e+3	39.94	Monkman-Grant
03FSR-SG003X	1.29	0.00e-16	0.00	Monkman-Grant
03FSR-SG003Y	0.67	8.83e+2	33.02	Monkman-Grant
03FSR-SG004X	0.60	5.01e+2	40.44	Monkman-Grant
03FSR-SG004Y	0.66	8.79e+2	33.91	Monkman-Grant
03FSR-SG005X	0.58	8.81e+2	42.00	Monkman-Grant
03FSR-SG005Y	1.91	0.00e-16	0.00	Monkman-Grant
03FSR-SG006X	0.78	5.89e+2	21.62	Monkman-Grant
03FSR-SG006Y	0.79	6.01e+2	20.79	Monkman-Grant
03FSR-SG007X	0.73	6.22e+2	27.13	Monkman-Grant
03FSR-SG007Y	0.72	5.77e+2	27.64	Monkman-Grant
03FSR-SG008X	0.57	7.48e+4	43.00	Monkman-Grant
03FSR-SG008Y	0.57	7.48e+4	43.00	Monkman-Grant
03FSR-SG009X	0.57	7.48e+4	43.00	Monkman-Grant
03FSR-SG009Y	0.57	7.48e+4	43.00	Monkman-Grant

Figure 7: Monitermo's screen with remaining life calculation of the main steam piping.

TAG	Accumulated Damage	Remaining Life (hours)	Remaining Life (%)	Calculation Method
03FRS-SG001X	0.55	7.66e+2	45.16	Monkman-Grant
03FRS-SG001Y	0.54	2.40e+3	45.85	Monkman-Grant
03FRS-SG002X	0.55	1.55e+3	45.31	Monkman-Grant
03FRS-SG002Y	0.54	2.21e+3	45.86	Monkman-Grant
03FRS-SG003X	0.70	6.95e+2	30.49	Monkman-Grant
03FRS-SG003Y	0.67	1.16e+3	33.35	Monkman-Grant
03FRS-SG004X	0.54	1.30e+3	45.56	Monkman-Grant
03FRS-SG004Y	0.54	1.35e+3	45.69	Monkman-Grant
03FRS-SG005X	0.65	7.99e+2	35.25	Monkman-Grant
03FRS-SG005Y	0.54	1.98e+3	45.80	Monkman-Grant
03FRS-SG006X	0.68	7.71e+2	32.34	Monkman-Grant
03FRS-SG006Y	0.68	5.42e+2	31.86	Monkman-Grant
03FRS-SG007X	3.71	0.00e-16	0.00	Monkman-Grant
03FRS-SG007Y	1.51	0.00e-16	0.00	Monkman-Grant
03FRS-SG008X	0.66	5.25e+4	34.00	Monkman-Grant
03FRS-SG008Y	0.66	5.25e+4	34.00	Monkman-Grant

Figure 8: Monitermo's screen with remaining life calculation of the hot reheat steam piping.

4. CONCLUSIONS

The methodology to calculate the remaining life of components on thermoelectric stations presented in this work has the following advantages:

- use of a criteria already established and accepted by the scientific community;
- use of high temperature strain gages to obtain strain rates in the component. These strain rates are used to calculate the remaining life through the the Monkman and Grant criteria.
- taking information from field inspection and operational registers as database, greatly reducing the conservatism adopted on the design codes;
- applicability to cyclic operating conditions, at different pressures, strains and temperatures, the prevailing operating regime in the Brazilian thermoelectric stations.

The use of a monitoring system in real time gives a faster response, allowing more precise remaining life calculations through reduction of errors from the manual method and refinement of the data used. Also, it can be used by the maintenance team as a powerful tool for decision making.

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ENDOMYCORRHIZAL INOCULATION EFFECT ON OAT (*Avena sativa* L.), BEANS (*Phaseolus vulgaris* L.), AND WHEAT (*Triticum aestivum* L.) GROWTH CULTIVATED IN TWO SOIL TYPES UNDER GREENHOUSE CONDITIONS

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SUMMARY

The objective of this research was to evaluate the effect of inoculation with *Glomus intraradices* on oat, beans, and wheat. The study was done under greenhouse conditions at the Montecillo Campus of the Postgraduate College, Mexico. Two soil types from San Luis Potosí State were used, one was red (Xerosol), and the other one was grey (Litosol). With and without *Glomus intraradices* inoculation. Three bean cultivars: Pinto Saltillo, Bayo comercial and Flor de Mayo; Chihuahua (oat variety); and Tlaxcala wheat were planted. The experimental design was factorial complete randomized block and three replications. The result showed that bean yield (average 3.7 g plant^{-1}), pod number and dry weight, leaf area, plant height, stem diameter, and aerial part dry weight were positively affected by the inoculation with *Glomus intraradices*, but not by soil type. A similar trend was observed in root length, volume and dry weight, and in the nodule number. In relation with the species studied, *Phaseolus vulgaris* varieties had higher values than wheat and oats in growth and yield variables evaluated. It is concluded that endomycorrhiza inoculation (*Glomus intraradices*) gave better growth and yield, especially in beans. The soil types studied did not affect significantly plant responses in this study.

Key words: *Glomus intraradices*, yield, nitrogen fixation, and growth.

INTRODUCTION

Farmers are facing new challenges every day. Input prices are constantly increasing. Fertilizers are a good example of those increments [13]. Moreover, those chemicals cause widespread and sometimes irreversible environmental degradation. Sometimes the impoverished soils make them increasingly dependent on chemicals [4]. The society is demanding sustainable and affordable food production. It puts pressure on producers to maintain their cost of production as low as possible.

Endomycorrhizas are a low cost option to improve plant nutrition. Several researchers consider that they are the most important organisms on earth interacting in agro environments. More than 80% of all terrestrial plants, among them most of horticultural and crop plants have a symbiotic relationship with these fungi. The stimulation of plant growth can be attributed mainly to the improvement of phosphorus nutrition [1, 8, 9, 15].

Currently, these fungi are classified in the Glomeromycota Division, particularly in the Glomerales Order. There are about 200 species described [1].

The objective of this study was to investigate the effect of *Glomus intraradices*, an arbuscular mycorrhizal fungus, on growth and yield of beans, oats and wheat in two different soils under greenhouse conditions.

MATERIALS AND METHODS

The study was done under greenhouse conditions at the Postgraduate College, Montecillo Campus, State of Mexico, in the spring and summer of 2009. Two soil types were used. One red (xerosol) and another grey (litosol) with the characteristics shown on Table 1.

The seeds were sterilized with 1% sodium hypochlorite during 4 minutes, and hydrated on filter paper in petri dishes for 48 hours. The seeds were sown in polyethylene bags that had been filled with 2 kg of two soil types. The treatments were: planting in red soil or grey one. Both soil types were collected at the San Luis Potosi State, north Mexico. Grey soil is medium alkaline, the red one is neutral. Both have medium amounts of inorganic nitrogen and a low one of phosphorus. The contents of iron, manganese, and zinc are adequate. Grey soil is deficient in copper, but the red one has sufficient quantity [3].

The soil organic matter was determined using the Walkey and Black method, for phosphorus, Olsen was used. Interchangeable bases were measured utilizing ammonium acetate pH 7:1 Normal (CH_3COONH_4), and micronutrients with DTPA (from dietilen-triamino-pentaacetic acid).

Three bean genotypes (Pinto Saltillo, Bayo comercial and Flor de Mayo), one for oats (Chihuahua), and one for wheat (Tlaxcala) were planted. The seed was provided by the National Institute for Agriculture, Livestock and Forestry Research.

Table 1 Soil analysis for the two types.

Soil	SP	EC	pH	OM	N inorg	P
		dS m^{-1}	1:02	%	mg kg^{-1}	
Xerosol (red)	28	0.54	8.3	1.78	35.27	0.85
Litosol (grey)	34.7	0.65	7.07	2.05	28.86	1.07

Soil	K	Ca	Mg	Fe	Cu	Mn	Zn
	mg kg-1						
Xerosol (red)	477.04	6413.24	110.0	12.33	0.11	19.18	1.90
Litosol (grey)	453.58	2249.79	209.6	21.96	2.81	47.96	2.28

Key: SP=Saturation point, EC=Electric conductivity, pH= Hydrogen potential, OM= Organic matter, N inorg= Inorganic nitrogen.

The inoculation was done during the planting, mixing 5 g of sand with sorghum roots with 85 % colonization of *Glomus intraradices* and 1050 spores per 100 g of inert material. Two levels of *Glomus* were applied, with and without *Glomus*.

The variables evaluated were plant height (PH, cm), stem diameter (SD, mm), biomass dry weight (BDW, g), grain dry weight (GDW, g), leaf area (LA, cm^2), root length (RL, cm), root volume (RV cm^3), root dry weight (RDW, g), pod number (PN), and nodule number (NN).

A factorial arrangement with 20 treatments (5x2x2) was used with a completely randomized block design using three replications. An analysis of variance for all variables registered was done and a Tukey mean comparison test for the significant variables.

RESULTS AND DISCUSSION:

There are significant differences among treatments for all the variables recorded, due to the positive effect of inoculation with *Glomus intraradices*. Also highly significant differences were found among cultivars for all the variables studied. The soils used in this experiment did not provide any significant difference. Significant interactions were recorded between cultivars and inoculation with *Glomus intraradices* for plant height, grain dry weight and leaf area, and among cultivars and soils for grain dry weight (Table 2).

Yield, root and shoot growth were superior to those of plants without inoculation (Table 3). This is an indication of a positive effect of mycorrhiza on plant growth originated by better mineral nutrient absorption required by the plant [1, 2]. Gardezi *et al.* [6, 9] also found this beneficial effect in *Leucaena lecocephala* associated with endomycorrhizal and with *Rhizobium.*

Positive responses to the inoculation with mycorrhiza were also found in a number of species, including those studied in this experiment [16], and in beans [2].

For the studied variables, the behavior was similar to that found by Gardezi *et al*. [7, 8, 9, 10, and 11]. The plants inoculated with endomycorrhiza fungi (*Glomus intraradices)* were taller than those not inoculated.

Table 2. Analysis of variance mean squares of the variables and treatments studied in oat (*Avena sativa* L.), common bean (*Phaseolus vulgaris*) and wheat (*Triticum aestivum* L.).

Source of variation	DF	Plant height	Stem diameter	Biomass dry weight	Grain dry weight
Treatments	19	4750.1219**	0.0380**	27.0074**	30.1439**
Cultivars (C)	4	17690.5167**	0.1447**	86.3889**	125.7250**
Soils (S)	1	322.0167	0.0002	0.0327	3.2667
C*S	4	283.6833	0.0022	1.3156	6.0583**
Inoculation (Glomus, I)	1	7063.3500**	0.0721**	86.4000**	17.0667**
C*I	4	1560.2667*	0.0078	7.3404	5.1083*
S*I	1	400.4167	0.0209	4.2667	0.2667
C*S*I	4	1082.1667	0.0027	10.5654	1.1417
ERROR	40	626.1333	0.0092	4.3912	1.4000

Table 2. Continuation

Source of variation	DF	Leaf area	Root length	Root volume	Root dry weight
Treatments	19	241198.3250**	112.1866**	25.9650**	0.5703*
Cultivars (C)	4	959932.9000**	296.0375**	88.5428**	1.7596**
Soils (S)	1	21470.4170	31.5375	2.2815	0.3271
C*S	4	16395.5000	21.7042	7.8786	0.2757
Inoculation (Glomus, I)	1	357744.8170**	392.7042**	32.4135**	1.0481*
C*I	4	51125.2330*	49.2458	7.7281	0.2611
S*I	1	936.1500	7.7042	7.2802	0.0770
C*S*I	4	23200.5670	57.9125	8.6906	0.0494
ERROR	40	18116.2500	24.6375	3.8043	0.2540

* Significant at 5% level of the treatment, main effect or interaction.
** Significant at 1% level of the treatment, main effect or interaction.

Table 3. Honest significant difference of the effect of *Glomus intraradices* on oat (*Avena sativa* L.), common bean (*Phaseolus vulgaris*) and wheat (*Triticum aestivum* L.).

Glomus intraradices	Plant height (cm)	Stem diameter (cm)	Biomass dry weight (g)	Grain dry weight (g)	Leaf area (cm^2)	Pod number
Inoculated	100,50a	0,34a	6,94a	4,10a	566,5a	1,25a
Non inoculated	78,80b	0,27b	4,54b	3,03b	412,07b	1,06b

Glomus intraradices	Pod dry weight (g)	Root length (cm)	Root volume (cm3)	Root dry weight (g)	Nodule number
Inoculated	0,97a	27,17a	5,89a	1,12a	1,97a
Non inoculated	0,61b	22,05b	4,42b	0,86b	1,64b

Means with the same letter in each column are not significantly different (Tukey α= 0.05)

A better vegetative growth of oat, bean and wheat plants inoculated with *Glomus intraradices* was the result of an enhanced root growth ($p \leq 0.05$) expressed as greater root length (23.2%[1]), greater root volume (33.3%), and higher root dry weight (30.2%); as well as a larger photosynthetic apparatus ($p \leq 0.05$), expressed in biomass dry weight (52.8%) and leaf area (37.5%).

Plants were taller with inoculation (27.5%), and with a thicker stem diameter (25.9%, Table 3)

Bean dry grain yield was also higher (35.3%) in plants inoculated with *Glomus intraradices*. This was a result of a higher number of pods per plant (18%), and especially heavier pods (59%). The increase in pod number and pod weight can be attributed to better root and shoot growth that provided a greater quantity of photosynthetic compounds and mineral nutrients, as well as a better nitrogen fixation because the number of nodules increased 20% in plants inoculated with endomycorrhizae.

In other experiments, *Glomus intraradices* has increased the yields. In most of the locations where trials were conducted, there was an increase in yields in comparison with the chemically fertilized control, of up to 60% in maize, 85% in wheat, 25% in oats, 74% in barley, 36% in common bean and 111% in orange trees. It is convenient to promote the transfer of this technology to farmers for obtaining higher yields and for the development of a more sustainable agriculture [14].

The beneficial effect of mycorrhiza was also documented in wheat [17] originating greater growth and yield. Legumes had the same positive results, especially when they combine mycorrhiza and bacteria fixing nitrogen [7, 8, 9, 10, and 11].

The varieties of bean do not show differences in plant height at harvest (Figure 1, $p \leq 0.05$). The Pinto Saltillo bean cultivar inoculated with Glomus showed the greater plant height. The lowest one corresponded to wheat and oats without inoculation. Both oats and wheat responded less to the inoculation with Glomus intraradices and to litosol soil type.

The diameter of the stem also did not show significant differences among bean varieties, with major values in Pinto Saltillo bean cultivar and lesser diameter in wheat and oats without inoculation ($p \leq 0.05$).

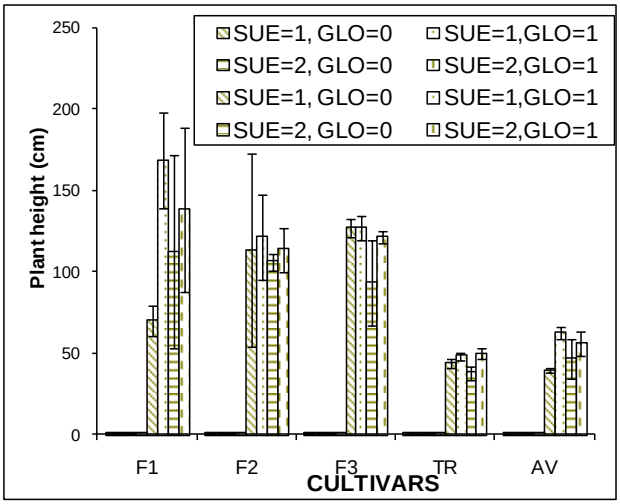


Figure 1. Effect of inoculation with *Glomus intraradices* on two soil types in plant height of three cultivars common bean (*Phaseolus vulgaris*), one of oat (*Avena sativa* L.), and another one of wheat (*Triticum aestivum* L.).

Key: Cultivars: F1: Pinto Saltillo bean, F2: Commercial Bayo bean, Flor de Mayo bean, TR: wheat, AV: oat. Soil type: Sue1= Litosol, Sue2= Xerosol. Glo0= Noninoculated, Glo1= Inoculated with *Glomus intraradices.* The vertical lines indicate standard error.

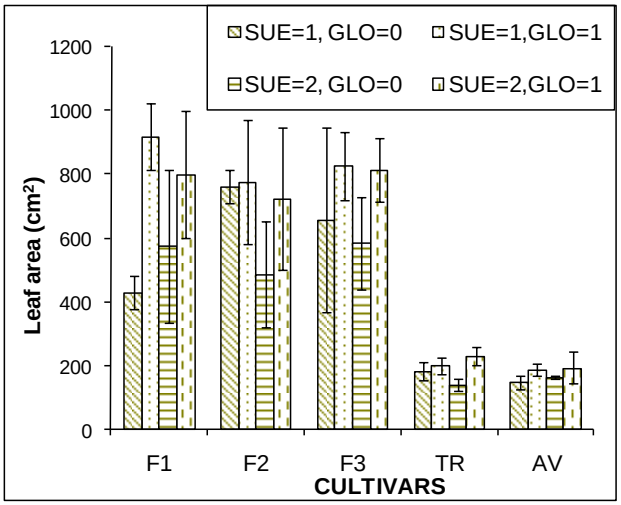


Figure 2. Effect of inoculation with *Glomus intraradices* on three cultivars in two soil types on leaf area of three cultivars common bean (*Phaseolus vulgaris*), one of oat (*Avena sativa* L.), and another one of wheat (*Triticum aestivum* L.).

Key: Cultivars: F1: Pinto Saltillo bean, F2: Commercial Bayo bean, F3: Flor de Mayo bean, TR: wheat, AV: oat. Soil type: Sue1= Litosol, Sue2= Xerosol. Glo0= Noninoculated, Glo1= Inoculated with *Glomus intraradices.* The vertical lines indicate standard error.

The three varieties of bean developed a leaf area with significant differences ($p \leq 0.05$). The greater leaf area (917 cm^2) occurred in Pinto Saltillo bean cultivar grown in litosol inoculated with Glomus intraradices, followed by Flor de Mayo in both soil types and inoculated. Also a significant interaction was observed between the bean cultivars, oats, and wheat and the inoculation with

[1] Increase rate are referred to the values found in oat, bean and wheat plants inoculated with mycorrhiza compared to those without inoculation.

Glomus intraradices ($p \leq 0.05$). The lowest leaf area corresponded to wheat and oats (Figure 2, $p \leq 0.05$).

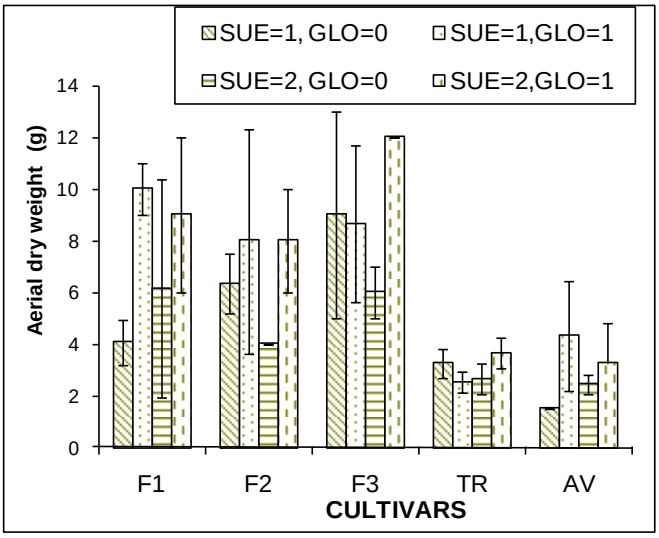


Figure 3. Effect of inoculation with *Glomus intraradices* on three cultivars in two soil types on aerial dry weight of three cultivars common bean (*Phaseolus vulgaris*), one of oat (*Avena sativa* L.), and another one of wheat (*Triticum aestivum* L.).
Key: Cultivars: F1: Pinto Saltillo bean, F2: Commercial Bayo bean, F3: Flor de Mayo bean, TR: wheat, AV: oat. Soil type: Sue1= Litosol, Sue2= Xerosol. Glo0= Noninoculated, Glo1= Inoculated with *Glomus intraradices.* The vertical lines indicate standard error.

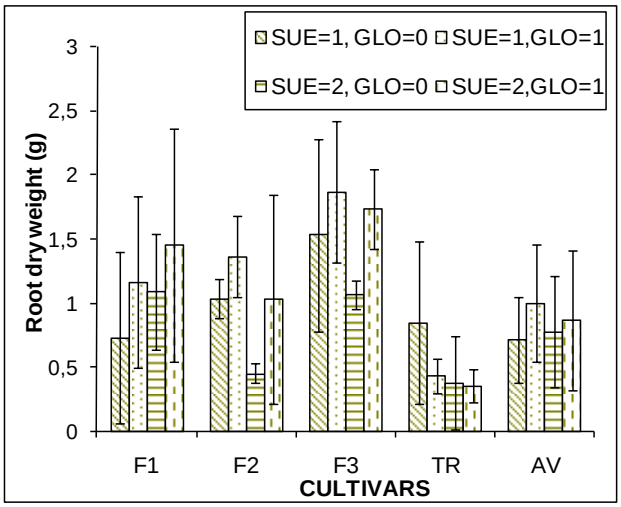


Figure 4. Effect of inoculation with *Glomus intraradices* on three cultivars in two soil types on root dry weight of three cultivars common bean (*Phaseolus vulgaris*), one of oat (*Avena sativa* L.), and another one of wheat (*Triticum aestivum* L.).
Key: Cultivars: F1: Pinto Saltillo bean, F2: Commercial Bayo bean, F3: Flor de Mayo bean, TR: wheat, AV: oat. Soil type: Sue1= Litosol, Sue2= Xerosol. Glo0= Noninoculated, Glo1= Inoculated with *Glomus intraradices.* The vertical lines indicate standard error.

In the case of the root system, the length, volume, and dry weight had similar development in the bean cultivars. The same happened between oats and wheat (Figure 4).

For the dry weight of the aerial part it was not found significant differences between varieties of bean (Figure 3, $p \leq 0.05$). The Flor de Mayo and Pinto Saltillo bean cultivars had the highest weight. Oats without inoculation in both soil types produced the lowest foliage.

Flor de Mayo bean cultivar had more nodules than Pinto Saltillo, but similar to Bayo Comercial. The Flor de Mayo bean cultivar in both types of soils and inoculated with Glomus intraradices presented the greatest number of nodules, followed by Bayo Comercial in xerosol without inoculation. Gardezi et al. [5] found a great genetic diversity in nitrogen fixation of 48 varieties of bean with six types of growth habits.

The number and weight of pods were similar among the varieties of beans. The Bayo cultivars of bean had a grain yield average greater than Pinto Saltillo, but similar to Flor de Mayo ($p \leq 0.05$).The treatments with a higher yield were Bayo and Flor de Mayo planted in xerosol and inoculated with Glomus intraradices. The yields of oats and wheat could not be evaluated.

The inoculation with Glomus intraradices improved root and shoot growth and also had a beneficial effect on the biological nitrogen fixation, possible joint with a higher absorption of nutrients [12], contributing to higher yield in beans, coinciding with other studies [2].

CONCLUSIONS

Mycorrhizal inoculation and nitrogen fixation provided higher bean root and shoot growth and therefore better yields. Previous evidence with legumes showed that they have benefited with this symbiosis because the treatments with this fungus produces the highest values for all evaluated variables. In oats and wheat, inoculation with *Glomus intraradices* leads also to superior root and shoot growth. The soil types did not limited the effect of mycorrhiza on beans, oats and wheat.

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Wireless Electricity Monitoring System for Smart House using Smart Plug

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ABSTRACT

We describe the smart plug with a wireless sensor network for monitoring of electrical usage in smart house. The smart plug integrates an AC power socket, a relay to switch the socket ON/OFF, a current transformer sensor to sense current of load appliance and a Kmote. The Kmote is a wireless communication interface based on TinyOS. We evaluated smart plug in a laboratory, analyzed and presented energy consumption data from electrical heater for 3 months.

Keywords: Smart Plug, Smart House, Wireless Sensor Network, Energy Consumption

1. INTRODUCTION

In a world of highly developed countries and emerging economics, energy supply plays a major role. In a modern household, hardly any device runs without electricity. Understanding household energy usage in-home is vital for the planning of energy consumption and conservation. Household are an important group when addressing energy conservation. Many researchers pointed out that changing life style is important to reduce the energy consumption.
The traditional electric meter, used by electricity companies for accounting is the electromechanical induction watt-hour meter. Its robust technical design is in use for over a century but is not capable of more than measuring the accumulated amount of consumed energy. A disadvantage is that either an employee, sent by the energy company or the customer himself has to read the meter manually which implies costs and administration effort [1]. Smart meter is a very general term for a more advanced metering device, which provides more detailed information on consumption to the customer and is mostly able to communicate with the electricity supplier via some network for the purpose of accounting, billing and monitoring. Capabilities range from simple display a meter, which gives a user feedback on current and past consumption, to high-tech meters which are capable of interacting with home automation systems and for instance are able to switch on a device when the supplier indicates cheap energy prices. Google PowerMeter is an on-line service that interacts with consumer's local smart meters via vendor or utility company. Load data is sent from a smart meter to the energy supplier, who forwards data to Google's data store by implementing and invoking the Google Data API. Google provides a uniform user interface to all customers including processed and analyzed data. This technology leads to vendor independent information processing and allows integration of multiple devices [2-3].
This paper presents the architecture, design, and evaluation of smart plug, a wireless sensor network for gathering electricity usage and controlling AC in a smart house environment.

2. SMART PLUG MONITORING SYSTEM

The overall design of the smart plug monitoring and control system is shown in Figure 1. The design we have made divides the system three parts. The three pieces of this decomposition are the smart plug, the base module, and the energy control panel.

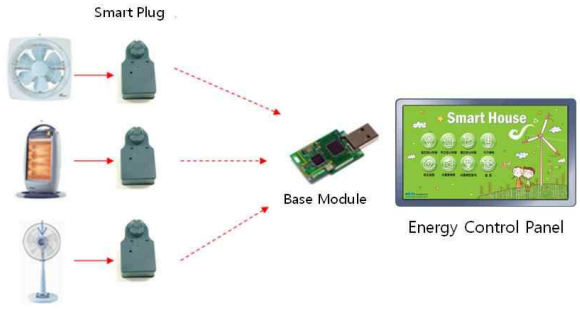


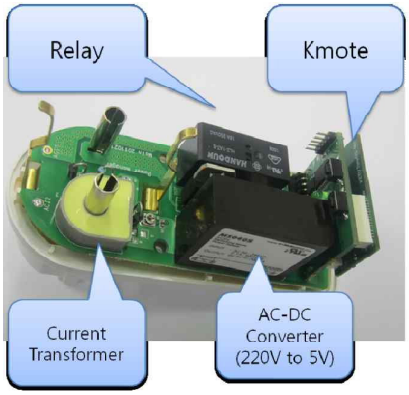
Figure 1. Smart plug monitoring system overview.

Smart Plug
An essential component of smart plug is the device that performs the energy measurement and control. This device consists of four components – CT (current transformer) sensor, AD/DC power supply, microcontroller with radio, and relay as shown in Figure 2.
To obtain power measurements, a dedicated IC is usually used to perform the necessary analog-digital conversions. In this paper, we use the CT sensor to convert current to voltage. These devices use the Hall effect to measure current and can be either clamp-on (non-contacting) or

in-line. Inline CT sensors intercept the AC current and couple it with an internally calibrated Hall effect element. This approach is compact and precise. More importantly, the high voltage AC input is electrically isolated from the low voltage output inside the in-line CT sensor.
The sensor network module is implemented from a commercial product (Intech co., Kmote-B) which is a clone of Telosb platform, including a microcontroller (Texas Instruments co., MSP430, 8MHz), a IEEE802.15.4 compliant RF transceiver chip (Texas Instruments co., CC2420) [4-6].



(a) Appearance



(b) Configuration
Figure 2. Smart plug.

Energy Control Panel
The role of the energy control panel is to store packets from the smart plug to a database as show in Figure 3. We choose a small size embedded board for easy development of client program and convenient management of the in-house monitoring system.
The smart plug reads the packet from base module and writes it with additional information into the MySQL database. The UI program is implemented under the Linux using Qt.



Figure 3. Energy control panel.



Figure 4. Base module (Kmote)

The energy control panel program can be converted into a smart phone apps using RF-to-Bluetooth dongle as show in Figure 5. The smart phone is based on android platform.



Figure 5. Smart phone apps.

3. EXPERIMENTS

Figure 6 illustrates the experimental measurement set-up. The smart plug measures the current per 1 second, and transmits the wireless data to the energy control panel per 5 seconds. We measure the current consumption and electric power. It was based on the result of saved data in the energy control panel as shown in Figure 7.

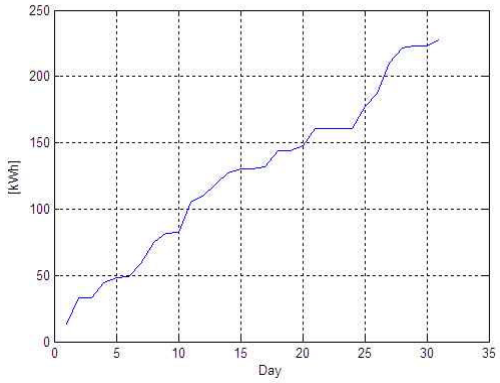


Figure 6. Experiment set up.

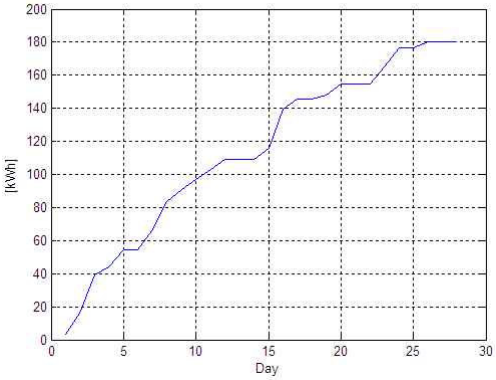


Figure 7. Measurement results.

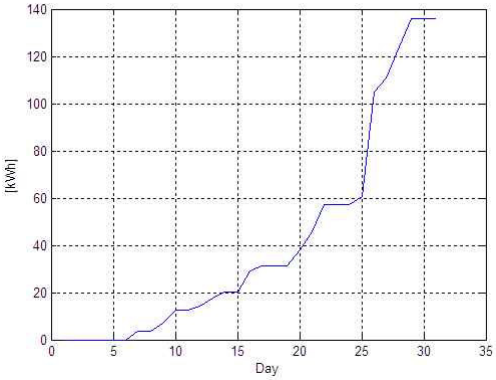
Figure 8 are power consumption traces from electrical heater under measurement.



(a) January



(b) February



(c) March

Figure 8. Power consumption traces.

In Figure 9, it is showed the trend of the electricity power consumption as a function of the temperature difference. The quadratic regression curve can be estimated on the Equation (1).

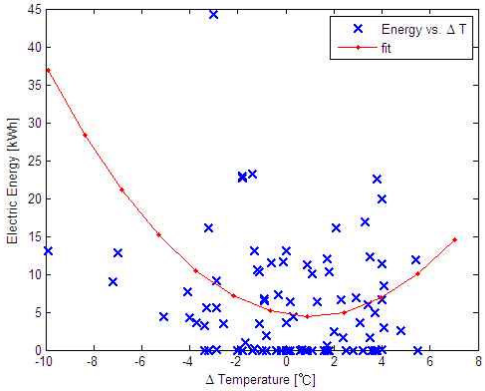
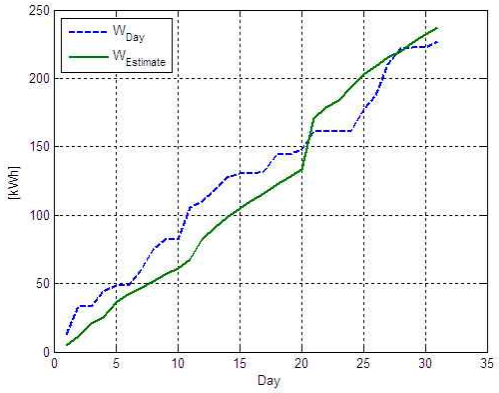


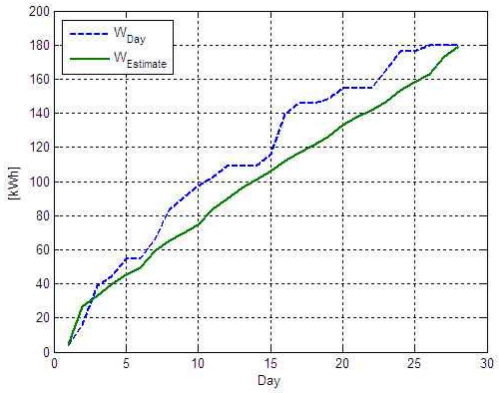
Figure 9. Power consumption vs. temperature difference

$$W_{Estimate} = 0.2753x^2 - 0.5376x + 4.659 \qquad (1)$$

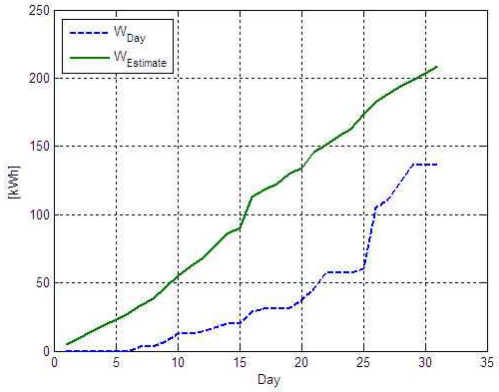
Estimation results have been investigated and presented in Figure 10.



(a) January



(b) February



(c) March

Figure 10. Estimation results.

4. CONCLUSIONS

In this paper we describe the home power monitoring system using smart plug which we have developed. The developed monitoring system is composed of the wireless power outlet, which named smart plug, and the energy control panel. The smart plug integrates AC power receptacle and wireless sensor node into a power socket to switch the power ON/OFF and to measure the power consumption of plugged appliances. The energy control panel stores the received signals into the database. The experiment results show the adaptability and feasibility of the energy consumption data.

Future research may integrate into the end devices to allow them to be tasked with more sophisticated data processing and generation.

5. ACKNOWLEDGMENT

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A Review of Spacecraft AI Control Systems

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ABSTRACT

The history of artificial intelligence control systems for use in space is discussed in this paper. The two fields started separately in the 1950s and first merged in the 1970s due to control requirements for a Jet Propulsion Laboratory project. While spacecraft have a special need for AI systems due to communications delays and other factors, much of AI control system development is conducted for earth-based applications. To mitigate risk factors, space-bound AI systems are also tested extensively via simulations. As a result, virtually all AI space control systems get their start on the ground. Additionally, ground support systems are required to facilitate communication with and command of AI controlled and other space craft. Numerous successful missions incorporating or controlled by AI technology have been launched. Further, many more are planned. Examples of ground, space-flown and future AI control missions are all discussed herein. While, spacecraft AI was born out of necessity (due to communication delays and such), it is now becoming desirable for other reasons such as cost savings and mission enhancement.

Keywords: autonomous robotics, autonomous spacecraft, artificial intelligence, robotic control, AI control, control systems

1. INTRODUCTION

To many, space exploration and artificial intelligence just seem to go together. For some, science fiction may be responsible for building the strong association between the two. However, to-date autonomous technology has been deployed in a limited fashion to meet specific mission objectives which in most cases could not be otherwise met. In most instances, autonomy technology has met with success in its limited mission role. Fully autonomous spacecraft control has been demonstrated in a limited capacity and appears to hold promise for reducing mission cost, increasing scientific returns and allowing the operation of more complex multi-vehicle missions. What follows is a look at the history and possible future of artificial intelligence control systems in space.

2. ORIGINS OF AI, SPACE EXPLORATION AND AI FOR SPACE EXPLORATION

Both space exploration and artificial intelligence got their start in the 1950's. One of the first developments in AI was Newell, Shaw and Simon developing IPL-11, the first AI language, in 1955. In 1956, John McCarthy first used the term "artificial intelligence" to state the topic of the Dartmouth conference (which was the first AI conference). Also in 1956, Newell, Shaw and Simon created "The Logic Theorist" which could solve math problems and Ulam developed a chess playing program: Maniac I. On October 4th, 1957 the Sputnik satellite (the first human-built space craft) was launched. Sputnik 2 followed on November 3rd, sending the first mammal in to orbit. On the AI front in 1957, Newell, Shaw and Simon introduced their General Problem Solver. In 1958, McCarthy introduced LISP, the MIT AI lab was established and the National Aeronautics and Space Administration (NASA) was launched. [47, 5, 23]

The two fields, however, would continue to develop separately until 1972 when the Jet Propulsion Laboratory (JPL) started its AI Research on a mars rover vehicle. By 1975, scientists on this project had determined that additional planning capabilities were needed and started construction of an expert system to assist in planning. The DEVISER system was created by the Automated Problem Solving Group at JPL and was used initially to generate commands that would be sent by operators to VOYAGER. VOYAGER program staff expanded the knowledge base of DEVISER and used it to model spacecraft activities. The same group at JPL created a diagnostic expert system, FAITH, which had an initial focus of monitoring telemetry from VOYAGER and other spacecraft. FAITH, based on its monitoring of telemetry streams, could generate alarms if necessary. [18]

In 1979, Carnegie-Mellon University established its' Robotics Institute. This institute was launched with five projects one of which was space construction and exploration. [6, 17]

3. GROUND BASED TESTING & SUPPORTING SYSTEMS

Autonomous spaceflight starts on the ground. For each craft that is sent into space to explore, numerous concepts must be proposed, developed and tested on Earth to ensure a successful mission. Projects and experimental and concept craft such as Carnegie Mellon University's Ambler program, the Self-Mobile Space Manipulator project, the Tessellator robot, Dante I, Dante II, the Automated Scheduling and Planning Environment (ASPEN), the Rocky 7 Rover, Nomad, the Modified Antarctic Mapping Mission, the Distributed Spacecraft Technology (DST) program, Skyworker, TEMPEST, Hyperion, Zoe, the Hetereogeneous Agricultural Research Via Interactive, Scalable Technology (HARVIST) project, the DepthX project, Scarab and MISUS pave the way for future autonomous space exploration. Many of these programs are of a dual-use nature in that they further space exploration goals while providing a (in many cases primary and more immediate) benefit on Earth.

As an example, under the auspices of the NASA Instrument Incubator Program, the Jet Propulsion Laboratory began development of an autonomous Unmanned Airborne Vehicle (UAV) system for earth sciences use. While this system is, at

present, designed only for earth-based use it clearly represents a technology that may have future application for planetary exploration missions. The UAV is designed to carry radar to study earth deformation via repeat passes both over the long term and phenomena which can cause deformation in the short term such as glaciers and earthquakes. The system is currently being developed on a Proteus aircraft, which requires a crew of two to operate it. The researchers believe that the Proteus could be further developed to include UAV capabilities which are necessary due to the fact that human pilots are not able to fly with the precision required to collect the repeat track data. [21, 30]

Important UAV, Unmanned Ground Vehicle (UGV) and Unmanned Surface Vehicle (USV) capabilities are also being developed by a variety of military entities. These include the combined U.S. Army and Navy Mobile Detection Assessment Response System (MDARS) program, the U.S. Army's Future Combat System (FCS) program, the Defense Advanced Research Projects Agency's (DARPA) Perception for Off-Road Robotics (PerceptOR) program, the Cooperative Unmanned Ground Attack Robot (COUGAR) program, and the U.S. Army and Navy SPARTAN Advanced Concept Technology Demonstration (ACTD) program. MDARS and PerceptOR are UGVs which can serve as a mobile launch, landing and support platform for UAV units. SPARTAN is a water-based USV which can similarly serve as a UAV base. The FCS program will incorporate UAVs as part of a network-centric combat system. The COUGAR system involves a command vehicle which carries a control unit, long range weapons robot, and UAV. The UAV is used to survey targets and confirm the missile strike. All of the aforementioned involve various levels of human control, at present. For example, the COUGAR system requires that a human operator pre-program the flight path of the UAV and initiate its launch. SPAWAR Systems Center (SSC), Allied Aerospace and others are working to combine these various technologies to create a system to provide an autonomous response. To this end, testing has been conducted in 2002 regarding the launch of a UAV from a UGV. Additional work regarding landing and refueling of a Allied Aerospace 29" iStar UAV has been conducted and technology from Carnegie Mellon, the Jet Propulsion Laboratory and Geodetics, Inc. is being used to facilitate autonomous landing. [32]

4. AUTONOMOUS SPACE EXPLORATION

A spacecraft encounters a somewhat unique problem as it moves further and further from earth. The increasing distance makes it take longer to receive guidance and ask for help from ground-based controllers. As such, a spacecraft that will be any significant distance from earth must have some autonomy for basic functions such as to be able to take collision-avoidance actions and to reestablish communications with earth should they be lost. The use of autonomous technologies started with meeting these basic requirements and performing actions (such as docking) which required too much precision to be done reliably by a human. They have gone on, however, to be implemented because they can make missions better and less expensive.

The Soviet Union has implemented autonomy technology to dock its spacecraft: first with the IGLA system and later with its replacement, the KURS system. Both the IGLA and KURS systems are radar-based and calculate distance and position based on the relative strength of signals between antennas. The IGLA technology was used by the Soyuz T spacecraft while KURS was used by Soyuz TM and Progress M spacecraft. The MIR space station supported both technologies. The first docking of a Suyuz TM was in 1986; Progress M first docked in 1989. [22]

In 1993, the Jet Propulsion Laboratory started construction on the Mars Pathfinder and its Sojourner rover. The Pathfinder and Sojourner launched on December 4th, 1996 and arrived at Mars on July 4, 1997. Sojourner was the first craft to explore another planet (Viking 1 had landed on Mars in 1976, but wasn't able to move from its landing site). The Sojourner craft was autonomous: while all planning was done on-the-ground and uploaded, the craft was able to respond in a limited fashion to changing conditions and avoid obstacles in the path of its preplanned route. Generally, Sojourner used straight-line navigation to follow the operator go to co-ordinate instruction; however, when an obstacle is detected by the craft's five laser stripe projectors and its two CCD cameras, it can execute one of several condition-specific pre-programmed behaviors in response to the obstacle. If the craft is not able to reach its goal (or not able to reach it within time requirements) it is able to determine what commands from the plan can and should still be run; however, ground operators must decide what the craft should do next. This can, for example, include providing a more specific route (via adding more waypoints), telling the craft to take greater risks to reach its goal, or manually operating the craft remotely. [44, 46]

Starting in 1994, the Jet Propulsion Laboratory was asked by the NASA Office of Space Communications to develop an autonomous unmanned technology for ground control of the Deep Space Network (DSN). DSN is a network of antennas in three locations: California, Spain and Australia which are used to communicate with spacecraft. The Deep Space Station Controller (DSSC) technology was developed in response to this request. The first demonstration of DSSC in 1994 consisted of a test downlink from the SAMPEX and EUVE satellites. In 1995, the ability to uplink was added to the prototype unit. A week long uplink/downlink demonstration was conducted in December. Following the demonstration, the system remained in operation and recorded 3120 hours of tracking during the next 26 months. DS-T followed and demonstrated the feasibility of autonomous uplink/downlink operations with deep space craft. [41]

The DSSC system architecture is a combination of CLEaR (which includes the CASPER and TDL), the Beacon-Based Exception Analysis for Multi-missions (BEAM) system and Spacecraft Health Interface Engine (SHINE). CLEaR, which is a continuous planner based on the CASPER system, determines what should be done. TDL, on the other hand, provides sequencing capabilities and reactive planning. BEAM and SHINE are used for error detection and recovery. BEAM monitors system performance indicators and compares them to a model, identifying any anomalies. SHINE is a knowledge-based expert system which interprets the BEAM information. SHINE uses heuristics to quickly isolate possible fault causes and causal-reasoning to analyze the fault and further refine the possible causes. [41]

NASA has identified a need to transform the Deep Space Network further into the Interplanetary Network to support

future mission plans. As part of this transition, it is likely that the existing three site network will expand to encompass additional sites. Some of which may be in remote locations. As such, there is an even greater need for autonomy technology to facilitate the operation of these various stations within budget constraints. [48]

In 1999, the Deep Space One craft was controlled by an autonomous agent called the Remote Agent Experiment (RAX) for a few days. RAX was one of three autonomy technologies tested on Deep Space One. RAX was developed by researchers at the Jet Propulsion Laboratory and the Ames Research Center. It was selected for testing on Deep Space One based on a successful simulator test where it was required to navigate through Saturn's rings and respond to simulated spacecraft failures; it accomplished all of these objectives and also responded to an unplanned simulation failure. Deep Space One was the first spacecraft to use a remote agent for most control. [8, 34, 37]

The remote agent consisted of four parts: an executive, mission manager, planner/scheduler and the Mode ID and Reconfiguration (MIR) system. The executive was the top-level program in the system and executed plan instructions. The mission manager kept track of mission objectives and resource constraints. The planner/scheduler unit was responsible for plan generation based upon high-level goals. The MIR system was responsible for assessing the craft's health and proposing alternates for failed components. The planner unit generates a plan which is implemented by the executive. If the executive is not able to execute the plan due to a failure or other change, the MIR unit can suggest an alternate solution; failing that the executive asks the planner unit to create a new plan. [38]

The first test of RAX was interrupted due the agent failing to shut down the main engine at the expected time. A second test was conducted during which the agent correctly responded to three simulated failures and also correctly avoided use of the main engine due to the previous command failure. These tests validated the use of remote agent technologies on future missions. Unlike previous missions such as Cassini, which required 100 to 300 staff to operate it, Deep Space One required significantly less staff. It also had reduced communications needs, freeing the deep space network for use by more craft simultaneously and allowing more science data to be transmitted instead of control and monitoring data. [33, 35, 39]

Also being tested on Deep Space One was the AutoNav system. AutoNav consisted of five components: navigation executive functions, image processing, orbit determination, maneuver planning and encounter knowledge updates. The executive is responsible for all AutoNav communication to the actual flight control systems. Image processing identifies the objects captured by the craft's cameras. Orbit determination identifies the craft's position; maneuver planning uses the orbit determination information to identify necessary course correction maneuvers. Encounter knowledge updates is a special mode that AutoNav enters after all required pre-encounter course corrections are completed. In this mode, AutoNav provides target position information to the altitude control system to facilitate craft pointing changes. AutoNav started operating on October 24, 1998 and gradually increased the scope of its control as more components were tested through to April 20, 1999 when the craft was placed completely under AutoNav's autonomous control. [2]

The third autonomy technology tested on Deep Space One was beacon software. This represents a new methodology where a spacecraft determines when it needs help from controllers and requests it. The system has two parts. A tone system advises ground controllers of communications needs. The tone can indicate one of four possible contact need timeframes: immediate, within a time period, when convenient or no need. When ground controllers respond to the tone, the second system sends a summary back to controllers. This summary contains high level information, information about sensors that have violated an alarm threshold, snapshot data from all sensors and performance data (which is data that is of known interest to controllers). Alarm thresholds are determined by Envelope Learning and Monitoring using Error Relaxation (ELMER) technology. ELMER uses a neural network to provide faster error detection with fewer false alarms and can be trained either in space or prior to the mission. [2]

In 2003, the Autonomous Sciencecraft Experiment (ASE) onboard Earth Observing-1 was launched. ASE had several AI elements. Its onboard science algorithms were designed to detect phenomena of interest. It used the Spacecraft Command Language to allow it to be event-triggered and to have low-level autonomy. It also made use of the CASPER software which generated and regenerated mission plans based on the aforementioned science algorithms as well as accomplishments on previous orbit-cycles. Its onboard analysis software identified changes and phenomena of interest and CASPER made plans to allow the satellite to observe phenomena of interest and to transmit the most valuable information to earth first. ASE resulted in an increased amount of scientifically important data being transmitted over the fixed-bandwidth radio communications channel through its prioritization. It also allowed the satellite to respond quickly and capture short time span events and it streamlined operations. [25]

Also aboard the EO-1 satellite is the Livingstone Version 2 (LV2) software. Livingstone is an expert system software package developed at NASA's Ames Research Center which detects and diagnoses hardware and software problems on a spacecraft. On EO-1, this is being tested by detecting and diagnosing simulated failures. It also monitors the Autonomous Sciencecraft Experiment software running EO-1's imaging system. It compares actual performance to a model of proper performance. If a difference is noted, the LV2 reasoner attempts to ascertain the cause of the failure and provides human operators with probable causes. LV2's reasoner is independent of the model to allow reuse; software of this type should allow future spacecraft to enjoy longer operating periods by facilitating recovery from errors. [3]

Related to the EO-1 satellite are several sensorweb projects including the volcano sensorweb which started operating in 2004. Sensorwebs are networks of connected nodes which take automated action based on the detection of an event-of-interest by a sensor node. For example, the volcano sensorweb may detect an eruption based on an in or near volcano sensor or a low resolution orbital satellite such as NASA's Terra and Aqua satellites. Based on this event detection, the volcano sensorweb will relay a request for observation to the ASPEN/CASPER based ground planning service which will evaluate it and forward it to the EO-1 satellite which can gather high resolution imagery. The onboard planner on EO-1 will evaluate the request in the context of the current constraints of the satellite

and then take the required actions if it is able to action the request. Several sensorwebs have been created including the aforementioned volcano sensorweb as well as sensorwebs related to wildfires, floods and the chryosphere. In all cases, an automated review of sensor data identifies a condition of interest which then triggers a request to EO-1 for further observation to facilitate analysis. Ongoing research includes tasking a uninhabited aerial vehicle to fly-over areas of interest identified by a sensorweb and to act as a trigger-sensor-node. Sensorweb technology has clear applications in the coordination of future space missions containing multiple craft. [9, 42, 43]

In May of 2003, the Japanese Aerospace Exploration Agency (JAXA) launched the Hayabusa spacecraft carrying the Minerva robot. In 2005, Hayabusa made several autonomously controlled landings on an asteroid in an attempt to collect temperature data, images and samples. The November 20, 2005 landing was the first ever controlled landing on an asteroid and the subsequent ascent was the first ever ascent from any body other than the moon and Earth. Despite several hardware failures and a possible chemical fuel leak, controllers hope that the craft collected a sample either due the projectile firing (which is uncertain) or due to the impact kicking up dust in to the collection area. Hayabusa is presently scheduled to return to Earth in June of 2010. [1, 24, 36]

On June 10th and July 7th, 2003 the Jet Propulsion Laboratory's MER-A, known as Spirit, and MER-B, known as Opportunity, rovers were launched. Spirit landed on Mars on January 4th, 2004 and Opportunity landed on January 25th. The two rovers operate autonomously and are given goal-points to navigate to. The Jet Propulsion Laboratory notes that the autonomous driving has allowed the rovers to travel further in a day than they would have been able to if commanded from earth. [26, 27]

In November, 2006, new software developed by Carnegie Mellon was tested on the rovers which produced planned paths for the rovers to follow. On February 7th, 2007 this software was placed in control of the rover. This new software expands on the rover's previous ability to avoid obstacles or hazards and now allows the rover to navigate based on a wide-area terrain map. This software was based on Field D*, which was created for the Army research laboratory and had previously been used to control other robots such as Carnegie Mellon's Crusher unmanned ground combat vehicle. [7]

Both rovers use imagery from stereo camera pairs and generate three dimensional terrain maps which are then evaluated for traversability and cost. The lowest cost path is selected, the rover advances by between one-half and two meters and then recalculates available paths. Additionally, the imagery is used to determine how far the rover has traveled and correct for slippage in the sand. Opportunity has driven over 230 meters and Sprit had driven over 1250 meters, autonomously. [26]

Planning for the rovers on the ground is done using MAPGEN software created at the Ames Research Center. A human controller uses MAPGEN to generate an activity plan to be sent to the rovers. MAPGEN, which is based on the EUROPA framework (developed for Deep Space 1's Remote Agent Experiment), is a mixed-initiative planning system which uses a simple temporal constraint network to model the plan that it is developing. The system can operate at a variety of levels of autonomy ranging from a completely autonomous mode, where the system attempts to generate a full plan inclusive of all requested activities and obeying all constraints, to a more limited autonomous mode where it places selected activities in to the schedule. [4]

On March 2, 2004 the European Space Agency (ESA) launched the Rosetta spacecraft. Rosetta was originally planned to rendezvous with the comet 46 P/Wirtanen, but due to a launch date postponement it will instead rendezvous with comet 67 P/Churyumov-Gerasimenko; in route, it has flown by the Steins asteroid and will fly by the Lutetia asteroid in 2010. Rosetta is a fully autonomous craft as necessitated by the communications delay (which may be as much as an hour), long periods of time where communication with earth is not possible, and long periods of hibernation to save power. The Rosetta architecture includes a command and data management unit, attitude and orbit control system, image processor, mode manager, TC manager, TM manager, science payload manager, mass memory controller, on-board maintenance module and Rosetta basic software (which provides low level services). [12, 15]

In 2005, NASA's Demonstrator to Test Future Autonomous Rendezvous Technologies in Orbit (DART) mission attempted an autonomous rendezvous. This mission resulted in the loss of both satellites due to a navigation system problem which caused the satellites to collide. [31, 50]

On July 4, 2005 the Deep Impact Spacecraft's impactor spacecraft successfully and autonomously guided itself to impact with the Tempel I comet. The mission yielded the highest resolution images of a comet nucleus and resulted in a successful illuminated impact. The mission also gave scientists the first look ever at the inside of a comet via the impact crater. The impactor craft was released from Deep Impact approximately 24 hours prior to the time of impact. The final two hours were the critical autonomous portion of the mission. During this time, the craft was under the control of the AutoNav system which commanded three maneuvers to align the craft with the comet nucleus. AutoNav is the same navigation system created for the Deep Space One mission. While issues arose with the Attitude Determination and Control System due to large reported discontinuities in attitude quanternion data, these were resolved through the use of attitude filter parameters. All mission objectives were achieved without reliance on the use of contingency plans. [10, 29]

In 2007, the US Defense Advanced Research Projects Agency's (DARPA) ASTRO and NextSat satellites demonstrated the first US in-space autonomous docking and separation. Despite a mechanical issue requiring a change to how NextSat was released, the mission was successful and demonstrated a technology that could be used in the future to allow autonomous attachment to repair or refuel satellites. Autonomy, in this situation, is important as intermittent communications failures could make the precision maneuvers required for docking problematic if performed by ground controllers. [50]

5. THE FUTURE OF AUTONOMY IN SPACE

It seems that, for autonomous craft in space, the best is yet to come. Research, mission concepts and planned missions promise to deploy autonomous technology in to space with progressively greater mission importance. Far from being just a mission-enabler, autonomous technology looks to become the mission commander both on earth and on-craft.

Future prospective autonomous crafts in space include NASA's Snakebots which are to be autonomous snake-like robots which can be used to explore planets. Unlike traditional wheel-based robots, the Snakebots will be able to disembark the lander without a ramp and climb, dig and crawl into cracks in the surface of the planet. The Snakebots are to be autonomous and incorporate obstacle avoidance and decision making facilities. [28]

NASA's Autonomic Nano Technology Swarm (ANTS) is an architecture for the development of autonomous clusters of robots. ANTS clusters are patterned after the insect world which has demonstrated that a group of specialists will outperform a group of generalists and be able to perform tasks which a single individual could not. ANTS researchers are working to create a software neural basis function which will act as a bridge between the lower level neural system which deals with basic functions and safety and the higher level neural system which engages in problem solving and other goal-oriented computation such as scheduling and planning. The Prospecting ANTS Mission, which could launch in the 2020's, would involve investigating the asteroid belt within the solar system using nine hundred approximately one kilogram craft. The fleet would include various specialty craft such as several types of worker units (each of which has a different instrument onboard) and communications and leader units. The craft would function autonomously, and have the capability to change mission goals based on information that was collected. They would aim to categorize one thousand or more asteroids in each year. Other uses for ANTS technology include the Autonomous Lunar Investigator mission which seeks to explore the polar regions of the moon. [11, 19]

JPL mission concepts for missions to Titan and Europa also involve autonomous operation. A Europa submersible would likely have limited contact with its mission satellite and no direct contact with earth due to operating under a layer of ice. Due to this (as well as distance delay limitations), this vehicle would need to be completely autonomous and would not be able to rely on real-time teleoperation via earth-based controllers. A submersible concept could be part of a 2020 NASA mission to Europa. The Titan Aerobot concept involves an airship-like robot which would use various sensors and directional radio frequencies such as those from the deep space network, the sun and the mission orbital satellite to navigate. It is projected that the Aerobot would encounter numerous environmental conditions and would, thus, need the capacity to adapt to the situation. The Aerobot would include an autonomous planning, execution, health monitoring and recovery system components. Test flights have been conducted in California's Mojave Desert which have included limited tests of the autonomous control system. [13, 20, 40]

The Google Lunar X Prize is encouraging significant interest in autonomous exploration. The competition requires a winning team to land a robot on the moon, travel 500 meters and transmit pictures, video and other data back to earth before 2014 (or before 2012 for a larger cash prize). [49]

The Swedish Space Corporation plans to launch its Prototype Research Instruments and Space Mission Technology Advancement (PRISMA) spacecraft before February, 2010. PRISMA will be highly autonomous and demonstrate (from a guidance, navigation and control perspective) autonomous formation flying, homing and rendezvous, and proximity operations. The craft will also test several types of sensor technology. [14, 45]

A group of researchers at CalTech, the University of Arizona and the US Geologic Survey argue that more autonomy is needed. They note (as at 2005) that most space craft are not truly autonomous, which they define as including complete mission control such as goal identification, prioritization, navigation and other elements. Instead, they propose a new paradigm of multi-tier exploration craft. Under this model, a single or multiple satellites would deploy and command a set of airborne balloons or blimps which would deploy (deployment might also be direct from the satellite) and command a set of ground-tier rovers or other craft. The ground craft would pass observations to the airborne units which would pass this data, along with the data that they collect, to the satellites which would forward this, along with data collected by the satellite, back to earth. [16]

This approach, the researchers argue, would allow a more thorough exploration of the subject planet or moon as it would allow multiple areas to be studied in detail instead of the current model which generally studies only one area in detail or a wide area with limited detail. The researchers note that the understanding of the natural world is based on inferences, which are not made from a single observation but rather from numerous ones which are in many cases made at locations distant from each other. The new multi-tier approach, they argue, would allow more observations, covering more area. It would also create redundancy, prolonging the mission and allowing the investigation of areas which are of interest but would be too dangerous for a sole-craft (whose loss would end the mission) to explore. [16]

6. CONCLUSION

There is little doubt that artificial intelligence will continue to play a large role in spacecraft operations. With limited budgets, space exploration agencies and future private space operators will likely want to obtain the maximum benefit for their expenditure. Research and actual missions indicate that autonomous spacecraft are able to provide a higher level of return than a human operated one. They are able to go places where humans can not yet (due to life-support constraints), they are able to react faster using on-board AI than they could if they had to contact the ground for instructions and they are able to operate with a precision and redundancy that human operators would be hard-pressed to meet. Even for manned exploration, autonomous technologies will clearly have a role in preparing for these missions as well as supporting and assisting the humans who go on them. As such, the future of AI in space looks bright.

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Logistics for Decision Support in the Operation of both Terminals and the Corresponding Yards

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ABSTRACT

Forwarding agencies handling less-than-truckload (LTL) freight are confronted with the worldwide growth of transportation demands. The network operations of these companies are thereby strongly influenced by the performance of the individual nodes within the network, the terminals. Surprisingly, information of different handling processes like routing vehicles, yard operations and gate assignments are rarely used to generate additional benefits within the forwarding industry, even though such information is increasingly available in real-time. In this approach a scheduling heuristics is applied to several logistic operations. Based on usually limited resources for cargo handling, various weights and sizes of goods, varying und unknown truck arrival times and different departure times we apply and evaluate multiple strategies to schedule trucks in the unloading process at logistics terminals. A real-time decision algorithm applicable in practical situations has been developed to handle the problem of uncertain and changing information. This project, funded by the BMWi (Federal Ministry of Economics and Technology) in Germany, has an objective, which is twofold. On the one hand, the route planning is optimized and, on the other hand, the yard management and door assigned of trucks is optimized for improved intra-terminal material handling. The overall goal is to realize an interaction between these two optimization approaches to gain additional savings. In the following we describe mainly the methods and results of our optimizations in terminal and yard operations.

Keywords: Yard Management, Dynamic Gate Assignment, Scheduling Heuristics, Flexible Scheduling of Recources, User-guided Optimization of Logistics Tasks, Decision Support

INTRODUCTION

Typical forwarding agencies perform the pickups and the deliveries conjoined. They have to cope with hundreds of pickups and deliveries each day and a few tens of vehicles are necessary to service the customers in the short-distance traffic region. All these vehicles are bringing the inhomogeneous goods with at least partly unknown capacities and priorities to the corresponding terminal. The main task of LTL terminals is to guarantee a precise and timely transshipment of all incoming shipments to trucks heading to different destinations within a few hours.

In several approaches the gate assignment has been identified as a three-stage planning problem. Strategically the gate assignment means the division in input and output gates. In the medium term, there is the problem of mapping the local relations to the output ports and on the input side the locally and temporally assignment of the tours must be organized to the entrance gates. The optimization of the Interface „Gate“ has to be extended by the optimization of the internal time and flow of shipments through the forwarding terminal by using the involved resources and areas.

PROBLEM DESCRIPTION

The first decision is which vehicle should be unloaded first, at the same time when more than one vehicle is reaching the terminal. By approaching the cut of time (the latest arrival time for trucks so that shipments can enter the network on the same day) it is more likely that several vehicles are arriving simultaneously. Thereafter, the assignment of vehicles to inbound doors and with that intra-terminal transport decisions have to be made. The intra-transport routes are determined by fixed assignments of outbound relations to door, where the goods have to be moved to reach their destination in the transportation network. In literature exist only few approaches optimizing LTL processes and these are focusing only on the improvement of one of these activities (e.g., [2],[3],[5],[6],[7],[13],[15]). To our knowledge there are no approaches combining the existing individual approaches for door-assignment and vehicle routing in the context of LTL goods.

Small and medium-sized LTL-agencies as well as large cargo carriers have detected the opportunities in the coordinated control of sequences in the yard, resources and processes in the forwarding terminals. As a result of this contol centers are already implemented in several terminals. Mostly there is a monitor, an inner and an external camera system and a radio telephone system. On the monitor different systems are called to display information about the state of the yard. If in the course of the day a vehicle arrives then the dispatcher uses the camera system to get a survey of the plant and the assignment of goals. Thereafter he gives his decision to the gatekeeper on which gate or to which waiting area he should send the driver. Both approaches aim on the one hand to send the needed information to the planner, which he needs for his decision, and secondly to visually support the work. Although the two solutions are considered in practice to be very progressive, the lack of a central database and a software-based planning methodology are crucial disadvantages. The dispatcher must obtain the information he requires of the situation on the yard and the forwarding agency through various media. Especially in peak hours of operation, it can lead to congestion and lack of information. The lack of a standardized planning methodology currently leads to solutions that are only able to visualize the status quo of the system. Based on his experience the dispatcher generates good solutions and monitors in the screens of the control center. This raises the question whether a support of the dispatcher through intelligent planning makes sense because of the highly complex planning task. Although some work integrate intra logistical aspects in combination with the dimension of time and the models are very practical, they require long calculation times. Additionally, the developed algorithms lack dynamic aspects (e.g., late arrival) and are completely inflexible.

SOLUTION APPROACH

An efficient transport has a positive effect on the utilization of resources (e.g., buffer areas, forklift trucks). The objective is to maximize the throughput of a terminal within a fixed time-period. If possible the waiting time for vehicles shall be minimized as long waiting times result in high times of unproductiveness for the trucks and congested yards. In the test data we have a cross-docking terminal with 14 unloading gates with each 1 buffer area and more than 80 loading areas. Within the graphical layout all transshipment distances can be computed. In this terminal 25 fork lift trucks are operating. The algorithm has to handle 213 tours and more than 4,000 units, which have to be moved within 6 hours. All required intra-terminal operations are reproduced in the software according to their respective execution times in the real terminal.

To calculate the optimized unloading sequence, specifically adapted heuristics are developed and tested. As decisive reasons are cited here as follows: Heuristics are fast because they have mostly solutions in polynomial computation time and the quality of the determined solution for many practical applications is sufficiently high. Very advantageous for practical use is the property that the development of heuristics is also very easy to understand and therefore a transfer or integration with other applications is quite possible. In terms of usability of the solution ideas in this project helps the development of these heuristics, so that an application in a Transport Management System can be made easier.

The object of the research is:

1. Increasing level of detail in models for handling optimization (image from areas, different handling resources, heterogeneous charge units, etc.)
2. Extension of the models, (e.g., Extending the system boundaries of previous research approaches by linking supply and handling optimization and Yard Management)
3. Improving the solution process so as to realize in practice flexible and fast processes with a sufficient quality for the real application, (e.g., by exploring new approaches (Combining the advantages of discrete algorithms and methods of nature-analogous))

The chain of yard management can be considered starting with the arrival of the vehicles through the barrier on the yard. To complete the basic information (scanner-body data), the detailed shipment information must be submitted by the driver in the detection point of shipping [1]. The driver then receives a sign with a serial number indicating the position in the unloading sequence. If there are time-sensitive items on the vehicle, the driver gets a red card, which allows him a right of way at a next free unloading gate. Once he has docked at a gate, he opens the vehicle and automatically unloads all loaded packages into a buffer zone behind the unloading bays. Then he locks the car and pulls the vehicle off from the gate.



Figure 1: The process chain of the relevant yard movements in the discharge.

The connection of the sub-processes between discharge and transfer takes place in the buffer zone, where the transfer of packages from the driver to the forwarding agency happens. Subsequently, an employee can take the package with an appropriate transfer resource to the loading area to drop it there. The return trip to the buffer zone closes the process chain. The existing transfer resource fleet consists mainly of forklifts. The further loading of the tours has usually no effect on the discharge or handling processes and is therefore not considered.



Figure 2: The chain of internal cargo handling.

Yard management or Door assignment

The control of the yard in the input consists mainly of the sequencing of the unloading gates. The algorithms developed for this purpose base on the principle of scheduling, which makes it possible to combine a variety of resources in an overall plan ([4],[8],[16]). As all identified resources, unloading gates, transfer resource and buffer areas are used, each of the abstract buffer spaces is seen as one resource. Because of the downstream discharge of the tours, the calculation and optimization of the yard and hall usage is directly dependent on the arrival times of the tours. Consequently, a recalculation of the unloading sequence must be performed every time when a change occurs in the arrival list. Other changes such as the breakdown of a forklift, defect of an unloading gate or delay in the discharge can also make a recalculation necessary. The resulting non-functional requirements of the algorithm were derived as follows:

- Fast calculation of optimized unloading sequence to allow an operation in operational use
- Rapid response options for any plan deviation
- Inclusion of all relevant actors that are needed for unloading and transfer
- User-oriented input possibility of static data and calculation parameters

In addition, identification of several goals that should be achieved by optimizing the unloading sequence. Here, the overall objective is to achieve a more efficient handling of shipments. Specifically for the handling this means that the same handling work should be done with fewer resources in less time. The overall objective is illustrated by the following sub-goals.

- Minimizing movement ways of internal resources
- Shortening the periods of tours in the yard
- Preferred unloading of time sensitive shipments

Input data

To take into account all factors that affect the entire handling process, first all the necessary input data is divided into static and dynamic data. The group of static data include all parameters that are changed more than once daily. The group of dynamic data consists mainly of the list of tours. This data can expand, decrease or change at any time during the day. The following data of the yard and the hall are required:

- Internal surfaces (position, dimensions, relation (s))
- Gates (position in the hall, provided for discharge)
- Internal network of paths
- Cargo handling equipment fleet (count, velocity, shunting time)
- Process times in the yard (parking, docking / undocking, opening / closing, unloading a package)

To allow a user-friendly entry, Microsoft Visio drawing is used for modeling. Herein is modeled the layout of the forwarding hall with all gates, areas and ways to scale.

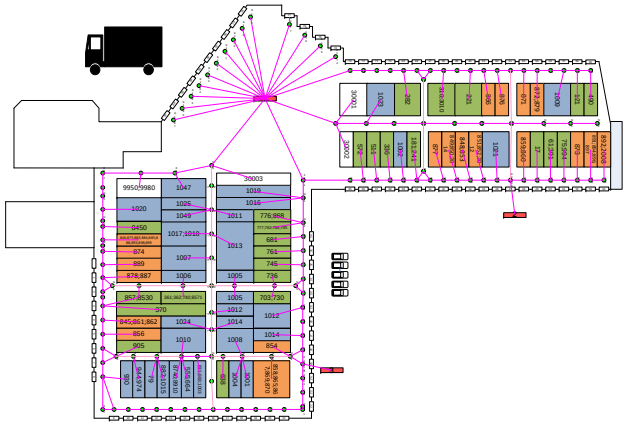


Figure 3: Input of parameters of the terminal of Schmidt-Gevelsberg by Microsoft Visio drawing.

The Figure 3 represents the terminal of „Schmidt-Gevelsberg GmbH“. For modeling a previous measurement of the transfer station is necessary. The network of paths is generated in the form of purple (route in both directions) or gray (one way) arrows. To calculate the duration of a transfer package, a pure driving time to the staging area the largest role. The calculation of all shortest paths starting from each buffer area corresponds to the problem of multiple „single-source shortest path problem“. In this case it is searched in a given graph with weighted edges of a path from a source node to all other nodes. The way is short, when it has the lowest weight. Transferred to the handling hall, it means that this problem must be solved twice as often as there are buffer zones for the unloading. Applied to the test scenario of the terminal of „Schmidt-Gevelsberg“, therefore, 492 shortest paths are calculated. The chosen algorithm of Dijkstra respectively calculates an exact solution in polynomial time [12]. A recalculation of the distances needs to be done only when the internal infrastructure changes. It is therefore sufficient to calculate once prior to initiate of the scheduling algorithms. The results of the distance calculations are then transferred into a database.

The group of dynamic data includes the arrival list as a holistic data packet, in which further information is integrated. It is actually a list of tours and includes all information to the vehicles and their shipments.

In detail, the arrival time of each tour, the number of the vehicle and a list of shipments is included. For each shipment the number of packages, the weight per package, the relation, the outgoing tour and the program type is stored. The dynamics of this data is reflected in several factors again. While the number of tours spread over the day generally remains constant, the predicted arrival times may change very frequently. The shipment number and the number of packages change when one or more new pick-up orders are entered into the system and are assigned by the dynamic trip planning to a tour. In addition to these input options, it must possible for a tour driver to add additional pick-up orders as new stopovers.

Calculation of the unloading sequence
The calculation and optimization of the sequence was developed and tested with several heuristics [9]. Overall, the following well-known and new scheduling methods were implemented.

FCFS ("First Come, First Serve"): All incoming vehicles will be added according to their arrival at the next free gate to the unloading schedule. This procedure is used only as a comparison heuristic.

FCFS with priority: This approach also serves as a comparison, but reflects the current unlaoding strategy in the examined forwarding agency. As an extension of the FCFS heuristic tours, where time sensitive shipments are preferred.

Shortest movement: It calculates a routes-optimal unloading plan for all tours. The plan will be created by adding the tours in, where their packages have the shortest internal ways. Since this strategy does not consider queuing in front of the zones, the worst case is that all tours would be unloaded in the same zone.

Longest movement: With this method, the upper limit for the shipment cost is calculated. It is the counterpart of the shortest movement and is used only for comparison.

Distance-Time-optimized: This unloading plan takes advantage of the short internal ways and the waiting time of already docked tours. So, it avoids an uneven distribution of tours to the unloading zones. The basic idea of this planning is to include every single tour with all their packages in the planning of each unloading area and then to determine the discharge end of the tour. The unloading zone in which the tour has the earliest discharge end, is foreseen for the discharge of this tour. This approach considers the following two cases of possible situations:
Case 1: The internal movements is not a bottleneck, and the discharge can begin in each zone at the same time. Thus, the tour is always discharged in those unloading area at the earliest, which causes the shortest movements ways. For these cases, the discharge has minimum movement ways, see heuristics *Shortest movements*.

Case 2: Is valid in all other situations. This means that the zone with the shortest movements ways must not be at the same time the zone with the earliest discharge of the tour. By an earlier discharge start one zone with longer ways can reach an earlier discharge end than the zone with the shortest ways.
This procedure selects accordingly the best zone for the shortest movements, but also takes into account the current situation in the unloading zones and ensures that no tour is scheduled in a zone that already has a high utilization. Basically, the order of the planning is based on the FCFS principle, so that still the „fair" distribution of waiting times for the drivers is guaranteed.

Distance-time-optimized with priority
While in the previous method already the distance-time problem is treated, this variant also takes care of the preferred discharge of tours. The integration of the priorities in the optimization is done by selecting the tour at the beginning of the calculation. First, the time of the next available free gate is determined and the amount of tours $TYard$ is searched, which are at that time at the yard and could be discharged. Contains at least one tour of $TYard$ time-sensitive shipments, so the tour is scheduled for discharge, whose time-sensitive shipments has the earliest departure time. If in $TYard$ no tours with time-sensitive shipments are available, a priority is skipped and the further planning will continue similar to the previous strategy. As identified above, the calculation of power movements has to be considered down to each individual package. In the following figure a schematically scheduling of one tour with four packages is shown. For simplicity there is only one buffer space and one lift truck.

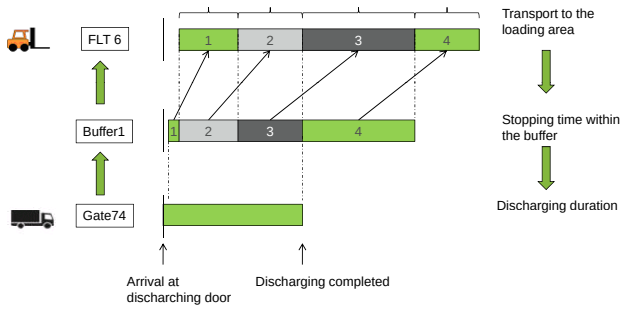


Figure 4: Illustrative example of scheduling one tour with four packages.

The calculation of the discharge duration of the tour begins from the arrival at the gate 74 and can only end when its last item is placed in the buffer. The duration of a package in the buffer ends with the beginning of the movement of a forklift. The forklift is released as soon as he has moved the fourth package and has returned back to the unloading area. In this example, it can be seen how the internal movements affect the discharge duration of the tours in spite of the buffer between.

Because of the described heuristics for discharge, the problem arises that always all packages of one tour are planned directly one after another in the bufferplan and are

not mixed with the parallel unloadeing tours. Translated into practice, this would mean that just one single driver can unload at one time and therefore any parallel upcoming tours cannot be unloaded. Since this does not reflect reality and leads to false results, the scheduling of packages in the buffer plan and the movements plan is made as follows:

1. Remove any packages from the buffer and movements plan
2. Shuffle the packages of the current tour to be planned with the removed packages
3. Sort any packages alternating between their tours
4. Insert the packages now in sequence into the plans
5. Adjust the new discharge end of the tours

It is hereby ensured that the discharge duration is not affected directly by unloading parallel tours and therefore long pauses occur, rather the backward congestion on the discharge occurs only via the buffer area to the unloading area.

Output data
Various visualization and many performance indicators are created that provide information about the expected yard and facility usage.

Gate schedule: To represent the gate-occupation of the unloading zones, a Gantt chart is used, see Figure 5.

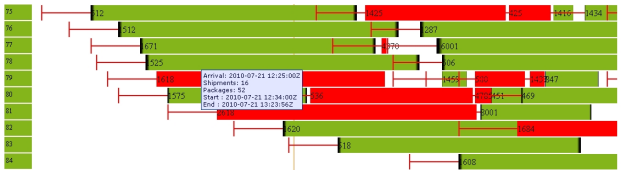


Figure 5: A gate schedule for 10 gates as a Gantt chart.

In the first column, all the discharge gates of a zone are displayed and marked with their respective gate numbers. The duration of each tour discharge is visualized as a horizontal light green bar. A dark red bar represents a tour with at least one time-sensitive shipment. The vertical line before the unloading start represents the arrival of the tour at the yard. The Gantt chart is displayed as an HTML file and makes a tool tip to a tour discharge as soon as one moves the mouse pointer over a bar. As additional information, the arrival time, the number of shipments, the number of packages, the beginning and the end of the discharge are visualized.

Buffer Schedule: The occupation of the buffer spaces of one unloading area is also displayed as a Gantt chart. The buffer space is mapped one line and the residence of a package on a buffer space is shown as an horizontal bar. Red bars represent packages of time-sensitive shipments.

Movements resources schedule: Similar to the representation of the occupancy of the buffer, each package is shown as a bar in the movements resources plan.

Area occupancy: based on package weights, a graphic is displayed for a further overview of the resources of the hall, which gives information about the filling progress. In Figure 6 are shown as an example the target areas of the forwarding hall.

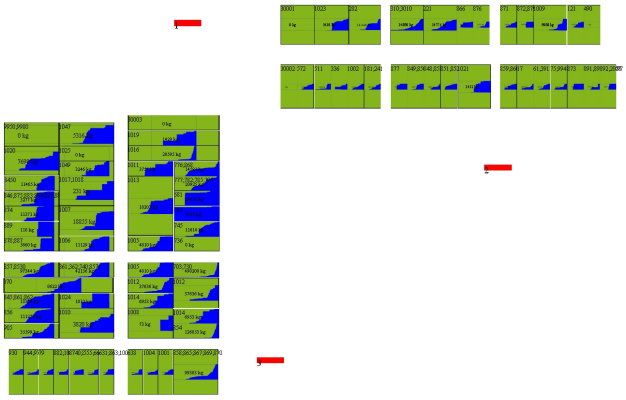


Figure 6: Illustrative example of the relative area utilization.

The overview has been intentionally connected with the hall structure, so that individual areas which are spatially connected with each other can be considered individually. This allows also for the strategic arrangement of areas to evaluate reference days afterwards. Various choices for area arrangement and sizing are supported by this.

Performance indicators: In addition to detailed evaluations of each unloading area, internal movements and time-sensitive shipments, various performance indicators are calculated, which can be used to make detailed comparisons.

CONCLUSION

Three different scheduling heuristics are developed to solve this complex problem. One is planning unloading slots for the trucks, one is scheduling the buffering of the shipment units, and one schedules the required resources. This enables computing a solution for all tours and allowing the quick integration of additional tours. Especially within this approach is the regard of the buffer in the unloading area. It only has a negative impact, if maximal capacity is reached (i.e., all resources are used). The implemented scheduling heuristics are similar to „first come, first serve“ also with different priority implementations, minimization of intra-terminal distances, maximization of intra-terminal distances (for reasons of performance measures), earliest unloading times of each tour with and without priorities. Especially the computation of the unloading times is crucial and, depending on the terminal, challenging.
To determine the quality of the optimized yard management and utilization of the hall, the heuristics above are used for comparison. In direct comparison, the main performance indicators *total distance traveled*, *total discharge*

end, *total waiting time of tours* and *average discharge duration* are compared. In Figure 7 it can be seen that the heuristic *Distance-Time-optimized with priority* is with $337km$ distance only 14% above the optimum (strategy *Shortest movements*) and well below the pessimum (strategy *Longest movement*).

Strategy	Total distance [km]	Total discharge end [hh:mm:ss]	Total waiting time of ts-tours [h]	Avg. discharge duration [hh:mm:ss]
FCFS	350	20:09:28	52:01	0:25:41
FCFS (+prio.) (=actual strategy)	*370*	*20:11:27*	*18:46*	*0:25:26*
Shortest movements	**299 (opt.)**	(>23:59:59)	(600)	(3:06:09)
Longest movement	524 (pes.)	(>23:59:59)	(3372)	(5:57:11)
Distance-time-optimized	332	20:10:27	50:00	0:25:30
Distance-time-optimized (+prio.)	337	**20:04:20**	**18:22**	**0:24:38**

Figure 7: Comparison of the main performance indicators of the developed discharge heuristics.

Compared to the current behavior (strategy *FCFS with priority*), the performance indicators of the optimized strategy *distance-time-optimized with priority* show the best results, which demonstrates the potential of the gate-assignment strategies and a confirmation of the developed solutions.

OUTLOOK

The developed solutions have been specifically adapted to the problems in less-than-truckload terminals. The obtained knowledge and methods of scheduling techniques are developed in subsequent projects. It is planed to consider additional resources in handling process chain and to generalize these methods so that related problems can be applied to this. The goal is to develop a user-oriented modelling of the process chain and availability of resources to thereby achieve a flexible, user-guided optimization of logistics tasks.

Furthermore it is planned to evaluate the results of the unloading sequence with detailed simulation runs. For this purpose, the aim is to expand the current simulation model, so that possible strategies can deal with more than one unloading zone ([10],[11]). Within this new approaches additional strategies can be implemented to consider new goals of the optimization of yard management.

Referring on the calculation time we see great potential. Within the strategies *Distance-Time-optimized* and *Distance-Time-optimized with priority* cloning the plans with thousands of activities requires the most time. Although the computational effort of the two strategies remains polynomially, the efficiency of these calculations can be improved by cloning only relevant parts of the plans, due to the fact that these plans are only needed for testing the discharge of one tour.

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PLANTOGRAF V09 and Optimal Size Determination Sensor Electrodes

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ABSTRACT

Attention is mainly focused on the experimental verification the optimal geometry arrangement for the electrodes system of the tactile transducer. This one is intended – to be caught the mechanical part of Tactile Information – for the Plantograf V09 (the latest from the row of Plantograf – line system), which enables tactile data: capturing, processing, evaluating, and visualising. The conductive elastomer is used as sensing material. The new electronic part is introduced, too - to be reached the better results by the output signal digitising; besides that the minimization and significant simplification of electronic circuits – has been archived, too.

Keywords: Tactile Information, conductive elastomer, electrodes system, sensor matrix arrangement, sensor sensitivity, pressure distribution.

1. INTRODUCTION

For a long time, we concentrated our effort on development the system, which enables the detail analyzing of the mechanical part of Tactile Information. Step by step, we received the experiences – to be implemented as improvements into the Plantograf – line system. Of course, our motto: "To be – the next one, rather the better one, than the former one" – as natural criterion of progress. In this contribution, the latest of Plantograf series - Plantograf V09 would be briefly introduced, but from the point of view - the most progressive parts only. The Plantograf V09 has been developed from the Plantograf V08. What concerns, the most significant changes: first, the total exchange of the electrodes system has been realized, which primarily ensures the data collecting; second, the completely new electronic circuits for data digitising have been used; third, practically no great changes have been done by SW and data evaluation.

Plantograf V08 is a tactile transducer, which enables pick up tactile information of particular object, and to transfer this information into electrical signal. This sensor system is focused for the following applications: measurement of static and dynamic pressures distribution: human steps analysis, sitting position analysis, pressure distribution on foot flat, and analysis of big joint status.

Plantograf V08 has to fulfil the following conditions: sensor can not change measured pressure distribution, has to measure static and dynamic load, has to have sufficient sensitivity and accuracy for given applications in each point of the sensor matrix.

The contribution is focused on description of the Plantograf V09 matrix construction (with respect to the above mentioned conditions), description of the electronic circuits which enable the cooperation with sensor matrix, and optimal electrode size determination in the points where a thin film (from a conductive silicon elastomer - as sensing layer) is used - to transfer load to electrical signal.

2. Plantograf V09 - PERFORMANCE

Transducer description

Construction of the Plantograf V09 was designed with regards to minimization of influence to the matrix measured points, and maximization of matrix point sensitivity. The matrix construction is described in a patent application [1].
A part of Plantograf V09 – the cross section is shown in Fig.1. Both electrodes are corroded on one Cuflex film placed as the bottom part of the sensor matrix. Between electrodes are measured changes of elastomer resistance.
Every electrode is covered by the conductive elastomer in its whole surface. The electrodes system and conductive elastomer are protected by non-conductive flexible material which saves the elastomer from mechanical point of view. The electrodes surface is gilded, either to be realized the

better conductivity, and either to be realized the protection against the surrounding influences. The new one electrodes system prefers the longitudinal conductivity of elastomer sensing elements before the transversal one, what is the total declination from the "traditional" approach - used by the former Plantograf line. For better understanding - currents which flow in their sensor matrix and their directions are shown by indicators on the Fig. 1 and 2.

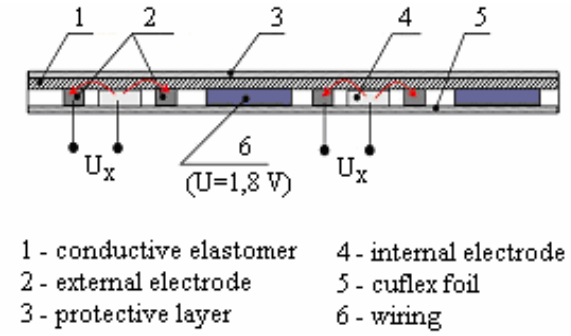


Fig. 1 Cross section of Plantograf V09

What means, that the currents flow from the inner electrode through the conductive elastomer to the outer electrode. We have had only little experiences with this arrangement. There was no quite clear, the system behavior as the whole – for what, we started the experiments, either to be verified the functionality, and either (by any reasonable electrodes size) - to get the adequate sensor sensitivity.

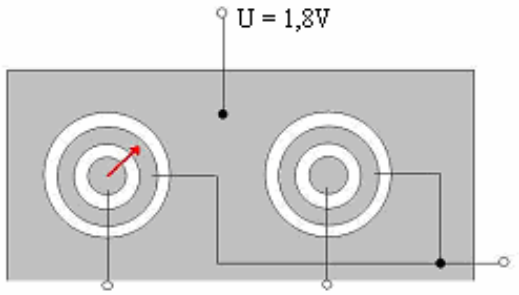


Fig. 2 Two tactile sensors of Plantograf sensor matrix

Plantograf V09 electronic circuits

The previous Plantograf V05 construction had several drawbacks that we tried to remove with the new construction type. It had high current consumption causing heat-up and dependency of power consumption on applied load. Also the construction used high speed digital converters and the relatively complicated circuits. In the new version, all A/D converters were replaced by a simple RC circuit discharged over the sensor resistance. The connection operates as resistance to time converter. All function and control are integrated in a Xilinx Spartan 3 FPGA. These changes allowed miniaturizing the whole circuit and improving speed significantly. The estimated rate is currently approximately 1000 frames/s for online measurement and 5000 frames/s for offline measurement where the data is stored to a memory card.

3. EXPERIMENTS, TESTS RESULTS

Determination of optimal electrode size

A basic task of measurement was determination of optimal electrode size which gives to the sensor matrix the maximal measuring properties - namely the maximal measuring sensitivity.

A special modular system dedicated for tactile sensor measurement was used for measuring of the points placed on the sensor matrix. This system measures load of the matrix points in real time [2]. Simultaneously rate resistance is measured by means of SW and electronic circuits. Resistance can take values between 0 – 255 (8 bit A/D converter).

The six different construction of the sensor matrix were measured during determination process. The sensor matrix elements had following sizes:
ØE=2mm, Ød=0,4mm, M=0,1mm – LH
ØE=2mm, Ød=0,1mm, M=0,1mm – PH
ØE=2,5mm, Ød=0,4mm, M=0,25mm – LD
ØE=2,5mm, Ød=0,1mm, M=0,25mm – PD
ØE 3,5mm, Ød=0,4mm, M=0,25mm, separated measuring points – OB
ØE 3,5mm, Ød=0,4mm, M=0,25mm, connected measuring points – SB

Construction sizes are described on the Fig.3.

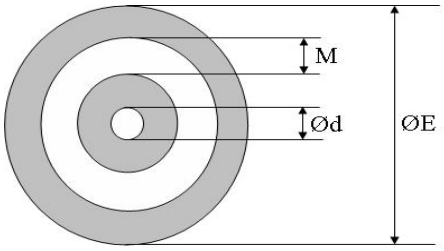


Fig. 3: Sizes of Measured Electrodes

Construction number 5 and 6 has got the same electrode size. Construction number 5 has got the conductive elastomer just in the measuring spots. Construction number 6 has got the conductive elastomer in its whole surface of the sensor matrix.

Every construction was measured in the following way:
Three points were measured on every construction
Every point was measured three times in range 0,5 – 9,5N (10 measurements) – loading
Every point was measured three times in range 0,5 – 9,5N (10 measurements) – unloading
The average values from measurements are shown on the Fig.4.

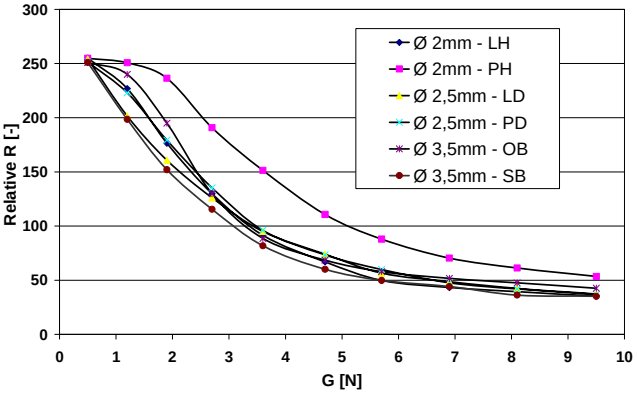


Fig. 4: Measured values of different electrodes type

The sample for testing of the electrodes system – can be seen in Fig. 5.

4. EVALUATION

Main advantages and disadvantages, results
The construction of the tactile transducer Plantograf V09 is the newest of the Plantograf Vxx line. It is designed to improve the features of the tactile sensors Plantograf V05 and Plantograf V07. The disadvantages of listed sensors were:
Plantograf V05 – there occurred influence of the unloaded points which were placed in proximity of the loaded point.
Plantograf V07 – difficult sensor matrix construction which needed precise production. Also there was a low sensitivity of the measuring points.

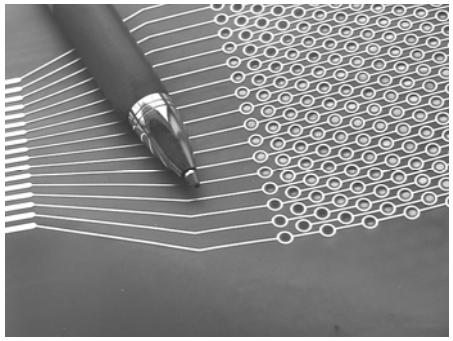


Fig. 5: Sample for electrodes system testing

Measurement result shows that sensor sensitivity varies with used construction type of the sensor matrix. Construction type PH has got the lowest sensitivity Fig.4. Construction type SB has got the highest sensitivity. Next measurement result says that the highest sensor size is used the highest sensitivity is reached. This construction size fulfils conditions which were designed for.

Why we stay by the conductive elastomer as sensing material – to be simulated the elastic, pliable touch – similar as by the human touching, grasping, gripping, handling the object, where is no so much important, what precise force is used, but the total relations among the pressed points of the followed surface. Especially, the space model of the pressure penetration under this followed surface can be useful by grasp, grip or touch, if e.g.: the more effective way is demanded by manipulation. The Plantograf system is equipped - to be realized 3D-model (as "mountain model", "wire model", "contour model", etc.) – what can be seen in Fig. 6. The other reason for this "soft" material is – to have enough time to react by the manipulation control – e.g.: don't be damaged the object of interest by using inadequate forces; or to be manipulated into no-demanded situation etc. Then, the elastomer thickness (usually 0,5mm) is used partly as preventative feed-back; besides that – partly as damping against mechanical shocks, too.

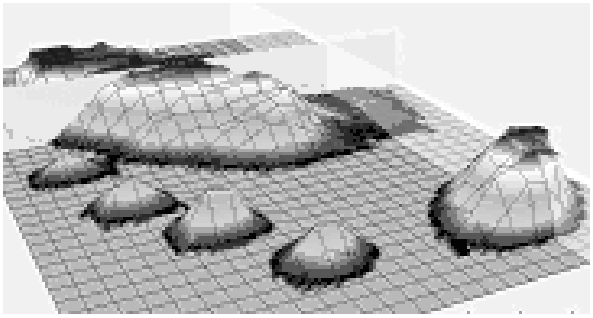


Fig. 6: 3D-model TIP-TOE
as "mountain model"

Using possibilities
From the mentioned above, it is quite clear, that the main using possibilities are the technical branches as: Robotics, manipulation and control technique. Further, the biomedical branches, too – originally this Plantograf system has been developed for improvements of the pedobarography methods in Orthopedics, later - for dental necessities, prosthesis design etc. Not only delivering tactile information by treatment can be demanded, but in sport medicine, or by Rehabilitation and Physiotherapy, too. Of course, we cannot to forget the sports and entertainment, about as the "best"

prevention before diseases. Believed that, Plantograf system could be used as interactive platform, too – through which the moving activities would be realized, as: tennis playing, balancing pad by skating, skiing, dancing or perhaps golf training (don't be tested, to this time).

Outlook

The other electrodes optimization can be done by mathematical or physical model using (with the various difficulties degree) – as e.g.: resistive mesh network, method of infinite elements, etc. – to be received results similar as by modeling temperatures, or magnetic fields; however - to be received the specific result , usually the specific input parameters (initial conditions) are demanded. First, we had no any; second, each model is necessary to verify – for what we started the experiments.

Challenge, seems to be – to realize the material with the "human skin properties", but with the great mechanical durability (e.g.: as by mentioned elastomer – guaranteed almost over 10^6 cycles, unless the significant exchange of conductivity is realized; besides that – this one is chemical resistive for a number substances). Such a one copy of "Artificial skin" should be allowed – to be caught not only the pressure distribution, but to determine the space forces orientation, too. Besides that, to be better completed the total superficial sensation – and to be better analyzed the others qualities - the others sensing elements would be integrated there too, as for: temperature, humidity, surface unevenness, etc. More than probable, such a one material could be prepared by the Nanotechnology using.

5. CONCLUSION

The functionality has been verified for the new projected electrodes system with the new conception of longitudinal conductivity – intended for the tactile transducer – line - Plantograf V09.

For pre-selected variants of the sensing elements arrangement has been received the valuable results – what concerns – the geometrical dimensions for single sensors; and their sensitivity in matrix arrangement (parameters – given in 3rd point).

The new conception enables the significant simplification by the transducer realization – as single Cuflex sheet only, with the complete electrodes system (former Plantograf – line – used 2 sheets); the other simplification, all sensing elements can be completely covered with one elastomer sheet, too (instead – the separated single points covering – up to 7500 sensing points).

Beside that, the new electronic part enables to control the data capturing, logging or sending for the other processing (worth seeing – dynamic parameter – promising to be caught up to 1000 frames/s). The significant circuitry simplification allows the other device minimization.

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Using a systemic model of accident for improving innovative technologies: Application and limitations of the STAMP model to a process for treatment of contaminated substances.

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Abstract: This paper presents the STAMP accident model, based on systems theory, and describes its application in the context of risk prevention related to the remediation of contaminated materials. The implementation of the model is described, and results are presented both in methodological and technical terms.
Keywords: hazard analysis, hazards assessment, accident analysis, contaminated sediments, STAMP, systems theory models

1 INTRODUCTION

Control theory was initially developed in order to develop analytical tools for controlling systems; this engineering control can be seen as the intentional use of feedback mechanism to control the behaviour of a dynamic process and its safety level.

Dominant methods in the field of system safety are still based on linear approaches in which the accident is generally seen as a sequence of events. These approaches are so-called traditional models of accident due to their linear nature and dynamics.

Twenty years ago, a new class of models emerged based on a holistic and systemic approach. Among these systemic models of accident, the model STAMP (System-Theoretic Accident Modeling and Processes) developed by Professor Nancy Leveson, Massachusetts Institute of Technology, considers these two aspects and defined accident not as a chain of events but as a control problem. STAMP is based on system theory developed by Ludwig von Bertalanffy, and the work of Norbert Weiner on control theory in the field of (negative) feedback.

Like any model, STAMP is not intended to be directly applied within a system. For this purpose, Nancy Leveson has developed a technique based on this model, called STPA (STamP-based Analysis). This system safety technique, still in development, aims to analyze an entire system throughout its life cycle while considering three concepts mentioned above. This technique has been applied in many industrial sectors ranging from aerospace to chemistry. In the development of this technique, STPA was used in a process for treatment of contaminated materials. Processes for remediation (removal of pollution or contaminants) of contaminated sediments have become very efficient. These technologies, which are particularly complex, call for a comprehensive approach to safety analysis which characterises all threats (to humans, equipment, local residents, the environment etc.).

This article is divided into three sections:

- A presentation of theory of control;
- A description of the systemic model of accident STAMP and its associated technique STPA which will be applied in the third section;
- Finally, an application of STPA methodology within an innovative system for treatment of contaminated sediments and a discussion of the results and limitations of the STAMP Model.

Control and Safety

Safety can be seen as a problem of control within a system. The accident occurs when the system of controls is unable to maintain failure, malfunction or external disturbance between system components. When the Challenger shuttle accident, the failed seal could not adequately control the propellant (Leveson, 2003), when the loss of the Mars Polar, the software was unable to control the rate of percent of the unit, it was helpless to understand that the "noise" from feedbacks of the measured variables indicated that the craft had reached the surface of the planet. Such accidents, involving design errors, can result from a combination of inadequate controls accumulating throughout the development of the system.

2 THEORY OF CONTROL AND CONDITIONS OF CONTROL

Controlling: A justified need

In general, several arguments justify the need to control a system, four are particularly important: the economy, safety, performance and reliability (Hardy, 2010). On safety, it is a crucial dimension in terms of control. A plane has at take off, a very low visibility and therefore must be controlled to guarantee a safe take-off track, a nuclear reactor should operate in such a way that the main variables are maintained within safe limits of functioning. Most systems are aware of danger areas, the aim of control is to avoid them.

Conditions of Control

To provided wide effects of a system, a control must generally meet four conditions (Leveson, 2006)

- a condition of goal: the controller must have one or more objectives (e.g. maintain safety constraints in the system);
- a condition of action: the controller must be capable of acting on the system's state in order to maintain a process within predetermined limits or safety constraints despite internal disturbances and / or external. In the presence of several controllers or decision makers, action must be coordinated to meet the requirement of goal. Uncoordinated actions can indeed lead to accidents when controllers fail to meet their responsibilities;
- a condition of model: the controller must possess a model of the system. Accidents occurring in complex systems frequently result from inconsistencies between the model of the used process by the controller (either human or automated) and the current state of the system;
- a condition of observability: the controller must be able to check the system status through feedbacks on the status of the process. Returns and feedbacks are useful for updating the process model of the controller.

If they are imposed by management functions within organizations, controls are in a different way. Challenger and Columbia investigations (Leveson, 2003) have pointed to inadequate controls in the launch process and system development, and communication errors. While failing events and behaviors reflect the presence of dysfunctional interactions and an inadequate application of safety constraints, inadequate control the system behavior. Dysfunctional events being due to systemic behavior in a given context, they are thus the result from inadequate control in the system. The structure of control must be examined to determine why it is inadequate to maintain constraints on a safe behavior and why events occur. In the case of Challenger, the unsafe behavior of the shuttle resulted in the spillage of hot fuel propulsion through a ring seal. This seal has not fulfilled its role and thus its control function of sealing. The loss of system is occurred due to a defective control in the conception of the system. Understanding the accident also ask for considering the phases of development and operations to determine at what point in the development or exploitation a safety constraint has no or poorly integrated within the system.

3 THE STAMP MODEL AND THE STPA TECHNIQUE

The accident model described in this section is a systems-based model. It was developed in the 2000s by Professor Nancy Leveson at the Complex System Research Laboratory of the Massachusetts Institute of Technology (MIT), and addresses the limitations of traditional accident models. This section is divided into three subsections. The first highlights the value of systems-based accident models in general. The second describes the STAMP model in particular. The third describes the STPA technique which has been developed from the STAMP model.

STAMP: A model of accident

The STAMP accident model is based on systems and control theory (Leveson, 2003). It was developed by Professor Nancy Leveson (MIT). In the STAMP model, safety is viewed as a control problem. The STAMP model is constructed from three interrelated concepts (safety constraints, hierarchical control structures and process models), described below:

Safety constraints: the concept of constraint is at the heart of the STAMP model. In systems theory, control always calls for the integration of constraints. An accident is not seen as the result of a series of events, but as a deficiency or lack of integration of constraints at each level of the socio-technical system. Safety constraints target the relationships and decisions between the many and various system variables.These constraints are also associated with a control process which aims to manage changes and adaptations in system behavior. Unlike the classical vision of the accident (that it is due to a sequence of events) in STAMP terms, accidents are viewed as the inadequate enforcement of constraints within a socio-technical system. Safety constraints therefore target the relationships and decisions between system variables that constitute non-hazardous system states.

Hierarchical safety control structures: accident prevention or analysis requires the design of a control structure that includes a description of the socio-technical system which is as representative as possible of a given context. This structure takes into account constraints required during both the development of the system, and its subsequent operation in accordance with functional requirements. A control structure can be developed for each subsystem of a larger system. Systems theory understands a system as a hierarchical structure in which each level imposes constraints on the activity of the level below it (Leveson, 2004; Leveson, 2006). Accidents result from the inadequate enforcement of constraints within the hierarchical levels of a given socio-technical system.

Process models and control loops: a control process operates between each level of the hierarchy described above. The purpose of the control process is to translate an 'input' from one hierarchical level into a 'control' over another hierarchical level. This control process can operate both upwards and downwards though the hierarchy. It is represented diagrammatically as a control loop which describes the control process. In complex systems, one or more control loops link the hierarchical levels of each control structure, with a downlink channel providing the information and controls necessary to impose constraints on the lower level, and an uplink channel which feeds back the effectiveness of these constraints. At each level of the control structure, inadequate control may result from neglect of safety constraints, poor communication of safety constraints or safety constraints incorrectly applied at the lower level. This is why feedback represents such an important dimension in the operation of a system. For example, the constraints generated by the safety analysis process always include assumptions about the operating environment of the process. When the environment changes, these assumptions become false, and the controls in place are no longer appropriate. This discrepancy between the environment and the system can become the cause of a desynchronization and the source of inappropriate or even dangerous behavior.

The effective implementation and operation of the STAMP model is achieved through a technology known as STPA, presented in the next section.

The STPA technique

STPA is a systems safety technique developed from the STAMP accident model (Ericson, 2005). STPA hazard analysis ('STamP-based Analysis') was described by Nancy Leveson and her team (Leveson, 2003; Leveson et al. 2004; Stringfellow, 2007). The analysis has two main objectives: accident investigation and safety assessment. STPA hazard analysis is an iterative process which facilitates analysis of the origins and causes of an accident. In STPA analysis, the system is seen as a set of control loops which interact with each other. An accident is therefore the result of an inadequate control.

STPA analysis can be used for both accident prevention and to evaluate the safety level of a system. In the latter case, the aim is to collect information that drives a safety-oriented approach to design and development. Hazard analysis is essentially a procedure which aims to prevent accidents before they happen. A proactive approach to accident prevention, based on the STAMP model, may provide the information necessary for risk prevention and thus the occurrence of accidents.

Current hazard analysis techniques, such as those found in operational safety, are not equipped to take into consideration the dynamic and complex nature of modern systems, in which human-machine interactions are important. That said, the objectives of an STPA hazard analysis are broadly similar to those of a traditional hazards analysis:

On the one hand, it aims to identify hazards throughout the lifecycle of a system as well as safety constraints associated with the maintenance of an acceptable level of safety;

On the other hand, it aims to determine how safety constraints may be violated and how such constraints can lead to inappropriate actions which push the system toward an accidental state.

The STPA hazard analysis process is divided into five stages:

Stage 1: consists of a preliminary analysis of system risk, and in the definition of requirements and constraints applicable at the level of the system, in order to define safety requirements and constraints to be applied to the system as a whole.

Stage 2: consists of the establishment of the safety control structure (the roles and responsibilities of the elements and feedback mechanisms). It allows the establishment of the safety control structure for the system, which include the roles and responsibilities of each element, both control elements and feedback. This stage will ultimately define and establish the control structure for system safety as described by Leveson (2004). Every level or element of the control structure has roles and responsibilities that help determine whether system safety constraints are applied or not. Once the system elements to be included have been defined, the safety control structure must be modeled.

Stage 3: aims to integrate system requirements and constraints for each element of the system. The system requirements and constraints defined in Stage 1 must be integrated for each element of the safety control structure defined in Stage 2.

Stage 4: involves a detailed analysis of the control structure and process models in order to identify inadequate controls actions which may play a role in the occurrence of an accident. In order to do this, inadequate controls actions are classified into four types (Hardy, 2010):

- a control action was not executed;
- an inappropriate or ineffective control action was executed leading to a failure;
- a potentially correct control action took place too early, too late, or at the wrong time;
- a correct control action was stopped too early.

Stage 5: is a temporal (immediate, long-term, standard) categorization of identified risks (defects in control loops). This categorization is done primarily to determine the impact of inadequate control actions on system behavior. Control defects are then dealt with by identifying the processes that could lead to a breach of one or more safety constraints.

These five stages together form the STPA methodology which is the backdrop for the implementation of the STAMP model in an industrial setting. The remediation of contaminated sediment (carried out using a physicochemical process called Novosol®) was selected as the field of analysis to make the demonstration. The whole application is described in the next section.

4 THE CASE OF NOVOSOL® PROCESS

In this section each stage of the STPA methodology presented above is revisited and described in the context of Novosol® as a socio-technical system (Hardy, 2010). The level of complexity is directly affected by the numerous participants involved in the procedure. Implementation of the Novosol® program requires the development of a Nosovol® facility. In this example the facility is managed by Company A, who are in direct contact with Company B. Company B is in charge of the operation of the Novosol® process.

This section is organized into five subsections which illustrate each of the five stages of the application of the STPA technique to the Novosol® program.

The Novosol® Process

In 1993, Solvay SA began the development of Novosol® (Hardy, 2010) initially to deal with fly ash from incineration then, from 1999, for a range of contaminated sediments. It responds to a wider need for the treatment of contaminated sediments and is operated under license by a company (or local collective) involved in environmental protection (Breugelmans, 2007). The process is divided into two treatment stages (Solvay SA, 2010):

- Stage A: phosphation, which stabilizes heavy metals in the sediment.
- Stage B: calcination, which destroys organic matter and provides usable products such as bricks or material for making roads.

A system like this, which brings together technology for the treatment of contaminated sediments and a large number of people on the ground creates a high level of activity and risk, which must be controlled. Control is achieved through the application of the STPA risk analysis technique, which is associated with the systems-based accident model STAMP. STAMP facilitates a global risk analysis of the socio-technical system (Leveson, 2003).

Stage 1: Preliminary risk analysis and definition of requirements and constraints at system level

During a safety assessment, a preliminary risks and hazards analysis is performed at system level, in order to define the safety requirements and constraints to be integrated. It must be carried out in the early stages of the life-cycle of the socio-technical system. This preliminary system risk analysis, when applied to the Novosol® system, consists of two levels of analysis. The first concerns the technical implementation of the Novosol® process, while the second focuses on the socio-technical aspect of the system, and includes all actors in the system and their interactions. This approach meets the requirements of the Solvay SA group, and the methodology of the STPA hazard analysis technique.

An initial investigation was undertaken in response to a request from industry for a risk management analysis of the Novosol® system. The request concerned risk assessment of the phosphation phase of the technical process.

An occupational risk assessment was carried out using compliance and risk analysis software (http://www.preventeo.com) followed by a HAZOP analysis. It was apparent that the HAZOP methodology is suited to the analysis of the physicochemical aspects of the Novosol® procedure (Ericson, 2005), and also underlined the fact that, like the STPA technique, HAZOP methodology looks for potential differences between the desired state of the system and its actual condition. However, while HAZOP focuses on technical parameters in a technical system, STPA deals with control problems in a socio-technical system, taking into account human and organizational factors. The HAZOP-based analysis was used to characterize the initial safety constraints of the phosphation phase of the Novosol procedure, which are focused on process engineering.

This set of analyses led to the formulation of safety recommendations to improve both the design of a future Novosol® installation and safety levels in preparation for becoming fully operational. They were supplemented by a second study and subject to a more comprehensive analysis. This second study focused on Novosol® as a socio-technical system. It included both human and organizational factors at the site, as well as the companies involved in the evolution of Novosol®, in terms of its development and operation.

System requirements and constraints are defined for each hierarchical level of the system. In this way, for the company operating the Novosol® process (Solvay SA during the technological development phase) and in the current context, requirements and constraints can be identified, using the STPA method. They are shown in Table 1.

Table 1: Sample requirements and constraint definitions for the controller (the operating company)

Company operating Novosol® (Company B)
Safety constraints and requirements
Treatment of sediments contaminated by organic compounds and heavy metals
Responsible for the smooth conduct of inspections and preparation of reports on the use and development of Novosol® in collaboration with national and international bodies
Responsible for defining operational requirements and performance of Novosol® in accordance with national and international regulations

Taken together, the definition of requirements and constraints for each of the hierarchical levels enables the hierarchical control structure to be established.

Stage 2: Establishment of the safety control structure

This second stage allows the construction of the safety control structure of the system in question, including the roles and responsibilities

of each element (control elements and their feedback loops) (Hardy and Guarnieri, 2011).

The definition and establishment of the system safety control structure (as developed by Leveson, 2004) is the cornerstone of this STPA stage Each level or element of the control structure has roles and responsibilities aimed at ensuring system safety constraints are applied within the system. Once the safety control structure has been defined, it is necessary to model it.

The model is built by linking the various hierarchical levels using the interactions between elements. This stage includes all the actors defined in Stage 1, when the requirements and constraints of the Novosol® system were established.

This stage not only provides an overview of the system in question, but also highlights the interactions between levels in the hierarchy. The control structure integrates roles and responsibilities. This makes it easier to determine the influence elements have on each other (Figure 1). The structure provides a static overview of the whole Novosol® system, showing the roles and responsibilities at each hierarchical level. These roles and responsibilities are used to support the definition and integration of constraints (identified in Stage 3) at the level of each actor in the structure.

The purpose of the structure thus defined is to represent the interactions between different hierarchical levels, and to characterize the controls between elements. It sets limits for the analysis that will subsequently determine potentially inadequate controls between levels.

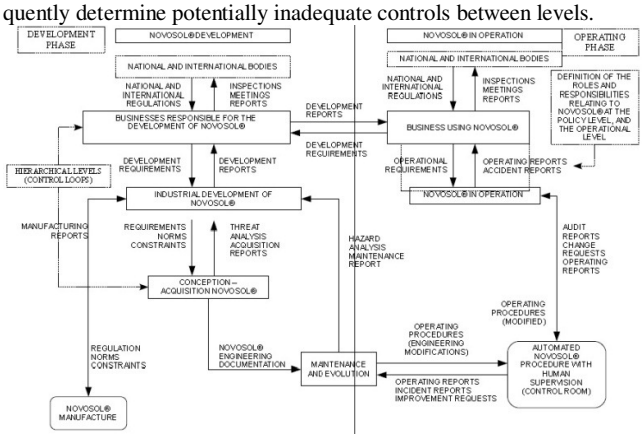


Figure 1: Structure of the Novosol® system following analysis using the STPA technique

Stage 3: Integration of system requirements and constraints at the level of the element

The system requirements and constraints defined in Stage 1 must be integrated into each hierarchical level of the safety control structure defined in Stage 2. This third stage is based on the previous two, and aims to integrate safety requirements and constraints within each hierarchical level. This is done taking into account the various interactions between elements. This stage allows the definition of requirements which are translated into safety constraints, given the various interactions between elements of the safety control structure.

From Figure 1, the higher hierarchical level - for example the decision-making level of the company responsible for the development of Novosol® (Company A) - sets developmental requirements for the lower hierarchical level (the industrial development of Novosol®). This lower level must provide feedback (control checks) through the submission of development reports to the higher level (the decision-making level of Company A). This is the case for each interaction and each variable.

In practical terms (at this level of the structure) the decision-making level of Company A must define and provide requirements for the development of a Novosol® facility to the service or entity responsible for industrial development. In return, and in order that management of Company A is informed of the successful integration of these developmental requirements (controls), the service or entity provides development reports describing the progress of the project, including any potential difficulties.

Specifically, for the two hierarchical levels 'the decision-making level of the company responsible for the development of Novosol®' and 'the industrial development Novosol®', the wording might be: "The decision-making level of the company in charge of the development of Novosol® (Company A) must provide developmental requirements to the level responsible for the industrial development of Novosol® (Company A)". In return, "the level responsible for the industrial development of Novosol® (Company A) must provide reports indicating the progress of development to the decision-making level of the company responsible for the overall development of Novosol® (Company A)".

Stage 4: Detailed examination and analysis of the control structure and process models for inadequate controls

In this stage a detailed analysis of inadequate controls is required. The analysis helps to identify potentially inadequate controls which may lead to an accident. The analysis is based on identification of the four types of inadequate controls described in Stage 4 of the STPA methodology (see Section 0). This analysis leads to the definition of actual inadequate control measures (or potential in the case of a safety assessment). For each hierarchical level, inadequate controls are defined using the relationships established when the control structure was constructed (Table 2).

Table 2: Inadequate control actions for the controller (the company operating Novosol®)

Company operating Novosol® (Company A)
(Potential) inadequate control measures
The decision-making level of the operating company does not provide operating requirements for the safe use of Novosol® to the operational level
The decision-making level of the operating company does not make their developmental requirements known to the decision-making level of the company responsible for the development of Novosol® (Company A)
The decision-making level of the operating company does not provide inspection reports to control bodies

Collectively, inadequate control measures are translated into constraints and safety requirements which have to be integrated at the level of each system element (Table 3).

Table 3: Potential constraints on the controller (the company operating Novosol®)

Company operating Novosol® (Company A)
(Potential) constraints
The decision-making level of the operating company must provide operating requirements for the safe use of Novosol® to the operational level
The decision-making level of the operating company must make their developmental requirements known to the decision-making level of the company responsible for the development of Novosol® (Company A)
The decision-making level of the operating company must provide inspection reports to control bodies

This translation of potential inadequate and defective controls form an inventory of defects and dangers that could lead the system towards an accidental state. This list allows the definition of the constraints that each hierarchical level must respect in order to maintain an acceptable level of safety. These inadequate control actions and constraints are termed 'potential' because they are assumed to exist and are only defined in the context of a safety assessment.

Stage 5: Categorization of identified risks

The first step is to categorize the risks identified in order to determine the impact of inadequate control actions on the behavior of the system. The second step is to implement a risk management strategy through the identification of the process(es) leading to the breach of one or more safety constraints. This step aims to create a hierarchy of control defects. It aims to optimize system safety by first, quickly addressing immediate risks that might migrate the system to an accidental state, then addressing long-term risks (which could lead to an accident at some point in the future), then finally tackling 'standard' risks which are dealt with using a risk management strategy during the life-cycle of the system.
The challenge here is to identify which safety recommendations need to be implemented as a priority. The identification made, it is then necessary to identify where, in a control loop a safety constraint may be violated. At each level of the loop, and in each interaction between loop levels, there may be inadequate controls. The goal is, for each hierarchical level, to identify inadequate controls that can migrate the system to an accidental state. During execution of the loop each of these controls may result in the creation of an inadequate output control at another level, resulting in the migration of the system (Figure 2) into an unstable state.

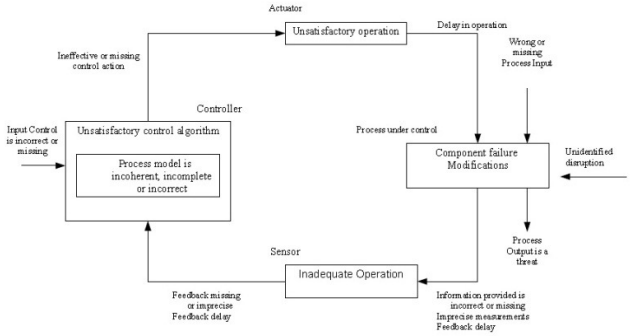


Figure 2: Inadequate control loop
Actions carried out within the control loop may lead to an inadequate control. These potential actions must be identified so that the hierarchical level can provide adequate control.

Figure 3 illustrates the 'Maintenance' level. This description of the control loop is simplified, i.e. potentially inadequate controls within it are not included.

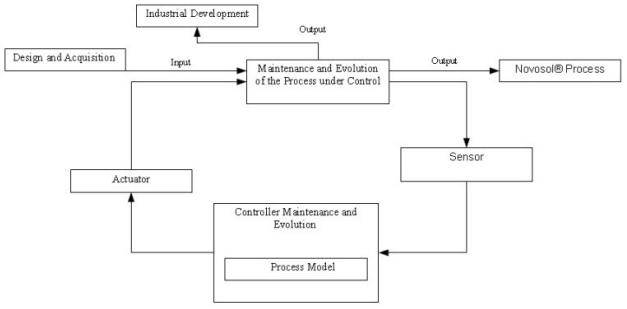


Figure 3: The 'Maintenance and Evolution' control loop (Hardy, 2010)

The 'Maintenance' control loop, highlighting the collection of elements involved in the control process at this level, in interaction with the levels 'Industrial Development' and 'Design'. Based on Figure 4, this control loop may contain incorrect information that could cause an inadequate control output to the 'Design' and 'Industrial Development' levels.
These, and all other loops in the control structure, are part of the Novosol® system and it is therefore essential to analyze them from the point of view of the entire system in order to determine the potential source of inappropriate controls.

This phase of risk categorization begins with the development of a Novosol® installation, in the analysis of existing control loops, and continues throughout its life-cycle, as the organization of the control loops changes.

5 LIMITATIONS OF STAMP MODEL AND STPA TECHNIQUE

The purpose of this section is to take a critical vision of the STAMP model and the associated technique STPA. The key contribution of technical STPA is to provide an analytical tool for industrial area in the system safety. This tool is considered as a new system safety technique (Hardy, 2010). The limitations of the technique STPA are mainly due to the theoretical aspect of the STAMP model. Indeed, the STAMP model is a model of systemic accident based on the theory of control and system theory and seeing the incident not as a chain of events but as a problem of control. However, contributions of STAMP model are also its limitations. That concerns the inclusion of notions of "balance" and "time". As part of systemic models of accident, the nonlinearity notion is at the heart of the approach in the search for the balance of socio-technical systems. This nonlinearity requests also to consider the dynamical aspect of a system and therefore its evolution over time.
These notions of balance and time are contributions in the light of changing patterns in the representation of reality. However, these concepts are also limitations in the representation of systems more complex and require different approaches. An analyzed system should not only focus on finding a stable equilibrium but on its ability to adapt by being far from equilibrium (Hardy, 2010). Thus, it is opportune to study a system out of general system theory to investigate stability passes through the concepts of dissipative structures or arrow of time. The arrow of time (Hardy, 2010), characterizes the presence of nonlinear phenomena, source of irreversibility and evolution. Thus, the STAMP model seeks to enhance the robustness and stability of a system dealing with volatile situations and nonlinear based on the general theory of systems in order to seek to maintain a state of stable equilibrium or close to that balance. That is a contradiction.

6 CONCLUSION

This article has presented a systems-based accident model called STAMP (developed at MIT) and applied it to a system for the treatment of contaminated sediments. The first step was to outline the problem of contaminated sediments, notably their origin and associated hazards. Given these many dangers, the article has highlighted the need to implement a comprehensive, systems-based approach which takes an overall view of the dangers and risks associated with the problem in question. The second part of this article presented the STAMP accident model. The model is systems-based and aims to analyze a system holistically. STAMP is the origin of the associated STPA technique, also described in this section of the article. Finally, the third part of the article describes the results of the application of the STPA technique to the Novosol® system for the treatment of contaminated sediments. This application shows that it is possible to implement a methodology for the overall analysis of system hazards by focusing not on a chain of events, but on a problem of control in a hierarchical structure.
The application of a systems-based accident model to the treatment of contaminated sediments contributes greatly to so-called traditional model of accidents. The study of system risk at an organizational level, rather than technical risks at a 'field' level, can open roads to improved solutions for the treatment and recovery of contaminated sediments. A task which every day become a little more complex.

7 ACKNOWLEDGEMENTS

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Building an Accelerated and Energy-Efficient Traffic Monitor onto the NetFPGA platform

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ABSTRACT

[1] A traffic monitor system has been implemented on the NetFPGA. The NetFPGA is an open networking platform accelerator that enables researchers and instructors to build working prototypes of high-speed, hardware-accelerated networking systems. The traffic monitor application allows network packets to be captured and analyzed from up to all four of the Gigabit Ethernet ports. A log file with statistics of the packets is generated and updated runtime. The project has been implemented as a fully open-source project and serves as an exemplar project on how to build and distribute NetFPGA applications. All the code (Verilog, hardware, system software, verification scripts, makefiles, and support tools) can be freely downloaded from the NetFPGA.org website. System performance has been compared with other two implementations: one using the same NetFPGA architecture but implementing the reference router with port mirroring, and the other being a software implementation built on top of the Click Modular Router.

Keywords

Traffic Monitor, Packet Sniffer, Port Mirroring, Click Modular Router

1. INTRODUCTION

The innovation in computer networks used in our everyday life has become notably crucial. Usually, network devices as IP routers, bridges, hub and switches are compacted and closed platforms which are not possible to change or enhance. Their functionalities are limited and restricted by vendors who are often hostile to allow researchers and programmers to modify and extend their products. This implies a substantial decrease in the rate of innovation and improvement. One of the goal of this paper is to allow researchers and developers to access and modify the architecture we have worked on, and, thus accelerating the deployment of innovations. Today, many of the ideas proposed in literature are limited to a paper or conference and do not find application in practice. The NetFPGA platform [4] allows everyone to prototype and develop multi-Gigabit networking applications. It is an open platform and user community developed to enable researchers to build high-speed, hardware-accelerated networking systems. The platform is used by instructors to show how to build line rate Ethernet switches and Internet Protocol (IP) routers. The open-source NetFPGA distribution consists of gateware, hardware and software. As far as the hardware is concerned, it consists of a PCI card that has an FPGA, memory (SRAM and DRAM), and four 1-GigE Ethernet ports. Source code and scripts are provided to build reference designs, enhance a design, or create new applications using supplied libraries. Hardware description source code (gateware) and software source code are freely available online. The NetFPGA platform not only consists of the NetFPGA board, but also the development environment and scripts that allow for rapid prototyping and development of hardware projects. The development environment is available from the NetFPGA website [4]. Reference designs comprised in the system include an IPv4 router, an Ethernet switch, a four-port NIC, and SCONE (Software Component of NetFPGA). Researchers have used the platform to build advanced network flow processing systems. A single NetFPGA board can route packets over any number of subnets, and multiple NetFPGA boards can be installed in the same PC. In addition, there are several user-contributed projects available such as the netflow probe, OpenFlow switch, the Packet Generator, and the RCP router. This paper describes the implementation of an accelerated and energy-efficient traffic monitor on the NetFPGA. The main purpose of traffic monitor tools is monitoring (and counting) the IP traffic between local area networks (LAN) and Internet. Having these tools more accelerated and with limited power consumption is more and more appealing. We have developed the traffic monitor project on top of the reference router project. First, we have created a

[1]The work leading to this invention has benefited from a fellowship of the Seventh Framework Programme of the European Community [7ą PQ/2007-2013] regarding the Grant Agreement n. PIRG03-GA-2008-231021.

new Verilog module which duplicates each incoming packets and sends them through the bus to the higher levels of our NetFPGA system, in order to be analyzed and displayed. Then, a log file containing a summary of the statistics of the incoming packets is produced. We have compared the performance of such a system against a similar NetFPGA system with port mirroring. Port mirroring, also known as a roving analysis port, is a method of monitoring network traffic that forwards a copy of each incoming and outgoing packet from one port of a network switch to another port where the packet can be studied. A network administrator uses port mirroring as a diagnostic tool or debugging feature, especially when fending off an attack. It enables the administrator to keep close track of switch performance and alter it if necessary. Port mirroring can be managed locally or remotely. An administrator configures port mirroring by assigning a port from which to copy all packets and another port where those packets will be sent. A packet bound for or heading away from the first port will be forwarded onto the second port as well. The administrator places a protocol analyzer on the port receiving the mirrored data to monitor each segment separately. The analyzer captures and evaluates the data without affecting the client on the original port. The monitor port may be a port on the same SwitchModule with an attached Remote Network Monitoring probe, a port on a different SwitchModule in the same hub, or the SwitchModule processor.

Port mirroring can consume significant CPU resources while active. Better choices for long-term monitoring may include a passive tap like an optical probe or an Ethernet repeater.

This paper is structured as follows: Section 2 introduces the NetFPGA platform; Section 3 shows how port mirroring feature works. Section 4 describes the traffic monitor application we have developed. We have compared the performances of our NetFPGA system against a software implementation using the Click Modular Router [9] of the traffic monitor. The experimentation and the obtained results are shown in Section 5 whereas Section 6 ends the paper with the conclusions and potential future works.

2. NETFPGA PLATFORM

The NetFPGA is an accelerated network hardware that augments the function of a standard computer. It consists of three parts: hardware, gateware, and software. The development board itself is a PCI card that can be installed in any PC with an available full-length slot. In more detail, the hardware of the board has the following core components:

- Xilinx Virtex-II Pro 50
- 4x1 Gbps Ethernet ports using a soft MAC core
- Two parallel banks of 18 MBit Zero-bus turnaround (ZBT) SRAM
- 64 MBytes DDR DRAM

The FPGA directly handles all data-path switching, routing, and processing of Ethernet and Internet packets, leaving software to handle only control-path functions [10]. Hosted on the board are a user-programmable FPGA (with two PowerPC processors), SRAM, DRAM, and four 1Gbps Ethernet ports. Software and gateware (Verilog HDL source code) are available for download under an open source license from the NetFPGA website [4]. This allows jump starting prototypes and quickly building on existing designs such as an IPV4 router or a NIC. The gateware is designed to be modular and easily extensible. Designs are implemented

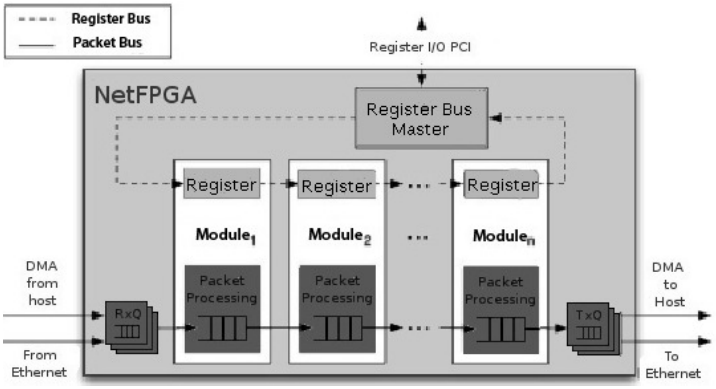


Figure 1: Modular NetFPGA pipeline structure. The high-bandwidth packet bus (in light gray) is used for packet processing while the register bus (in dark gray) is used to carry control and status information between software modules and the hardware.

as modular stages connected together in a pipeline, allowing the addition of new stages with relatively small effort [11]. The pipeline is depicted in Figure 1.

The platform can be used to show how to build Ethernet switches, Internet Prototcol (IP) routers using hardware rather than software, to implement precise network measurement systems, and to design hardware-accelerated network processing systems. The platform can be used by researchers to prototype advanced services for next-generation networks.

Accent Technology [2] offers pre-assembled NetFPGA computer systems as approved by Stanford University. These pre-built and completely tested Linux-based computers are available in a compact desktop cube or standard 1U rackmountable server configuration. In the researcher laboratories, the NetFPGA is usually installed inside a desktop PC so researchers can access the hardware [8, 13]. Several project has already been developed in the NetFPGA (see the NetFPGA project page [3]).

2.1 Gateware and Software

One of the most appealing features of the NetFPGA platform is the availability of the open-source Verilog gateware, and the related software. Its design is modular and allows users to implement new modules and connect them in new configurations. Programming and administration of the development board are performed by the host PC via the PCI bus. This allows users to remotely develop and deploy designs since physical access to the board is not required. There are three main components of the NetFPGA architecture:

1. Kernel module. It is used to communicate to the NetFPGA through a register interface implemented using the shared memory and through the PCI bus of a Linux based PC. The DMA is used by all the reference systems to receive and send network packets from the card. Software, running on the host PC, writes control data and reads statistic counters using several registers.

2. Common utilities used to communicate with the card. Among the utilities there are a bitfile download utility, and programs to read and write on to registers (ie. regdump which dumps the contents of the registers, a java gui that allows the user to change entries in the routing table and ARP cache as well as the router's MAC and IP addresses, and a standalone command line interpreter (CLI) which allows the user to change routing table entries, ARP cache entries and other settings).

3. Reference pipeline. It is described in Section 2.2.

2.2 Reference Pipeline

The reference pipeline consists of the user datapath, eight receive queues and eight transmit queues. Its architecture is depicted in Figure 2. Both the queues are classified into two types: MAC and CPU. The MAC queues are assigned to one of the four NetFPGA ports whereas one CPU queue is associated with each of the MAC queues. Developers can

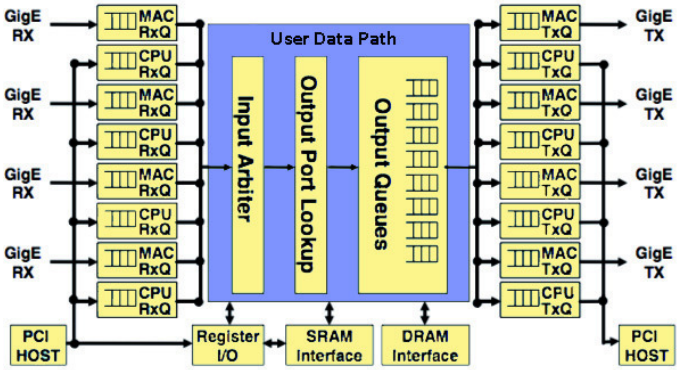


Figure 2: NetFPGA Reference Pipeline.

create their own modules. They can add and connect all the available modules to the User Data Path. There are a few modules that are present in almost all the NetFPGA projects: they are the Input Arbiter and the Output Queues modules. In particular, the Input Arbiter supplies a wide 64-bit packet pipeline to the eight input queues in a round robin fashion. Details of the implementation are contained within the NetFPGA Verilog library (which contains the source code of all the modules). All the modules may be inserted into the pipeline through the register system. There is a register interface which allows software programs running on the host PC to send data and receive data from the hardware modules. Registers and counters are assigned names that are common to the hardware design and C or Perl software that runs on the host PC.

3. PORT MIRRORING

Figures 3 and 4 show four computers (A, B, C and D). On figure 3 they are connected to a managed switch with port mirroring support, while on figure 4 they are connected to a general switch without port mirroring support. A network traffic is sent between computers A and B (one portion of data is sent from A to B and another portion is sent in reverse direction from B to A). On figure 4 you will see how a general unmanaged switch works. It forwards packets directly between ports, where computers A and B are connected to. Other computers (C and D) do not see these packets. On figure 3 you will see the same scenario, but on the switch with port mirroring function. The network traffic is sent again between computers A and B. But there is a computer D, which is listening (monitoring) to that traffic. Every packet, which is sent or received by computer A is duplicated (mirrored) to computer D port. When configuring port mirroring on the switch, the "source monitoring port" is a port, where computer A is connected to and the "destination analysis port" is a port, where computer D is connected to.

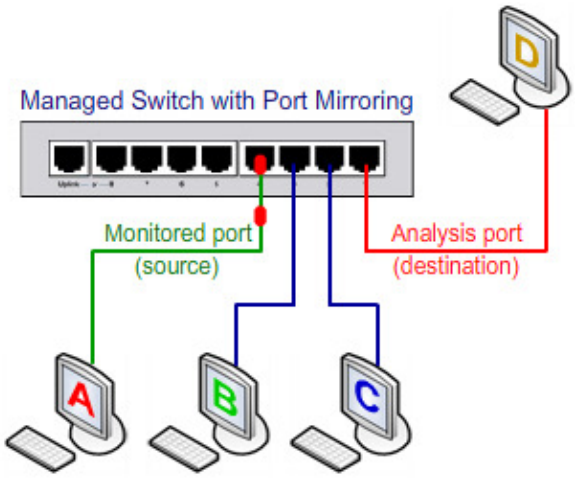


Figure 3: Managed switch with port mirroring.

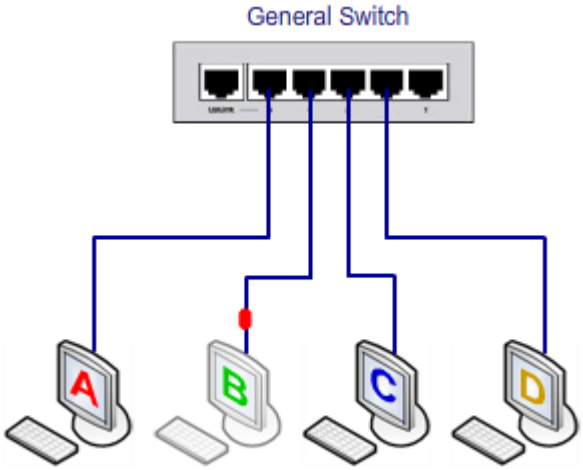


Figure 4: General switch.

4. TRAFFIC MONITOR ARCHITECTURE

Our accelerated and energy-efficient hardware traffic monitor system consists of hardware and software. The hardware component is an extended NetFPGA IPv4 reference router that sends a copy of each incoming packet to the host system (see Figure 6). The traffic monitor we have built on top of the reference router has been developed editing the Output Port Lookup module of the reference router. In particular, we have modified the *op_lut_process_sm.v* file in order to duplicate each incoming packet and send it to the higher levels. As far as the software is concerned, the software component analyzes the packets and writes a summary of the data to the $traffic.log$ file. The traffic monitor is written in C, and reads packets from the first NetFPGA software interface, i.e. nf2c0, using raw sockets. Raw sockets have been used because they allow packets to bypass the linux TCP/IP stack and be handled directly to the application in the same form they were sent from the NetFPGA hardware. We have also created an API so that anyone can build on top of our software any kind of related application (for example a complex graphical user interface or something like Wireshark [6]). Network packets coming from the network to the reference router through any of the MAC receive queues are duplicated within the user data path. A copy of each network packets is sent through the PCI bus to the higher levels and analyzed by the software. On the other hand, the other copy of the network packets is forwarded through any MAC transmission queues to the network. Figure 5 shows a diagram of our system.

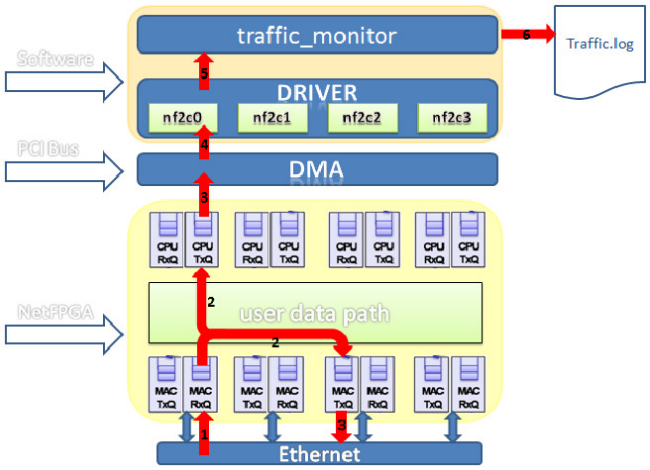


Figure 5: Traffic Monitor Diagram. The network packets are duplicated at the user data path level (see 2). One stream goes to the higher levels through the PCI bus (see 3,4,5,6); the other stream goes back to the network.

5. EXPERIMENTATION

In this section we present a test we have carried out to show how our traffic monitor system improves on other two software implementations. The used network is shown in figure 6. Two machines $PC1$ and $PC2$ and a router R have been used. The traffic monitor implementation needs a NetFPGA card installed and configured on the router machine R. In particular, this machine was based on a host computer system running the CentOS 5.2 operating system and contained an AMD X2 6000+ dual core processor running at 3.0 GHz, 2 GB DDR2 RAM, an Intel Pro/1000 PT Dual-port NIC, and an ASUS M3N78-VM motherboard with an on-board gigabit NIC. Figure 6 shows how the topology of our local network has been set. The IP of $PC1$ was set to 192.168.1.10 whereas the IP of $PC2$ was set to 192.168.0.10. They were connected to the router R through the NetFPGA ports nf2c1 and nf2c0, respectively. The router R is logically connected to the host system where all the packets are analyzed and logged into the $traffic_monitor.log$ file. For the experiments shown below, we have used Harpoon [12] to generate representative packet traffic at the IP flow level.

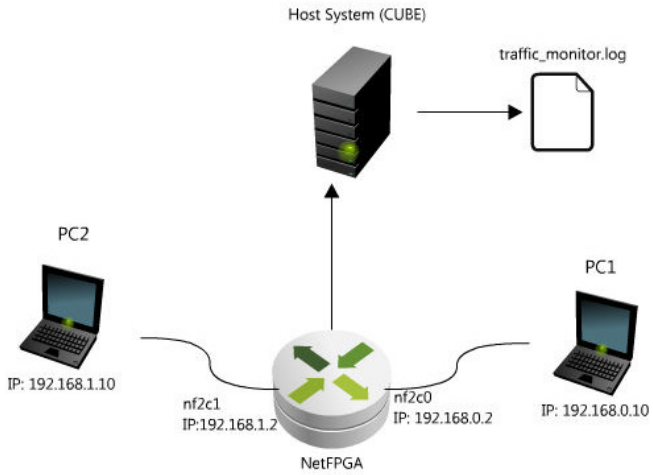


Figure 6: Schema of the local network used for the experiments.

We have compared our traffic monitor system against two other systems we have implemented: ROUPROM, which is built on top of the original reference router but it works with port mirroring, and ROUCLICK, a software traffic monitor implementation developed on top of the Click Modular Router [9]. We will describe in Section 5.1 the architecture of ROUPROM and in Section 5.2 the details of ROUCLICK. Finally, Section 5.3 will show the obtained results for all the systems and the energy saved.

5.1 ROUPROM - Traffic monitor using the port mirroring

In the reference router normal running, network packets addressed to any of the four Gigabit NetFPGA ports are forwarded to the host computer through the CPU Transmission queues and the PCI bus; otherwise, if the IP address of the network packet is different from the IP addresses of the NetFPGA ports, the packets will be forwarded according to the routing table of the NetFPGA router. We have slightly changed the behavior just described changing the Output Port Lookup and IO_queues modules (in particular, we have edited the *op_lut_process_sm.v* and $nf2_mac_grp.v$ files, respectively) in order to make the reference router work with port mirroring. The resulting router ROUPROM with port mirroring will always forward to the host computer all the network packets. In this way, all the incoming packets may be read, analyzed and stored by the host computer.

Then, if these packets are not addressed to the NetFPGA ports, they will be forwarded down to the NetFPGA router through the PCI bus. In particular, these network packets will be sent to one of the CPU receive queues and, then, transmitted to the network through the MAC transmission queues. With such an architecture, there is a considerable delay for transmission and receive as all the network packets will have to go through a longer path.

5.2 ROUCLICK - A software implementation of the traffic monitor

We have considered an IP router that forwards unicast packets in nearly full compliance with the standards. We have used the IP Click Modular Router described in [9] with the topology shown in Fig. 6. On top of that, we have developed a basic traffic monitor ROUCLICK which captures all the fields of any network packet, analyzes them and stores the resulting data into a file. We have installed on the host system of figure 6 the Click Modular Router 1.5.0 on top of SUSE Linux 1.0 distribution with kernel 2.6.13-15. Then, on $PC2$ we have run a script which downloaded the 1.8 GB file from $PC1$. For such a kind of architecture, the CPU of the host computer, which behaves as a router, is more stressed as it will have to do much more processing. In particular, it will have to perform all the router operations (which for the NetFPGA system were performed by a dedicated card).

5.3 Results

Figure 7 shows the comparisons in terms of CPU utilization of our traffic monitor system against ROUPROM and ROUCLICK. The CPUs utilization for the ROUCLICK is almost full; ROUPROM is able to use fully just one CPU. Our system outperforms ROUCLICK and ROUPROM being able to use just the 10% of the dual core machine used. Figure 8 shows the packets per second received by all the systems described above. The shown results have been taken for an execution of 9 hours. These lines, which indicate respectively the ROUPROM and ROUCLICK systems, have the same trend as for both the systems network packets are processed by high levels.

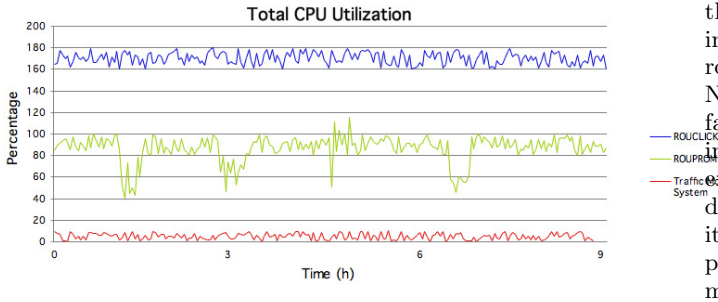


Figure 7: CPU utilization in 9 hours for the three different traffic monitor systems.

Finally, we have compared the three systems in order to measure the consumed energy. Figure 9 shows the different power consumption for the three systems for 9 hours of traffic monitoring. The system in idle state has a power consumption of 43 W. Then, the reader may notice how our system outperforms the others also in terms of power consumption.

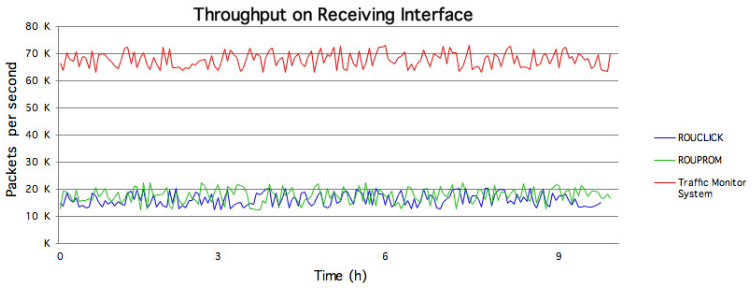


Figure 8: Throughput on the receiving interface.

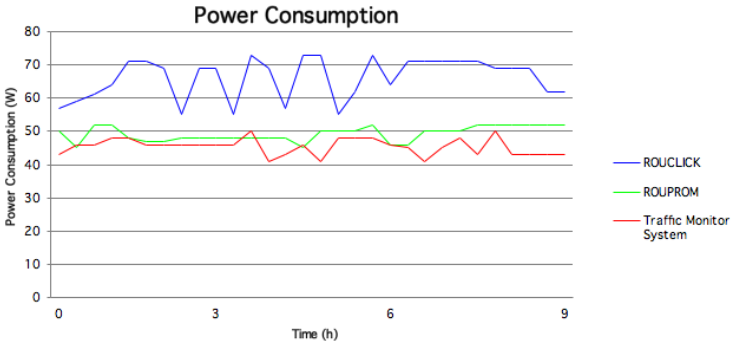


Figure 9: Power consumption for 9 hours of traffic monitoring.

6. CONCLUSIONS

Our hardware traffic monitor system is implemented on top of the NetFPGA platform. It performs filtering of every packets and then extraction, storage, and display of all the related information. We believe this mix of hardware (high performance) and software (high flexibility) makes the NetFPGA platform very suitable for traffic monitor. We have shown that full packet extraction in a software-based router or in a NetFPGA router working with port mirroring, consumes substantially more CPU cycles when compared to the NetFPGA platform and has lower performance as far as the throughput is concerned. Of course, a fully hardware-based implementation of the traffic monitor, say in a commercial router, would involve long development time. Using the NetFPGA, this implementation would more effective and fast. Our code has been released, following the guidelines in [7], to the larger community for re-use, feedback, and enhancement. It can be downloaded from [1]. Our future development consists of building on top of our traffic monitor an energy-efficient graphical user interface which displays all the information about packets as different commercial and open-source software do and reports network usage and statistics for network packets (see Wireshark [6] or tcpdump [5]). These tools will also be compared with our future developed software.

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Implementation of Refined Ray Tracing inside a Space Module

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ABSTRACT

Modern space modules are susceptible to EM radiation from both external and internal sources within the space module. Since the EM waves for various operations are frequently in the high-frequency domain, asymptotic ray-theoretic methods are often the most optimal choice for deterministic EM field analysis. In this work, surface modeling of a typical manned space module is done by hybridizing a finite segment of right circular cylinder and a general paraboloid of revolution (GPOR) frustum. A transmitting source is placed inside the space module and test rays are launched from the transmitter. The rays are allowed to propagate inside the cavity. Unlike the available ray-tracing package, that use numerical search methods, a quasi-analytical ray-propagation model is developed to obtain the ray-path details inside the cavity which involves the *ray-launching*, *ray-bunching*, and an adaptive cube for *ray-reception*.

Keywords: Space module, Surface modeling, Ray tracing, Refined ray tracing

1. INTRODUCTION

Although ray tracing has been employed extensively for high-frequency asymptotic EM field computations, particularly for the scattering and diffraction problems, a closer scrutiny reveals that the differential approach to ray tracing have been primarily applied to the convex surfaces [1]. The ray tracing becomes extremely cumbersome in the important applications of crevices and concavities within an enclosure (such as space modules, aircraft engine, cockpit and passenger cabins) due to ray proliferation, arising from multiple reflections, transmission and diffraction. In fact the only route to ray-tracing available in such cases is *ray casting*, which improves the prediction only when the spatial rays are increasingly dense (in angular separation) leading to computational intractability. For the estimation of RF field inside a space module, the ray-path data is required for direct plus cumulative reflected rays up to the N^{th} bounce. In this paper, a refined ray-tracing method is implemented in conjunction with analytical surface modeling for a typical manned space module.

The present work has two parts viz., the surface modeling and ray tracing. Surface modeling of the space module is done by hybridizing a finite segment of right circular cylinder and a general paraboloid of revolution (GPOR) frustum. A transmitting source is placed inside the space module and test rays are launched from the transmitter. The rays are allowed to propagate inside the cavity. As the surface model involves the use of parametric equations, the ray-propagation model takes care of the surface normal at different incident points. The surface normal of the GPOR and right circular cylinder are defined by the analytical equations [2], which significantly reduces the ray-path computation time.

The simulation results for the ray propagation inside the modeled manned space module are presented *w.r.t.* number of bounce. A detailed analysis of convergence studies and computation time is also carried out.

2. SURFACE MODELING OF A SPACE MODULE

A typical manned space module can be modeled as a hybrid of a general paraboloid of revolution (GPOR) frustum and a finite segment of right circular cylinder. In this work all the rays are obtained up to a given time. Hence the rays are provided in a cumulative manner upto a given number of bounces.

Geometry of the space module

The internal dimension of a typical manned space module considered [3] is given as:

Right circular cylinder length: 7.5 m
Right circular cylinder diameter: 4.5 m
GPOR frustum height: 5 m

For the GPOR frustum, shaping parameter is assumed to be 0.75 such that the basis parameter coordinate varies from u_1= 2 to u_2= 3. A matching lower radius of 2.25 m results in the required upper radius of the GPOR frustum of 1.5 m. The transmitter and receiver are located at S(0.5, 0.9, -15.5) and R (0.5,-0.4, -6.0) without loss of

generality, inside the space module. The ray tracing is done using ray-casting method. A quasi-analytical refined ray tracing method in conjunction with analytical surface modeling is used here for ray-path data generation.

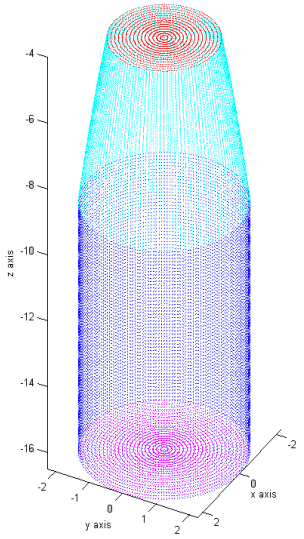


Figure 1 The space module modeled as a hybrid of GPOR frustum and a finite segment of right circular cylinder

3. RAY PROPAGATION INSIDE THE SPACE MODULE

After modeling the space module, the ray-path details between the transmitter and receiver are determined using a refined ray-tracing algorithm described below.

Refined ray-tracing inside the modeled space module

The hybrid structure of GPOR frustum and finite right circular cylinder is assumed to be closed at both the ends.

Ray casting is done from the isotropic source (transmitter) using a *uniform ray launching scheme* [4]. Let the angle that the ray makes with the x-axis and the z-axis be θ and ϕ, respectively. Each ray is defined by their θ and ϕ values. The rays are then allowed to propagate inside the cabin. Considering the intersection formula between a line and the surface of right circular cylinder [5], the first intersection point is determined. As the hybrid structure has four surfaces at different heights, the z-coordinate of the first intersection point is checked and according to the surface, the equation is adopted for calculation of *first incident point*. The corresponding four surfaces of the space module as given below:

a) At z = - 4, Plane
b) If - 4 > z > -9, GPOR frustum
c) If -9 ≥ z > -16.5, Right circular cylinder
d) If z = -16.5, Plane

The unit surface normal vector at the first incident point is determined by taking the normal equation of the corresponding surfaces [2].

The intermediate point on the reflected ray is then obtained using the *Snell's law of reflection*. The same process is repeated for the given number of bounces.

A receiver is considered as a small sub-cube placed inside the space module. The centre of the sub-cube is the observation point. The rays that reach the reception sub-cube are considered as the rays required for the field build-up inside the cabin. The ray paths tend to appear as ray bunches (Fig. 2), which traverse nearly parallel manner and reach the receiver. Hence an algorithm is developed for identifying these bunches. The *ray within a bunch*, which is closest to the receiving point, is considered as the *required ray* (Red colour ray: Fig. 3). This ray converges by refining the angular separation iteratively (Green colour ray: Fig. 3), *i.e.*, to yield the ray solutions at the receiver after refinement.

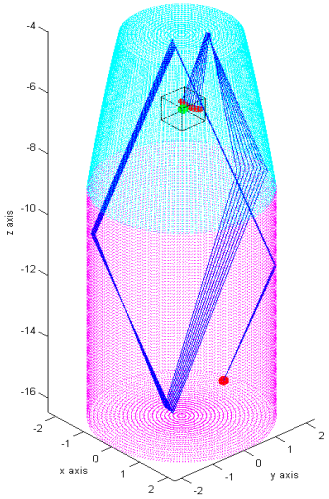


Figure 2 A single bunch of rays reaching the reception cube.

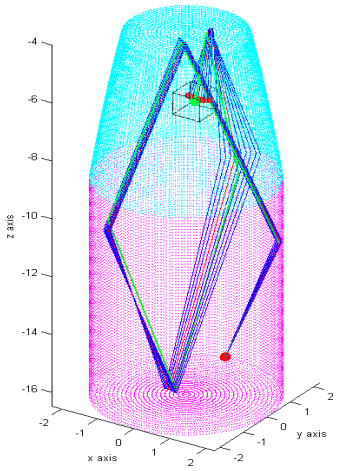


Figure 3 The converged ray (Green colour ray) reaches the receiving point.

Results and visualization of ray-path

The ray-path propagation characteristics are verified for conditions of co-planarity and equality of angles, and the unit surface normal vector for the 2nd degree quadric patches. Hence the ray-path data is imported in *Matlab* and reported in this paper. As ray casting is used, 4126183 rays are launched; out of which only 42 rays reach the receiver cumulatively upto 3 bounces excluding the *direct ray*. There are 4 rays which reach after one bounce, 10 rays after two bounces, and 28 rays after three bounces. Figures 4a through 4c gives the visualization of one-bounce, two-bounce and three-bounce rays reaching receiver and Fig. 4d shows the rays cumulatively till 3rd bounce. Figure 5 gives the 3D perspective of the ray path details inside the space module up to 5 bounces. Similarly the ray path data are generated up to 40 bounces sorted *w.r.t.* their propagation time.

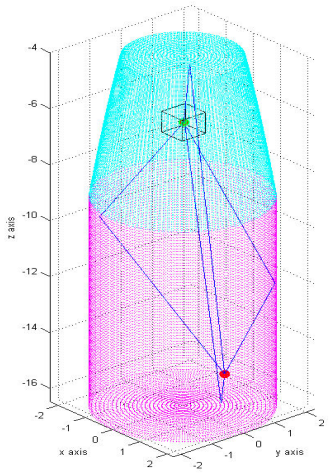


Figure 4a Single-bounce ray paths (Red dot represents the source point and green dot represents the centre of the reception sub-cube)

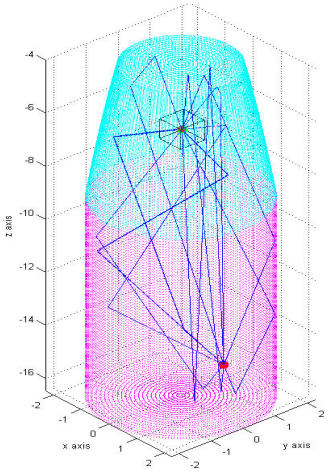


Figure 4b All two-bounce ray paths (Red dot represents the source point and green dot represents the centre of the reception sub-cube)

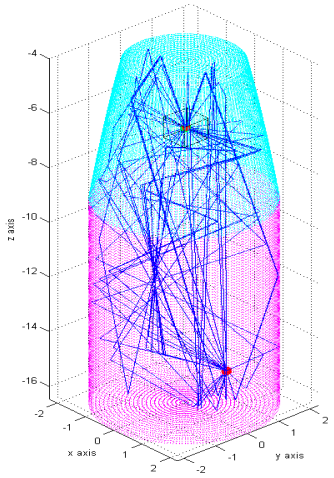


Figure 4c All three bounce ray paths (Red dot represents the source point and green dot represents the centre of the reception sub-cube)

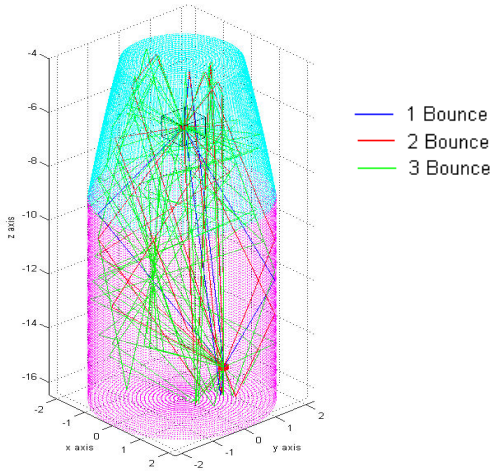


Figure 4d Cumulative rays up to three bounces

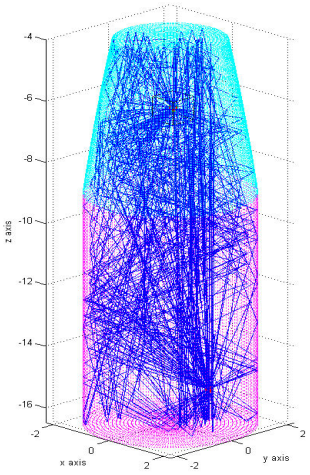


Figure 5 Cumulative rays that reach receiver up to five bounces

Ray Convergence Study

A convergence study of the number of rays that reach the receiving point *w.r.t.* the number of rays launched (a function of angular separation) is carried out. The cumulative rays (till 5 bounce) that reach the receiver after refinement is given in Table I. A close scrutiny on the table indicates that as the number of bounce increases, smaller angular separation (capable of launching more number of rays) is required for the convergence.

Table I
Convergence study of rays reaching at N bounce *w.r.t.* angular separation

Angular separation	No. of rays launched	No. of bounces (b)				
		1b	2b	3b	4b	5b
1	41345	**4**	6	16	11	11
0.5	165197	**4**	6	16	16	18
0.3	458675	**4**	9	16	20	22
0.2	1031769	**4**	**10**	28	23	41
0.1	4126183	**4**	**10**	28	24	54
0.05	16503013	**4**	**10**	**31**	**32**	71
0.03	45839676	**4**	**10**	**31**	**32**	85

Table II
Rays reaching receiver cumulatively upto N bounce and the execution time (4126183 rays are launched)

N--Bounce	No. of rays received	Program Execution time
1 bounce	4	25 Sec
5 bounce	120	1.55 min
10 bounce	538	6.67 min
15 bounce	893	11.00 min
20 bounce	1082	17.56 min
25 bounce	1205	24.35 min
30 bounce	1279	29.45 min
35 bounce	1318	34.12 min
40 bounce	1345	42.35 min

The cumulative ray-path data is generated for EM field computation till 40 bounces. The number of rays that reach the receiver *w.r.t.* N-bounce and the program execution time is given in Table II. From Table I and II it can be seen that at 0.1° the convergence achieved is till 4 bounces only. In the applications where higher bounces are required, denser rays are launched to achieve convergence, which often becomes computationally intractable. This may call for intelligent algorithm towards adaptive ray tracing.

4. CONCLUSION

Ray tracing inside a manned space module is carried out. The ray-path data generation and visualization of the rays that reach a particular sub-cube placed inside the cabin is done by *Matlab*. A *ray-bunching* algorithm is developed to differentiate the bunch of rays that travel nearly parallel and reach the receiving sub-cube. The refinement algorithm is then employed to find out the required ray, which reaches the receiving point from that bunch. A convergence study of the number of rays receiving the reception cube *w.r.t.* the number of rays launched is discussed and finally the cumulative ray path data till a given bounce (till 40 bounce) is generated.

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Revisiting the performance of mixtures of software reliability growth models

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Abstract

In this paper, we evaluate the performance of a mixture of software reliability growth models (Super models) against the original base models. The base models chosen are four well known nonhomogeneous Poisson process (NHPP) growth models proposed in literature. We use the method of maximum likelihood for fitting these models to data.

The Super models are based on the above base models plus a selection criterion based on past prediction measures.

Four Poisson type reliability models and four Super models are evaluated based on their performance on three data sets. The performance is judged by the relative error of the predicted number of failures over future time intervals relative to the number of failures eventually observed during the interval. Conclusions are drawn based on the analysis of the results and the use of the selection of models.

Key Words: Software reliability, Maximum Likelihood Method, Nonhomogeneous Poisson process

1. Introduction

Software has now become an integral part in industrial, financial, commercial, health, defense and real time safety critical systems. In a 2002 press release the National Institute of Science and Technology (NIST) estimated that 80% of development costs involve identifying and correcting bugs. It is estimated that costs related to software failure amounted to over 70 million US dollars. With the the increase of complexity of software systems. managing the quality of software in projects has never been more apparent The use of Software Relaibility Growth Models (SRGMs) can address this management problem by allowing the user to as accurately as possible predict the current and future reliability of the software on test.

Research using NHPP based software models have shown that these models do perform creditably when compared to expert opinion [1]. The problem that arise is that the estimates of these models however tend to either consistently overestimate or underestimate the quality of the software [2].

In this research we propose the use of four commonly referenced NHPP models and four mixture of models or Super models. This paper is a continuation of the work done by Keiller and Miller [3].

Our reliability growth models on test include several of the well known models in literature together with additional models that we call 'Super models'. These Super models are based on a set of the usual reliability growth models plus a selection criterion, which identifies one of the set to use for predictions at each point of time; the selection criterion is based on the 'quality-of-past prediction' measures. The object is to identify the best models or approaches to be use during the test phase.

2. Nonhomogeneous Poisson Process

"A Poisson process is a counting process characterized by its mean value function; and the cumulative number of software failures up to time t, N(t), can be described by the nonhomogeneous Poisson process (NHPP). We also know that the 'reliability growth process' can be represented as a counting process $\{N(t), 0 \le t\}$ where

$\{N(t) = \max\{i: T_i \le t\}, 0 \le t\}$, and T_i's are random variables and t_i's are real scalars. The process is observed for t: $0 \le t \le t_c$ where t_c is the "current time" and $(x_1, x_2, x_3, \ldots x_c)$ is a sequence of interfailure times- $x_i = t_{i+1} - t_i$.

If we let N(t) be the number of failures occurring in an arbitrary interval of time t, then for this counting process $\{N(t), 0 \le t\}$ modeled by the NHPP, N(t) follows a Poisson distribution with parameter M(t). M(t) is called the mean value function and describes the expected cumulative number of failures in (0,t)."[3]

Xie [4] and Lyu[5] outline the following information about the NHPP.

- The probability that N(t) is a given integer n is expressed by

$$P(N(t)= n) = \frac{(M(t))^n}{n!} e^{-M(t)}, \; n = 0,1,2,3,\ldots. \qquad (1)$$

- The function $\lambda(t)$ which is called the instantaneous

failure intensity is defined as

$$\lambda(t) = \lim_{\Delta t \to 0+} \frac{P(N(t+\Delta t) - N(t) > 0)}{\Delta t} \quad (2)$$

- If you are given $\lambda(t)$, the mean function $M(t) = E\{N(t)\}$ satisfies

$$M(t) = \int_0^t \lambda(s)ds . \quad (3)$$

- Reversing the process, if we know M(t), the failure intensity at time t can be obtained as

$$\lambda(t) = \frac{dM(t)}{dt} \quad (4)$$

- Also, the nonhomogeneous Poisson processes have an independent Poisson number of failures in disjoint intervals given by:

$$P((N(t+s) - N(t)) = n) = e^{-(M(t+s)-M(t))} \frac{(M(t+s) - M(t))^n}{n!}$$

$$0 \le t,\ 0 \le s;\ n=0,1,2,3,\ldots \quad (5)$$

- By using different nondecreasing functions M(t), we get different NHPP models.

- The reliability function at time t_0 is :

$$R(t \mid t_0) = e^{-(M(t+t_0) - M(t_0))} = P(N(t_0 + t) - N(t_0)=0) \quad (6)$$

- The estimation of the unknown parameters in M(t) is obtained by using either the method of maximum likelihood or the method of least squares.

- The likelihood function for the NHPP model with mean value function M(t) is the following

$$L(n_1, n_2, \ldots, n_k) = \prod_{i=1}^{k} \frac{(M(s_{i-1}) - M(s_i))^{n_i} \exp(M(s_{i-1}) - M(s_i))}{n_i!} \quad (7)$$

where n_i denotes the number of faults detected in time interval (s_{i-1}, s_i), and $0<s_0 < s_1 < s_2< \ldots.< s_i$, $i \ge 0$, are the total monitored test times of the software.

- The parameters in M(t) are estimated by maximizing the likelihood function. Taking the natural log of the likelihood function, we use numerical algorithms to solve for the parameters [6].

3. Software Reliability Models on Test

3.1 Base Models

In this study the following four parametric families of NHPPs, characterized by their mean functions:

M1	Logarithmic	$M_1(t) = \gamma \log(1+\beta t)$	$0<\beta$
M2	Pareto	$M_2(t) = \gamma(1-(1+\beta t)^{-\alpha})$	$0<\alpha,0<\beta$
M3	Exponential	$M_3(t) = \gamma(1- e^{-\eta t})$	$0< \eta$
M4	General Power	$M_4(t) = \gamma((1+\beta t)^{-\alpha}-1)$	$-1<\alpha<0,0<\beta$ $0<\gamma$

are selected to represent one group of models on test (the simple models). Model M1 represents the Musa-Okumoto model [7]; model M2 represents the Littlewood NHPP model [8]; and model M3 represents the Goel-Okumoto model [9]. M4, the 'General Power' curve arises naturally when considering order statistics of independent but non-identically exponentially distributed failure times. Musa and Okumoto [7] have promoted the use of the NHPP models in software reliability growth modeling. Miller [10] also gives strong theoretical justification for using the NHPP.

3.2 Super Models

We consider four Super models. Keiller and Miller [3] defines a Super model as a set of parametric reliability growth models and a selection criterion; for a given software failure data set and for a given time, the selection criterion chooses the parametric model in the set that is to be used for making predictions of future failure behavior. As time passes for a given data set, a given super model may change its choice of parametric family to use for predictions.

Our procedure for a Super model is as follows: using maximum likelihood estimation, we fit all four of the parametric models (M1-M4). Next, the selection criterion picks one parametric class based on the fitted models. The current fitted model of the chosen class is used for making predictions at the current time.

We consider four pure quality-of-prediction measures (8): the u-plot, the y-plot, the prequential likelihood, and the maximum likelihood values. Using these criteria requires fitting each of the four NHPP models (M1-M4) after each failure and calculating the predictive distribution and density of the time until next failure.

To summarize, our four super models are all based on four NHPP models (M1-M4). The selection criteria for the four super models are:

M5	U-plot
M6	Y-plot
M7	Prequential likelihood
M8	Maximum likelihood

The four additional “mixture of models” were developed using dynamic selection among models based on goodness-of-fit and quality-of-prediction criteria such as

the u-plot, y-plot, prequential likelihood and the maximum likelihood values.

3. Failure Data Collection

The failure data used in this research is taken from the research by Almering et. al [11]. The data is taken from three software development projects for high-end TV sets containing several million lines of code. The data sets related to the projects are referred to as TV2003, TV2004, and TV2005. To give the reader a rough idea of the data, it is presented in an aggregate form in Table 1. The total cumulative time for each data set is split into 10 equal intervals and the cumulative number of failures occurring up to each of the 10 elapsed points is shown. From this table, it is possible to construct very rough plots of the reliability growth. Figures 3.1a -3.1c show the relationship between the cumulative interfailure times against the % test times (100% of the total test time of the software) of the tested data sets.

Figure 3.1a (Data set TV2003)

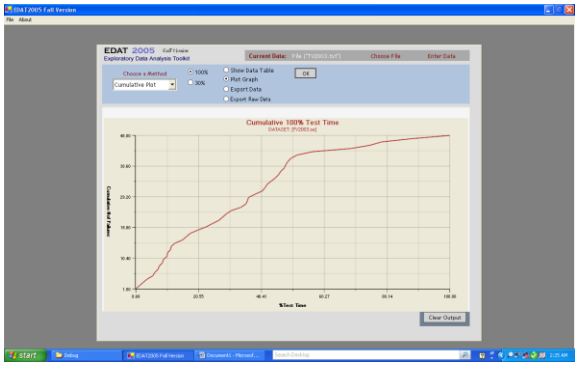


Figure 3.1b (Data set TV2004)

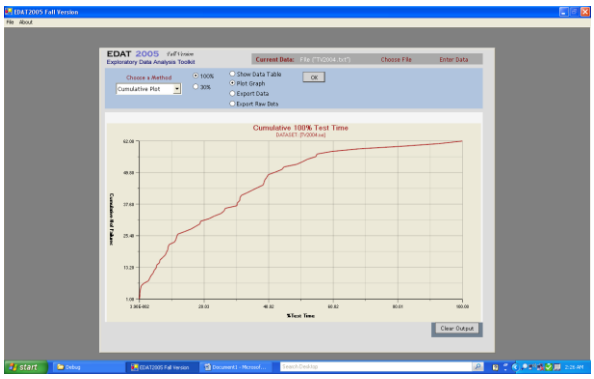


Figure 3.1c (Data set TV2005)

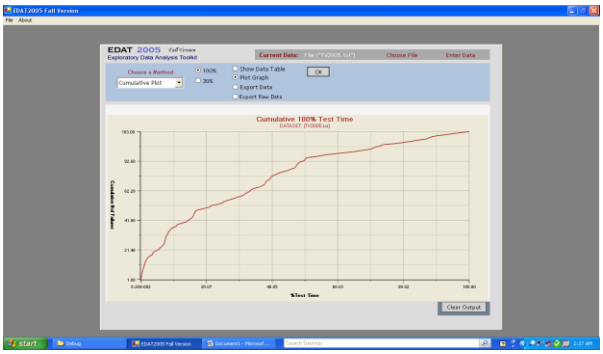


Table 1 Summary of Failure Data

SYSTEM	PERCENT OF TIME ELAPSED (# DEFECTS)									
	10	20	30	40	50	60	70	80	90	100
TV2003	10	18	24	30	41	43	44	46	47	48
TV2004	22	31	36	49	53	58	59	59	60	62
TV2005	36	50	58	72	83	87	90	95	100	103

4 Performance Measures

The performance measures are recapped from previous work [3].

4.1 Quality of Prediction

Let x_{i+1} be given as the interfailure time at time s_{i+1} (i.e. $x_{i+1} = s_{i+1} - s_i$). The first quality-of-prediction measure is the 'u- plot': it is well known that $U=F_x(X)$ has a uniform distribution on the interval [0,1]. Using this fact, if $\hat{F}_{i+1}(\cdot)$ is the true distribution of X_{i+1} then $u_{i+1} = \hat{F}_{i+1}(x_{i+1})$ will be an observation from U[0,1] distribution. Thus the empirical distribution formed from the u's should be closed to U[0,1]. If we observe n_o+n failures, starting to make predictions after the n_oth failure, the plot of

$$\{(u_{no+i}, i/(n+1)), i = 1,2,3,\ldots,n\}$$

is the u-plot. The maximum deviation of the u-plot from the identity function is a measure of quality-of-prediction.

The second measure of quality-of prediction is the 'y-plot': if the predictive distributions are good the u's should look like a random sequence of independent U[0,1] variables, and –log (1-u)'s like exponential random variates. In this case, let

$$y_i = \sum_{j=1}^{i} \log(1-u_{no+j}) \Big/ \sum_{j=1}^{n} \log(1-u_{no+j})$$

i=1,2,3,….,n

and plot the pairs $\{y_{i,}, i/(n+1)), i= 1,2,3,\ldots..,n\}$.

If the predictive distributions are good, this plot should be close to the identity function. A quantitative measure

of the quality-of-prediction is the maximum deviation between the y-plot and the identity function.

The third measures of quality-of-prediction is the prequential likelihood: based on Dawid's generalization of likelihood to a sequential situation , we have

$$PL_n = \prod_{i=1}^{n} \hat{f}_{no+i}; \text{ where } \hat{f}_{i+1}(s) = \frac{d}{ds}\hat{F}_{i+1}(s) \quad i \geq 0$$

For comparison purposes, the best predictive system should have the largest prequential likelihood. For a detailed discussion of these measures of quality-of-prediction, see Brocklehurst [12]. These three measures give a dynamic real-time evaluation of how well a given parametric model has done predicting interfailure times up to the present. Brocklehurst [12] argues that it would seem logical to calculate the next prediction using the model which has performed best up to the present on the particular software failure data set under consideration. These three measures give a basis for making this choice.

4.2 Goodness-of-Fit Measures

The performance of the model is investigated for each data set to see how well it can predict the number of new failures manifesting during finite future time intervals. The experiment is designed as a four step process.

For each data set D_k , where k =1,..., 3:

(1) The MLE's of the model parameters are determined based on the first d data points of data set D_k.

(2) The fitted model is then used to predict the number of failures in $[s_{d},s_{n,k}]$ where $s_{l,k} = \sum_{m=1}^{l} x_{m,k}$ and $x_{m,k}$ is the mth data point of data set D_k.

(3) The model is evaluated using

(i) predicted errors $e_{i,k} = \hat{n}_{i,k} - n_{i,k}$

(ii) relative errors $re_{i,k} = \dfrac{\hat{n}_{i,k} - n_{i,k}}{n_{i,k}}$

(iii) absolute relative errors $|re_{i,k}|$

(iv) relative error squared $(re_{i,k})^2$

where $\hat{n}_{i,k}$ ($n_{i,k}$) is the predicted (actual) number of failures in $[s_{10,k},s_{n,k}]$.

(4) For each data set, the analysis (1)-(3) is performed for d = 10, ..., n_{k-1}. The value ten was selected arbitrarily but is large enough to enable meaningful estimation and small enough to allow for meaningful evaluation of the procedure. The sum of the absolute relative errors (ARE), the sum of the relative errors (RE), and the sum of the relative errors squared (RESQ) are normalized by averaging over the number of predictions for the model.

5. Findings

Table 2 shows the comparison ranking of the Base models (M1-M4) for each of the datasets on test using the u-plot, y-plot, PL, and ML performance measures.

Tables 3a-3c show the Base models chosen by Super Models 5-8 for each of the datasets on test.

Table 2 Ranking of Base Models

PERFORMANCE CRITERIA	DATASETS AND BASE MODELS ON TEST											
	TV2003				TV2004				TV2005			
	M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4
U-PLOT	3	1	2	4	2	3	1	4	1	2	4	3
Y-PLOT	3	2	1	4	3	2	1	4	3	1	4	2
PL	3	2	1	4	2	3	1	4	2	3	4	1
ML	2	4	3	1	1	4	3	2	2	3	1	4

Table 3a Base Models Chosen by Super-Models M5-M8 **(SYSTEM ID: TV2003)**

SYSTEM ID: TV2003

PERFORMANCE CRITERIA	PERCENT OF TIME ELAPSED								
	10	20	30	40	50	60	70	80	90
U-PLOT:M5	M2	M2	M2	M2	M2	M2	M2	M2	M2
Y-PLOT:M6	M1	M1	M2	M2	M2	M1	M3	M3	M3
PL:M7	M4	M3	M1	M4	M4	M1	M3	M3	M3
ML:M8	M2	M4	M4	M3	M1	M3	M4	M4	M4

Table 3b Base Models Chosen by Super-Models M5-M8 **(SYSTEM ID: TV2004)**

SYSTEM ID: TV2004

PERFORMANCE CRITERIA	PERCENT OF TIME ELAPSED								
	10	20	30	40	50	60	70	80	90
U-PLOT	M3	M3	M3	M4	M3	M3	M3	M3	M3
Y-PLOT	M4	M3	M3	M4	M4	M3	M3	M3	M3
PL	M4	M4	M4	M4	M4	M4	M3	M3	M3
ML	M3	M3	M3	M3	M3	M3	M3	M3	M3

Table 3c Base Models Chosen by Super-Model M5-M8 **(SYSTEM ID: TV2005)**

SYSTEM ID: TV2005

PERFORMANCE CRITERIA	PERCENT OF TIME ELAPSED								
	10	20	30	40	50	60	70	80	90
U-PLOT	M2	M3	M3	M1	M1	M1	M1	M1	M1
Y-PLOT	M4	M4	M4	M4	M4	M4	M4	M2	M2
PL	M4	M4	M4	M4	M4	M4	M4	M4	M4
ML	M3	M3	M3	M2	M3	M3	M3	M3	M3

Tables 4a-4c show the ranking of models (RE, ARE, and RESQ performance measures) for the datsets on test

Table 4a Ranking of models M1-M8
(SYSTEM ID: TV2003)

SYSTEM ID: TV2003								
PERFORMANCE MESURES	**MODELS ON TEST**							
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
RE	**7**	**1**	**4**	**8**	**2**	**6**	**5**	**3**
ARE	**7**	**2**	**4**	**8**	**3**	**5**	**6**	**1**
RESQ	**7**	**1**	**4**	**8**	**2**	**5**	**6**	**3**

Table 4b Ranking of models M1-M8
(SYSTEM ID: TV2004)

SYSTEM ID: TV2004								
PERFORMANCE MESURES	**MODELS ON TEST**							
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
RE	**4**	**3**	**1**	**8**	**6**	**5**	**7**	**2**
ARE	**2**	**1**	**3**	**6**	**7**	**8**	**5**	**4**
RESQ	**2**	**1**	**5**	**4**	**7**	**8**	**3**	**6**

Table 4c Ranking of models M1-M8
(SYSTEM ID: TV2005)

SYSTEM ID: TV2005								
PERFORMANCE MESURES	**MODELS ON TEST**							
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
RE	**5**	**4**	**3**	**8**	**2**	**7**	**6**	**1**
ARE	**4**	**1**	**8**	**6**	**3**	**7**	**2**	**5**
RESQ	**5**	**1**	**8**	**6**	**3**	**7**	**2**	**5**

6. Conclusion

In this experiment four NHPP models (M1-M4) and four Super models (M5-M8) are investigated. The experiment uses 3 data sets. We noticed that there were no significant performance improvements when using the Super models (M5-M8) compared to the Base models. We had expected one of the simple models (M1-M4) to be truly a superior fitting model and expected the model to be consistently chosen by the Super models (M5-M8). This did not happen. We expect to continue this study in a more controlled experiment based on Monte Carlo data and using model recalibration methods[12]..

7. Acknowledgement

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Novel Application of Circular Frequency Selective Surface for Broadbanding of Monolithic Radome

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ABSTRACT

The application of circular aperture frequency selective surface (FSS) for the enhancement of electromagnetic performance of monolithic half-wave radome is presented. The performance parameters of the circular aperture type FSS embedded radome panel are computed based on equivalent transmission line method in conjunction with equivalent circuit method (ECM). The EM analysis shows that the circular FSS embedded monolithic half-wave radome panel has superior performance characteristics as compared to the monolithic wall alone configuration.

Keywords: Monolithic radome**,** Frequency selective surface, Radome performance parameters

1. INTRODUCTION

In order to meet the stringent EM performance requirements of modern airborne radomes, various radome design techniques (based on metallic structures like wire grids, wire meshes, etc.) have been reported [1-3]. Most of these reported works focused on the enhancement of transmission efficiency of the radome panels. Even though the transmission efficiency of the radome wall configurations can be improved with the inclusion of metallic structures, other performance parameters like boresight error, cross-polar level etc., may degrade drastically. This necessitates the development of new techniques, which can simultaneously improve the EM performance parameters of radome walls. In this regard, FSS find potential applications in the design of high performance radomes due to their inherent frequency selective characteristics.

In this paper, novel application of circular aperture frequency selective surface for broadbanding of monolithic half-wave radome wall configuration (Fig. 1) is presented. Monolithic half-wave radome wall is generally used for the design of streamlined nosecone radomes as it provides superior EM performance at the design frequency as well as sufficient structural rigidity for catering extreme aerodynamic stresses at high mach speeds. But the major disadvantage of monolithic half-wave wall is very narrow bandwidth, which limits its applications. Since modern airborne radar antennas have multi-band functional requirements, such designs may not be sufficient. Hence in the present work, the design parameters of circular aperture FSS embedded monolithic half-wave wall configuration are optimized such that it provides superior EM performance as compared to monolithic radome panel alone, over the X-band.

2. CIRCULAR APERTURE FSS EMBEDDED MONOLITHIC HALF-WAVE RADOME PANEL DESIGN

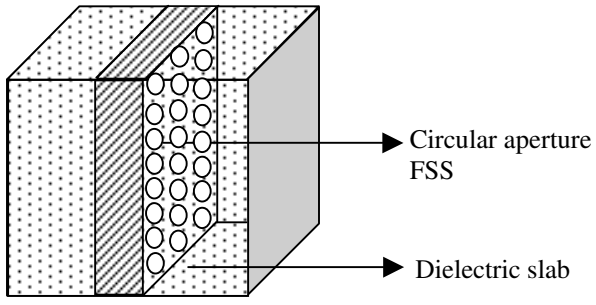


Figure 1 Schematic of circular aperture FSS embedded monolithic half-wave radome

The circular FSS array, consisting of periodic arrays of circular apertures, is embedded in the mid-plane of monolithic half-wave radome wall (ε_r = 4.0; $\tan\delta_e$ = 0.015). The thickness of the monolithic half-wave wall for optimum power transmission, is 7.44 mm at the center frequency 10 GHz, and at the normal incidence. The inductive susceptance of the aperture type circular FSS element is formulated using the equivalent circuit model (ECM). It is incorporated in the equivalent transmission line model [4] of the circular FSS embedded monolithic half-wave wall. The optimized design parameters of the

circular FSS at normal incidence (diameter = 17.1 mm and pitch = 19.6 mm) and high incidence angle 60° (diameter = 20.7 mm and pitch = 37.8 mm) are computed.

The circular aperture FSS embedded monolithic radome wall is considered as an equivalent transmission line with different sections corresponding to slab and FSS structure. The change in the characteristic impedance of the free space and monolithic half-wave wall is a major source of reflection of the wave incident on the structure. In the present radome wall structure, the FSS is symmetrically loaded in the mid-plane of the monolithic slab. As compared to the free space, different layers of circular aperture FSS embedded monolithic wall can be considered as low impedance lines connected end-to-end. Hence the whole configuration can be represented by a single matrix obtained by the multiplication of matrices corresponding to the individual layers.

Since the circular aperture FSS is located in the mid-plane of the monolithic slab, it is considered to be made up of two identical sections, with the circular aperture FSS in between them. Let Z_0 be the characteristic impedance of free space. The characteristic impedance of each half-section of monolithic slab is represented by Z_s. In the equivalent transmission line method, the matrix consisting of A_i, B_i, C_i, and D_i will represent the i^{th} layer of the radome wall. Let t and d_{FSS} represent the thickness of each half-section of monolithic slab and circular aperture FSS respectively. Here $t = (d_m - d_{FSS})/2$.

One half-section of the wall is represented by

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} \cos \Phi_1 & j\frac{Z_s}{Z_o} \sin \Phi_1 \\ j\frac{Z_o}{Z_s} \sin \Phi_1 & \cos \Phi_1 \end{bmatrix} \quad (1)$$

Φ be the electrical length corresponding to each layer, which is a function of the complex permittivity ε^*, of dielectric layer, the angle of incidence, θ and the thickness of the dielectric layer, d. The other half-section of the wall is represented by

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} \cos \Phi_2 & j\frac{Z_s}{Z_o} \sin \Phi_2 \\ j\frac{Z_o}{Z_s} \sin \Phi_2 & \cos \Phi_2 \end{bmatrix} \quad (2)$$

The interaction of incident EM waves with aperture type FSS is represented as a wave propagating along a transmission line, with shunt susceptance representing the FSS. The EM characteristics of single unit cell of circular aperture FSS are assumed to be same as that of infinite periodic array. The monolithic half-wave dielectric slab exhibits capacitive susceptance, while the aperture type circular aperture FSS exhibits inductive susceptance. The inductive susceptance of the aperture type circular apertrure FSS matches with the capacitive susceptance of the entire monolithic slab to provide broadband EM performance. Let A_{FSS}, B_{FSS}, C_{FSS} and D_{FSS} be the elements of the matrix representing circular aperture FSS. Then the circular aperture FSS is represented by

$$\begin{bmatrix} A_{FSS} & B_{FSS} \\ C_{FSS} & D_{FSS} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jB & 1 \end{bmatrix} \quad (3)$$

Here B represents the shunt susceptance of the circular aperture FSS. The equivalent circuit modeling of circular aperture FSS was discussed in [5]. Using this modeling approach, the inductive susceptance of aperture type FSS for perpendicular polarization is given by

$$B = -\frac{3ab\lambda}{\pi d^3} \quad (4)$$

Here a and b are the spacing between the holes. In the present case a = b. d is the diameter of the hole. λ is the wavelength of the incident EM wave. In order to eliminate spurious reflections and phase distortions, the medium present in the aperture section of the circular aperture FSS is assumed to be the same as that of the monolithic radome wall.

The entire monolithic half-wave wall with circular aperture FSS is represented by

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ jB & 1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \quad (5)$$

Using Eqn (5), the A, B, C and D parameters of the final matrix are computed. The power transmission coefficient is given by

$$P_{tr} = \left[\frac{4}{(A + B + C + D)^2} \right] \quad (6)$$

The power reflection coefficient is given by

$$P_{rf} = \left[\frac{A + B - C - D}{A + B + C + D} \right]^2 \quad (7)$$

The phase distortions are determined by the insertion phase delay (IPD) of the radome wall. For the present radome wall configuration, two symmetric dielectric layers and one FSS layer are cascaded. Hence the insertion phase delay is given by

$$\text{IPD} = -\angle T - \frac{2\pi}{\lambda}\left(2t + d_{\text{FSS}}\right)\cos\theta \quad (8)$$

Here $\angle T$ is phase angle associated with the voltage transmission coefficient of the entire radome wall.

3. EM PERFORMANCE PARAMETERS

The EM performance parameters (power transmission, power reflection and insertion phase delay) of the monolithic configuration with circular aperture FSS are computed for perpendicular polarization at 0° and 60°. A comparative study of the EM performance of circular aperture FSS embedded monolithic half-wave radome with that of monolithic slab alone is presented in the following sections.

(a) EM performance at normal incidence

The power transmission characteristics of the monolithic slab alone and circular aperture FSS embedded monolithic slab over the frequency range 8 – 12 GHz at normal incidence are shown in Fig. 2a. Even though the transmission efficiency of FSS embedded structure is same as that of monolithic slab alone, around 10 GHz, it is superior to that of monolithic slab alone, in the remaining portions of the X-band.

The power reflection of FSS embedded structure is almost negligible around 9 GHz and it shows increase beyond 10 GHz (Fig. 2b). For the monolithic slab alone, the power reflection characteristic is negligible around the design frequency of 10 GHz but it is very high at the end frequencies of X-band. It is interesting to note that the power reflection of circular aperture FSS embedded structure is low (well within 10%) throughout the frequency range as compared to the monolithic slab alone case.

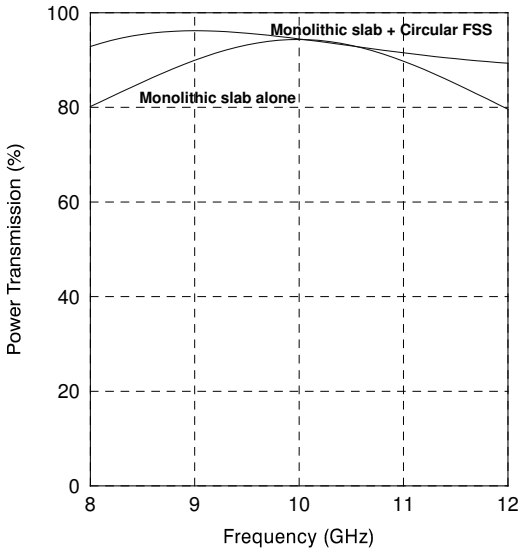


Figure 2a Power transmission characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at normal incidence

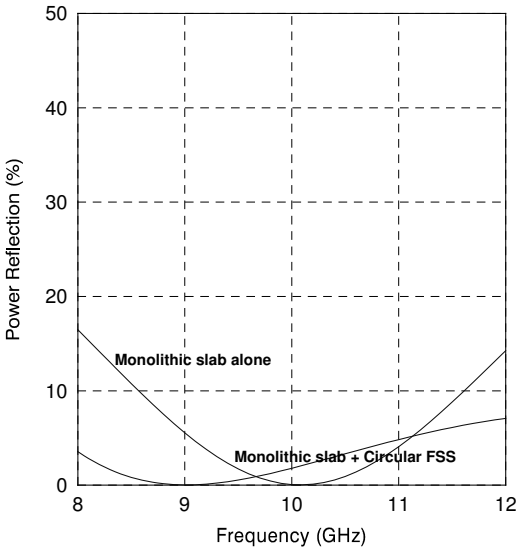


Figure 2b Power reflection characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at normal incidence

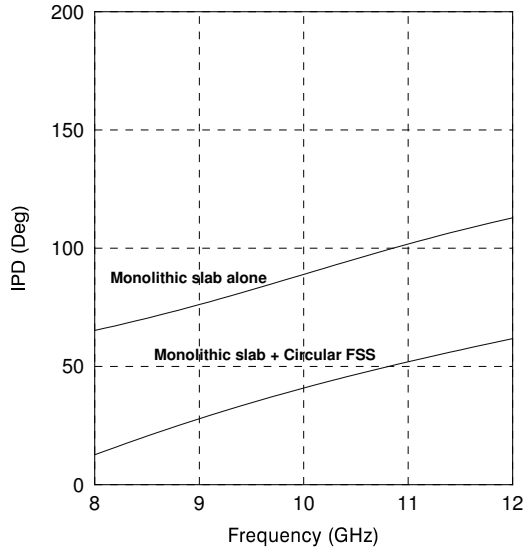


Figure 2c Insertion phase delay characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at normal incidence

The insertion phase delay (IPD) characteristics of both structures are shown in Fig. 2c. The IPD of both structures exhibit steady increase from 8 GHz to 12 GHz. Since the rate of change of IPD of both structures over X-band is similar, both structures will exhibit similar phase distortions and borseight error characteristics.

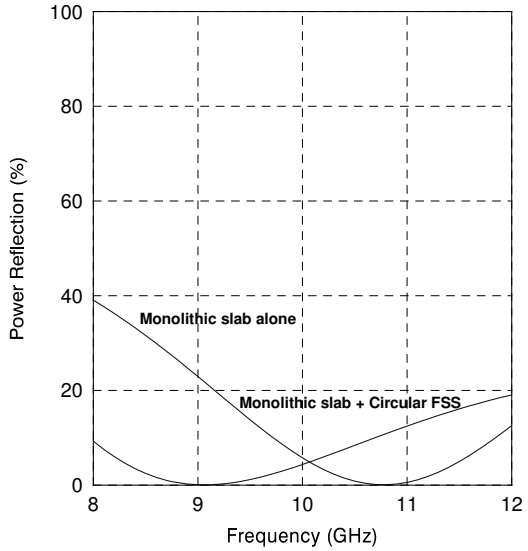


Figure 3b Power reflection characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at 60°

(b) EM performance at 60°

The EM performance characteristics of both circular aperture FSS embedded and slab alone structures at high incidence angle 60° are shown in Figs. 3a-3c. As compared to the normal incidence case, there is a decrease in the power transmission efficiency of circular aperture FSS embedded radome panel.

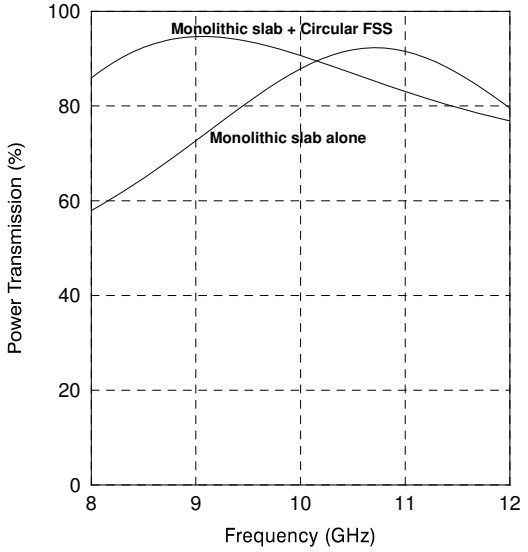


Figure 3a Power transmission characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at 60°

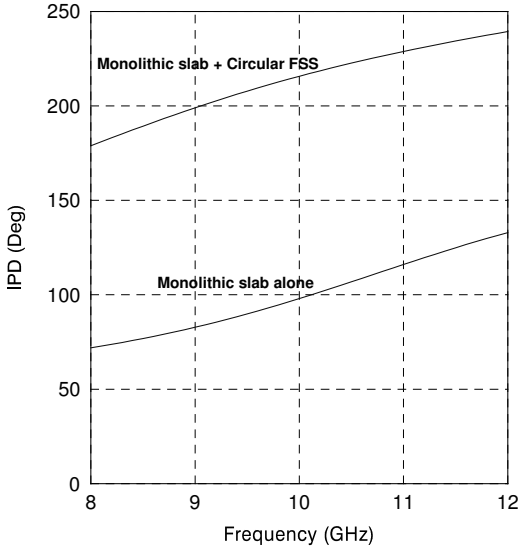


Figure 3c Insertion phase delay characteristics of *circular aperture FSS embedded monolithic slab* and *monolithic slab alone* at 60°

The power reflection of circular aperture FSS embedded wall is low as compared to that of the slab alone case below 11 GHz. It is observed that the IPD of both circular aperture FSS embedded structure and monolithic slab alone is rapidly increasing towards high frequency side of the X-band spectrum (Fig. 3c). As with the normal incidence case, the IPD variations of both structures are similar.

4. CONCLUSIONS

The EM performance parameters of circular FSS embedded monolithic half-wave at normal incidence and high incidence angle 60° have been analyzed. It is observed that the inclusion of circular FSS has improved the performance parameters over the selected frequency range. Since the conventional monolithic half-wave structure has very narrow bandwidth, the circular aperture type FSS embedded monolithic half-wave radome is a better choice for airborne radome applications.

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A Novel A-sandwich Radome using Metallic Strip Grating for Airborne Applications

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ABSTRACT

The application of metallic strip grating for the enhancement of electromagnetic performance of A-sandwich radome is presented. The performance parameters of the metal strip grating embedded radome panel are computed based on equivalent transmission line method in conjunction with equivalent circuit method (ECM). The EM analysis shows that the metal strip grating embedded A-sandwich radome wall configuration has superior EM performance as compared to the A-sandwich wall alone configuration.

Keywords: Radome, Metallic strip grating, Radome performance parameters

1. INTRODUCTION

Generally A-sandwich radome wall configuration is used for airborne radome applications, where high strength-to-weight ratio and bandwidth are required [1-3]. The major disadvantage of A-sandwich structure is that it shows degradation of EM performance parameters at high incidence angles. In order to circumvent this problem, metallic strip grating is embedded in the mid-plane of the core of A-sandwich radome panel. Equivalent transmission line method in conjunction with *equivalent circuit model* (ECM) is used for modeling the A-sandwich radome panel with metallic strip gratings and the computation of radome performance parameters. For a given thickness of metallic strip grating, its width and pitch are optimized at different angles of incidence such that the new radome wall configuration offers superior EM performance over the entire X-band as compared to the conventional A-sandwich wall. The EM analysis shows that the superior EM performance of A-sandwich with metallic strip gratings makes it suitable for the design of normal incidence and streamlined airborne radomes.

2. EM DESIGN OF A-SANDWICH RADOME WITH METALLIC STRIP GRATING

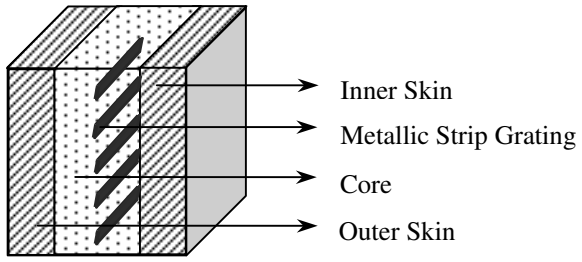


Figure 1 Schematic of A-sandwich with metallic strip grating

The A-sandwich wall configuration is assumed to consist of skin layers of glass composite ($\varepsilon_r = 4.0$; $\tan\delta_e = 0.015$). The thicknesses of the inner and outer skin layers are 0.75 mm and 1.5 mm respectively. The outer skin is coated with typical radome paint ($\varepsilon_r = 3.46$; $\tan\delta_e = 0.068$) of 200 μm thickness. In between the skin layers, there is a foam core ($\varepsilon_r = 1.1$; $\tan\delta_e = 0.002$) with the wall thickness of 5.44 mm, optimized for power transmission over X-band. The strip grating, consisting of thin parallel metal strips with uniform material properties, is embedded in the mid plane of the core of A-sandwich wall (Fig. 1).

The metallic strip grating embedded A-sandwich radome wall is considered as an equivalent transmission line with different sections corresponding to skin layers, core layer, and metallic strip grating. As compared to the free space, different layers of radome wall can be considered as low impedance lines connected end-to-end. The interaction of incident EM waves with the radome wall is represented as a wave propagating along a transmission line, with shunt susceptance representing the strip grating. The radome wall exhibits capacitive susceptance, while the

metallic strip grating exhibits inductive susceptance. The inductive susceptance of the metallic strip grating matches with the capacitive susceptance of the entire radome wall to provide broadband EM performance.

The A-sandwich wall embedded with metallic strip grating is represented by an equivalent transmission line. The skins, core, metal strip grating are represented by different sections of the transmission line. The optimum design parameters of metal strip grating (strip width and pitch) are evaluated based on the equivalent transmission line method [3]. The optimum dimensions of the strip grating (for perpendicular polarization) are determined for the selected frequency range of 8-12 GHz at the incidence angles 0° and 60°. For normal incidence, the optimum strip grating dimensions are width, w = 2.2 mm and pitch, p = 3.3 mm. Similarly, the optimum strip width and pitch at the incidence angle 60° are 2.6 mm and 4.5 mm, respectively.

The metallic strip grating incorporated A-sandwich radome wall is considered as an equivalent transmission line with different sections corresponding to slab and metallic strip grating structure (Fig. 1). The change in the characteristic impedance of the free space and A-sandwich wall is a major source of reflection of the wave incident on the structure. As compared to the free space, different layers of radome wall can be considered as low impedance lines connected end to end. Hence the whole configuration can be represented by a single matrix obtained by the multiplication of matrices corresponding to the individual layers.

The matrix representing each layer of A-sandwich wall are as follows:

The inner skin is represented by

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} \cos \Phi_1 & j \dfrac{z_s}{z_o} \sin \Phi_1 \\ j \dfrac{z_o}{z_s} \sin \Phi_1 & \cos \Phi_1 \end{bmatrix} \quad (1)$$

The metallic strip grating is located at the mid-plane of the core. Hence the core can be considered to be made up of two identical sections with wire grid in between them. Then the half-section of the core is represented by

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} \cos \Phi_2 & j \dfrac{z_c}{z_o} \sin \Phi_2 \\ j \dfrac{z_o}{z_c} \sin \Phi_2 & \cos \Phi_2 \end{bmatrix} \quad (2)$$

Let A_{MS}, B_{MS}, C_{MS} and D_{MS} be the elements of the matrix representing metallic strip grating

$$\begin{bmatrix} A_{MS} & B_{MS} \\ C_{MS} & D_{MS} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jB_G & 1 \end{bmatrix} \quad (3)$$

Here B_G represents the shunt susceptance of the metallic strip grating [4]. For perpendicular polarization, the shunt susceptance of the strip for perpendicular polarization is given by

$$\mathrm{B_G} = \frac{-4\mathrm{p}\sec\theta}{\lambda}\left[(\ln \cos\mathrm{ec}\,(\frac{\pi \mathrm{g}}{2\mathrm{p}}) + \mathrm{G}\right] \quad (4)$$

Here G is the correction parameter.

The other half-section of the core is represented by

$$\begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} = \begin{bmatrix} \cos \Phi_3 & j \dfrac{z_c}{z_o} \sin \Phi_3 \\ j \dfrac{z_o}{z_c} \sin \Phi_3 & \cos \Phi_3 \end{bmatrix} \quad (5)$$

The outer skin is represented by

$$\begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} = \begin{bmatrix} \cos \Phi_4 & j \dfrac{z_s}{z_o} \sin \Phi_4 \\ j \dfrac{z_o}{z_s} \sin \Phi_4 & \cos \Phi_4 \end{bmatrix} \quad (6)$$

The radome paint is represented by

$$\begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix} = \begin{bmatrix} \cos \Phi_5 & j \dfrac{z_p}{z_o} \sin \Phi_5 \\ j \dfrac{z_o}{z_p} \sin \Phi_5 & \cos \Phi_5 \end{bmatrix} \quad (7)$$

Thus, the entire A-sandwich configuration with metallic strip grating embedded at the mid-plane of the core may be expressed as

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ jB_G & 1 \end{bmatrix} \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{bmatrix} A_4 & B_4 \\ C_4 & D_4 \end{bmatrix} \begin{bmatrix} A_5 & B_5 \\ C_5 & D_5 \end{bmatrix} \quad (8)$$

Using Eqn (8), the *A, B, C* and *D* parameters of the final matrix are computed. The power transmission coefficient is given by

$$P_{tr} = \left[\frac{4}{(A+B+C+D)^2} \right] \quad (9)$$

The power reflection coefficient is given by

$$P_{rf} = \left[\frac{A+B-C-D}{A+B+C+D} \right]^2 \quad (10)$$

The phase distortions are determined by the *insertion phase delay* (IPD) of the radome wall. For the configuration considered, two skin layers, cores sections, metallic strip grating and radome paint are cascaded. Hence the insertion phase delay for the structure is given by

$$\text{IPD} = -\angle T - \frac{2\pi}{\lambda} \left(2t_s + 2t_{c1} + t_{ms} + t_p \right) \cos \theta \quad (11)$$

Here $\angle T$ is the phase angle associated with the voltage transmission coefficient. The thicknesses of skin layers, metallic strip grating and radome paint are given by t_s, t_{ms}, and t_p respectively. Let t_{c1} be the thickness of each section of the core.

3. NUMERICAL RESULTS AND DISCUSSION

A comparative study of the EM performance of *A-sandwich wall with metallic strip gratings* embedded in the mid-plane of the core and *A-sandwich wall alone* is carried out. The EM performance parameters are computed at normal incidence and at 60° for perpendicular polarization over X-band frequency range.

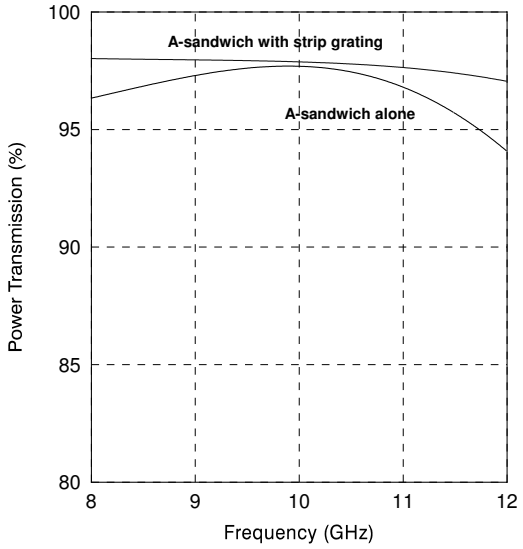


Figure 2a Power transmission characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at normal incidence

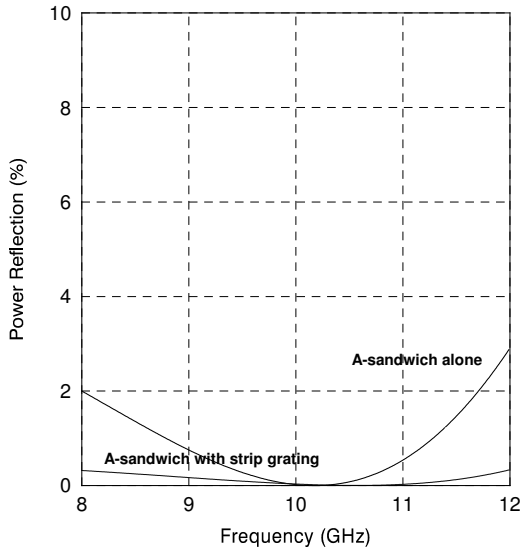


Figure 2b Power reflection characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at normal incidence

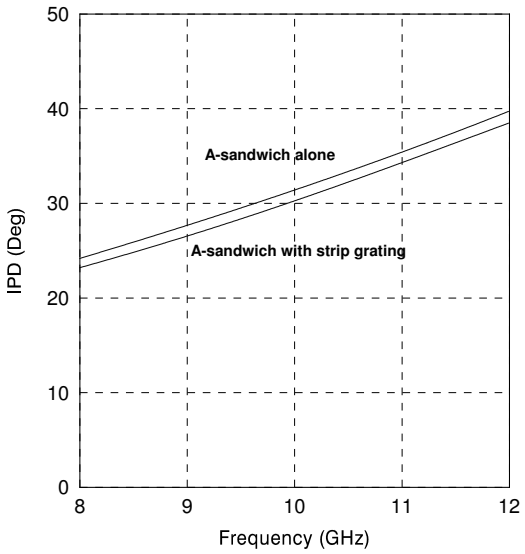


Figure 2c Insertion phase delay characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at normal incidence

Figures 2(a)-(c) show the EM performance characteristics. It may be observed that the *A-sandwich wall with metallic strip grating* shows superior power transmission characteristics as compared to the *A-sandwich wall alone* at normal incidence. Regarding power reflection characteristics, it is well within 1%. The IPD of *A-sandwich wall with metallic strip gratings* is less than that of *A-sandwich alone*.

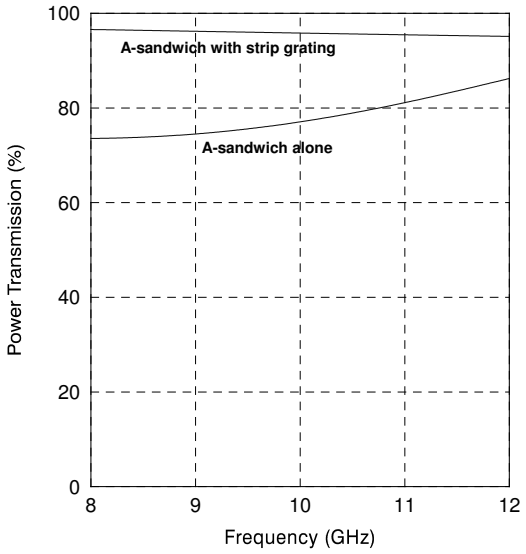


Figure 3a Power transmission characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at high incidence angle 60°

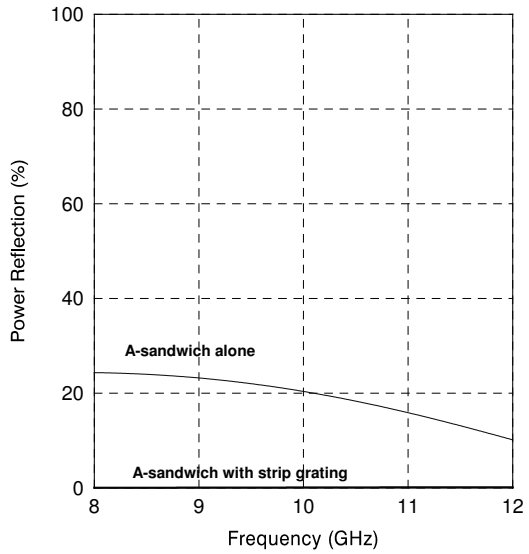


Figure 3b Power reflection characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at high incidence angle 60°

EM performance parameters of both structures at 60° are shown in Fig. 3 (a)-(c). The power transmission of the A-sandwich wall embedded with strip grating is well above 90%. But there is a slight degradation of power transmission efficiency at 60°. Figure 3b show the power reflection characteristics at 60°.

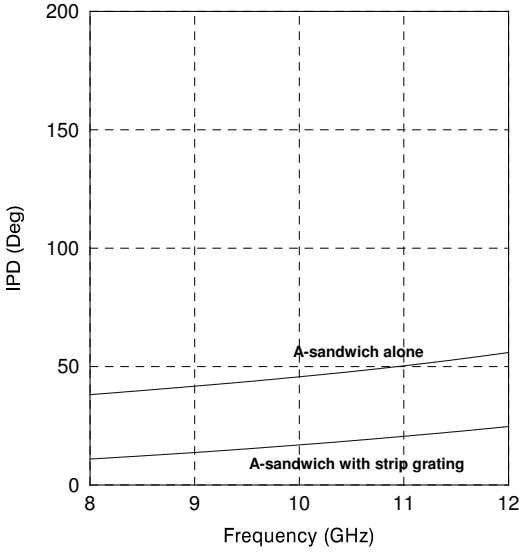


Figure 3c Insertion phase delay characteristics of the *A-sandwich with metallic strip grating* and the *A-sandwich alone* at high incidence angle 60°

The power reflection is very low for the *A-sandwich wall with strip grating* as compared to the *A-sandwich alone* wall, which is desirable for minimizing sidelobe level degradation and reduction of flash lobes. It is observed that the power reflection of the conventional A-sandwich structure increases with the increase in the incidence angle. Figure 3(c) show the insertion phase delay (IPD) characteristics of both structures. It is observed that the IPD of the *A-sandwich wall embedded with strip gratings* is low when compared to the conventional structure at all incidence angles.

4. CONCLUSIONS

The EM performance analysis shows that the strip grating embedded A-sandwich structure has superior EM performance as compared to the A-sandwich alone. Moreover, the new wall configuration has high power transmission efficiency along with low reflection characteristics necessary for modern airborne radome applications. The metal strip grating loaded core offer higher structural rigidity to meet extreme aerodynamic stresses. It is concluded that that this novel metallic strip grating embedded A-sandwich wall configuration has potential application in the design of streamlined airborne radomes.

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High-Frequency RF Field Mapping inside a Manned Space Module

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ABSTRACT

Space module is one of aerospace structures, which is of interest for radio-frequency (RF) mapping and its analysis. For RF field build-up inside a closed cavity like a manned space module, the concavity of the structure is an important aspect. Moreover the ray tracing tends to become complicated for such concave hybrid enclosure. An accurate surface modeling is required towards refined ray-tracing procedure for predicting the ray-path description for the electromagnetic (EM) field distribution within the structure. In this paper, a space module is modeled as a generalized paraboloid of revolution (GPOR) whose aft section is an end-capped right circular cylinder. The RF field distribution due to multiple radiating sources at different receiving points within the cavity is determined using the ray path descriptions and the various constitutive parameters of the space module material. The field build-up at the receiving point is taken as coherent sum of the fields associated with each ray reaching the receiver. The convergence analysis of the field build-up is carried out *w.r.t.* the propagation time and the number of bounces a ray undergoes before reaching the receiver.

Keywords: Space Module, Ray casting, RF field build-up, Convergence

1. INTRODUCTION

Space module is the fore section of the space shuttle where the astronauts frequently operate in presence of multiple radiating sources. Thus the space module is one of aerospace structures, which is of interest for RF mapping and its analysis. However, it is not sufficient to model such hybrid geometries as a facetted enclosure or merely as concavity of canonical cylindrical surfaces. An enhanced realism may follow from hybrid sections consisting of non-developable double-curvatured surface patches for the fore section of the space module.

The use of second-degree quadric patches is also adequate for RF field computation based on high-frequency ray-theoretic methods. Work has been reported earlier for EM analysis for *convex structures* using high-frequency methods in conjuction with analytical ray-tracing technique such as *Geodesic Constant Method* (GCM) [1], which pertains to the external (i.e. convex) part of such aerospace geometries. For RF field build-up inside a closed cavity like a manned space module, the concavity of the structure is an important aspect. Moreover the ray tracing tends to become complicated for such concave hybrid enclosure. An accurate surface modeling is required towards refined ray-tracing procedure for predicting the ray-path description for the EM field distribution within the structure.

In this paper, a space module is considered of practical dimensions currently in vogue [2]. The space module is modeled as a generalized paraboloid of revolution (GPOR) whose aft section is an end-capped right circular cylinder, shown in Figs. 1 and 2. This is done through analytical formulation using second-degree surface patches [3]. The RF field distribution due to multiple radiating sources at different receiving points within the cavity is determined using the ray path descriptions [4], and the various constitutive parameters of the space module material. Since an empty closed structure of space module is considered, only reflection is taken as dominant phenomenon for RF field distribution within the space module. The transmitting and the receiving antenna is taken as half-wavelength dipole.

The simulation results for the RF field build-up within a manned space module are presented for both perpendicular and parallel polarizations. The field build-up at the receiving point is taken as coherent sum of the fields associated with each ray reaching the receiver. The convergence analysis of the field build-up is carried out *w.r.t.* the propagation time and the number of bounces a ray undergoes before reaching the receiving point.

2. FORMULATION

The estimation of the RF field build-up within a closed cavity is based on the ray path description and coordinates of the reflection points obtained using a three-dimensional ray-tracing procedure. Although ray-

tracing becomes computationally complex when numerous ray paths and their multiple reflections are considered, it nevertheless offers an efficient method for volumetric ray tracing within the indoor environment where the number of observation points considered are particularly large.

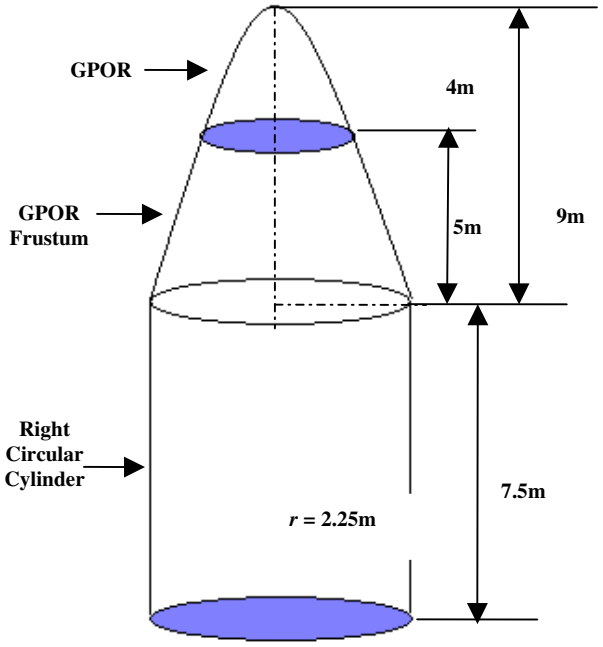


Figure 1 Geometry of a space module.

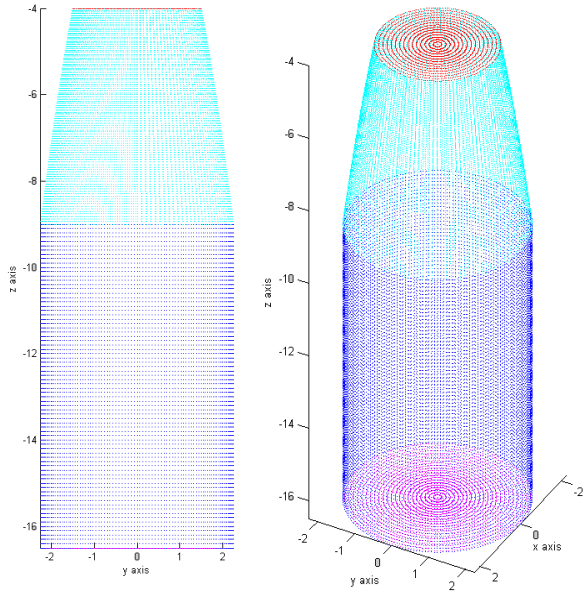


Figure 2 Surface modeling of a space module. [3]

The total electric field at an observation point P inside a cavity [5] is given by

$$E(P) = \sum_i E_i(P) \qquad (1)$$

where $E_i(P)$ is the field due to the i^{th} ray originating from the transmitting antenna and reaching the point P after experiencing finite number of reflections along its unique ray path towards point P. The number of the reflections depends on the angle at which the ray is originating from the transmitting antenna. Each ray will have its own ray-path history before reaching the receiver point. The time-independent field expressed in eq.(1) is the sum of infinite number of the field contribution terms within a closed metallic cavity. On the other hand, for a time snapshot, the computation is over finite time. Moreover the phase of each ray reaching the receiving point at different instant of time is adjusted to get the coherent superposition of each field contribution.

Each individual ray field contribution $E_i(P)$ is determined by ray tracing within the structure according to the laws of Geometrical Optics (GO). The value of the field depends on the number of reflections a ray undergoes while traveling from transmitter and receiver, the reflection points, the sequential order of reflections and other parameters such as constitutive material of the wall, geometry of the environment. Thus one has to follow the path followed by the ray and compute the field along the ray throughout a sequence of the reflections.

After N reflections, the complex electric field (in V/m) due to i^{th} ray at the receiving point P [5] is given by

$$E_i(P) = E_o F_{ti} F_{ri} \{\Pi_j R_j\} e^{-jkd} L_i(d) \qquad (2)$$

where, E_o is the reference field at the source, F_{ti} and F_{ri} are the transmitting and receiving antenna field radiation patterns in the direction of the ray, R_j is the reflection coefficient of the j^{th} object [6], e^{-jkd} is the propagation phase factor due to the path length d, $L_i(d)$ is the path loss distance dependence [5]. The dependence of the reflection coefficient on the material properties, viz. permittivity, conductivity, thickness, and angle of incidence is appropriately incorporated.

3. RAY PROPAGATION INSIDE A SPACE MODULE

The RF simulation for field build-up at the receiving point inside a space module needs detailed description of ray paths and the coordinates of the reflection points. Simulations are carried out for a metallic ($\sigma = 10^6$) space module. Both the transmitting and receiving antenna are taken as directional antenna (half-wave dipole). For modeling a space module following dimensions are used:

Geometry of the space module

The internal dimension of a typical manned space module is taken as:

Right circular cylinder: length: 7.5 m; diameter: 4.5 m
GPOR frustum: height: 5 m; matched diameter: 4.5m

A representing case is presented consisting of a transmitter positioned at (0.5, 0.9, -15.5) and the receiver at (0.5, -0.4, -6.0) inside the space module. The ray path details and the reflection point coordinates are obtained through refined ray-tracing algorithm [4]. These ray paths are weighted according the radiation pattern of the transmitting and receiving antenna within the space module.

4. RF FIELD BUILD-UP INSIDE A SPACE MODULE

RF field build-up at the receiving point inside a space module is obtained for the angular separation of 0.1° between the adjacent rays launched from the source placed inside the module. The trend of field build-up is analyzed for different bounces that a ray undergoes before reaching the receiving point. The effect of the frequency of operation on the field build-up is also studied. Simulations are done for 6 and 8 GHz, for both parallel and perpendicular polarization. Since the wall of the module is considered as metallic, rays after reflection do not suffer significant attenuation before reaching the receiver. Thus as more number of bounces are considered for RF field build-up at the receiving point, the amplitude of the coherent sum of the RF field increases. However after certain number of bounces and propagation time, the contribution from the rays reaching the receiver get optimized, leading to the convergence of the RF field build-up at the receiving point *w.r.t.* the number of bounces and the propagation time.

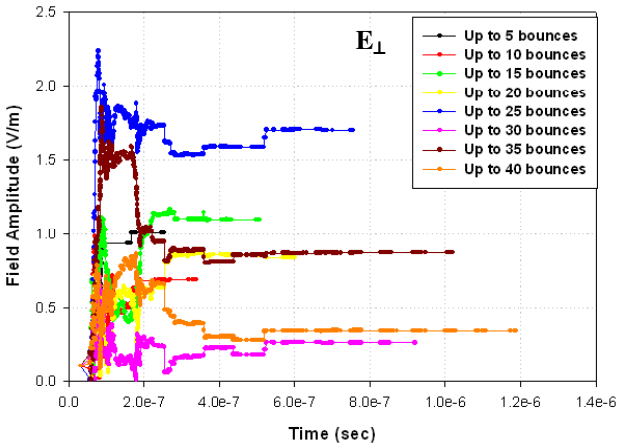


Figure 3 RF field build-up inside a metallic space module. Frequency = **6 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Perpendicular.*

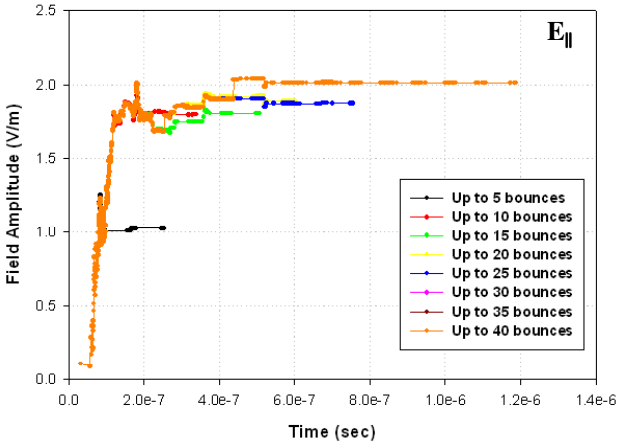


Figure 4 RF field build-up inside a metallic space module. Frequency = **6 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Parallel.*

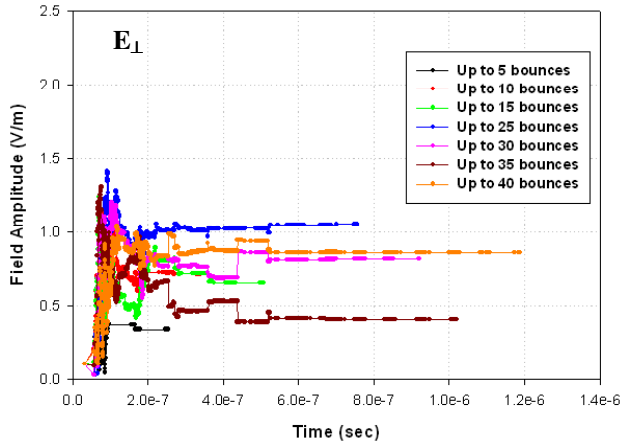


Figure 5 RF field build-up inside a metallic space module. Frequency = **8 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Perpendicular.*

The RF field build-up at the receiving point inside a space module at 6 GHz is shown in Figs. 3 and 4 for perpendicular and parallel polarization respectively. The results for 8 GHz are shown in Figs. 5 and 6 for perpendicular polarization respectively. The comparison of the converged RF field build-up for perpendicular and parallel polarization, at 6 GHz and 8 GHz is shown in Figs. 7 and 8 respectively. One can observe that as the space module is taken as metallic, although the RF field is converged *w.r.t.* both the number of bounces and propagation time, the dependence of amplitude of RF field on the frequency of operation is not clear. If the material of walls of space module is taken to be dielectric, a better convergence can be obtained.

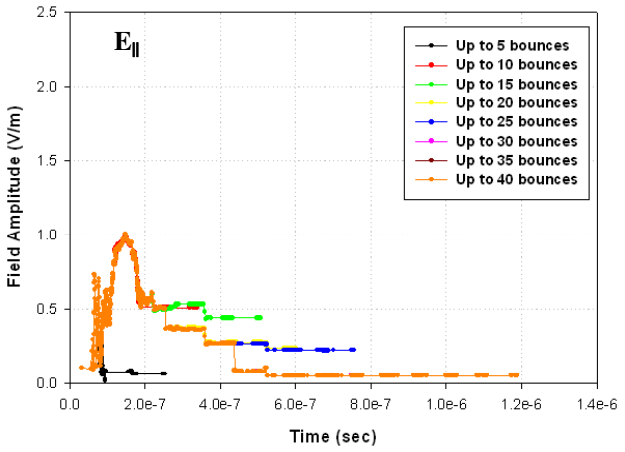


Figure 6 RF field build-up inside a metallic space module. Frequency = **8 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Parallel.*

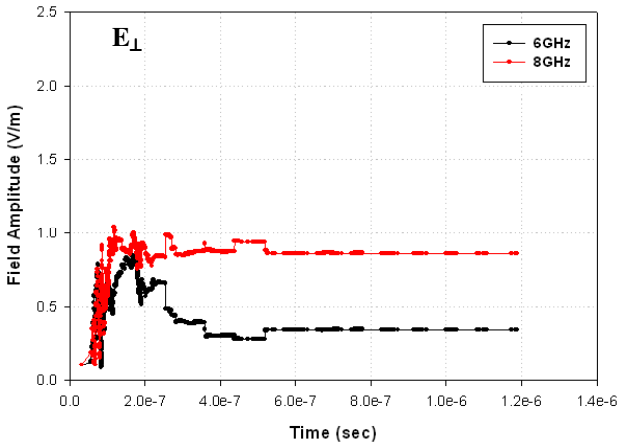


Figure 7 Comparison of RF field build-up inside a metallic space module at **6 and 8 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Perpendicular*

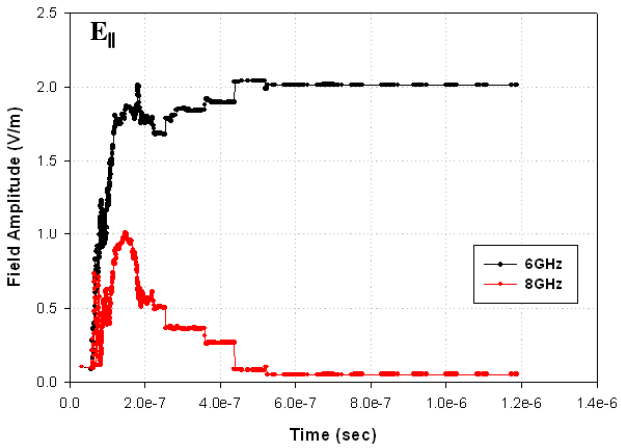


Figure 8 Comparison of RF field build-up inside a metallic space module at **6 and 8 GHz**; 0.1°; σ = 10^6 S/m, Polarization: *Parallel*

5. CONCLUSION

The RF environment inside a space module is analyzed based on the refined ray-tracing algorithm, considering the concavity of the surface. Since an empty closed structure of space module is considered, only reflection is taken as dominant phenomenon for RF field distribution within the space module. The field build-up at the receiving point is taken as coherent sum of the fields associated with each ray reaching the receiver. Both the transmitting and receiving antenna are taken as half-wave dipole. The convergence analysis of the field build-up is carried out *w.r.t.* the propagation time and the number of bounces a ray undergoes before reaching the receiving point. Since a metallic space module is considered, RF field convergence is slow both *w.r.t.* the number of bounces and propagation time.

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Replenishment Lot Sizing with a Cost Reduction Delivery Policy and Failure in Rework

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ABSTRACT

This paper considers optimization of a replenishment lot size problem with a cost reduction delivery policy and failure in rework. A prior work by Chiu et al. studied an economic lot size problem with multiple shipments and rework. With the intention of cutting down producer's inventory holding cost, this paper proposes an alternative distribution policy to improve solution in Chiu et al. An n+1 delivery policy is suggested here in lieu of their n multi-delivery plan. Under such a policy, one additional installment of finished products is delivered during uptime for satisfying customer's demand during production uptime and rework time. Then, in the end of rework, fixed quantity n installments of finished items are delivered to customer at a fixed interval of time. Failure in rework is also practically assumed in this study. Mathematical modeling and optimization techniques are employed and as result the optimal production lot size solution is derived. A numerical example is provided to demonstrate practical usage of research result and its significant savings in producer's stock holding cost.

Keywords: Replenishment lot size; Multiple deliveries; Cost reduction; Quality assurance; Failure in rework

1. INTRODUCTION

This paper combines an improved product distribution policy and failure in rework into an economic production quantity (EPQ) model examined by Chiu et al. [1], with the purpose of cutting down producer's stock holding cost. The EPQ model uses mathematical techniques to deal with the tradeoff between fixed setup cost and inventory holding cost during the production, and derives the optimal replenishment lot size to assist producers in minimizing the long-run average production-inventory cost [2-4].

The EPQ model implicitly assumes that all items produced are of perfect quality. However, in real-life production systems, due to process deterioration or other controllable or uncontrollable factors, generation of defective items is inevitable [5-12].

Defective items produced, sometimes can be reworked and repaired, and overall production costs can be significantly reduced. For instance, manufacturing processes in printed circuit board assembly, or in plastic injection molding, etc., sometimes employs rework as an acceptable process in terms of level of quality [13-19].

Gopalan and Kannan [13] considered a two-stage transfer-line production system with inspections and rework activities. They analyzed some of the transient state characteristics of such a two-stage production system subject to an initial buffer of infinite capacity, inspection at both the inter- and end-stages and rework. A stochastic model was developed to investigate the system. Explicit analytical expressions for some system characteristics have been obtained using the state-space method and regeneration point technique. Jamal et al. [15] determined the optimum batch quantity in a single-stage system in which rework is done under two different operational policies to minimize the total system cost. The first policy deals with rework being completed within the same cycle. The second policy deals with the rework being done after N cycles causing less than the desired quantity of good products in each cycle. Their models have been validated with illustrating numerical examples and the sensitivity of optimal batch size and total system cost with respect to the defective proportion have also been performed.

Another unpractical assumption of the EPQ model is the continuous inventory issuing policy. In real-life vendor-buyer integrated production-inventory system, periodic or multiple deliveries of finished products are often used instead of the continuous issuing policy. Goyal [20] examined an integrated inventory model for the single supplier-single customer problem. He proposed a method that is typically applicable to those inventory problems where a product is procured by a single customer from a single supplier. An example was provided to illustrate his proposed method. Many studies have since been carried out to address various aspects of supply chain optimization

[21-30]. Lu [24] examined a one-vendor multi- buyer integrated inventory model with the objective of minimizing vendor's total annual cost subject to the maximum costs that the buyers may be prepared to incur. Lu's model required to know buyer's annual demand and previous order frequency. As a result, an optimal solution for the one-vendor one-buyer case was obtained and a heuristic approach for the one-vendor multi-buyer case was also provided. Goyal and Nebebe [27] determined the economic production and shipment policy for a single vendor - single buyer system. The objective of their study was to minimize the total joint annual costs incurred by the vendor and the buyer. Chiu et al. [1] incorporated a multi- delivery policy and quality assurance into an imperfect EPQ model with scrap and rework. They assumed that the random defective items produced are partially repairable and are reworked in each cycle when regular production ends, and the finished items can only be delivered to customers if the whole lot is quality assured at the end of rework. Fixed quantity multiple installments of the finished batch are delivered to customers at a fixed interval of time. The expected integrated cost function per unit time was derived. A closed-form optimal batch size solution to the problem was obtained.

This paper extends the problem studied by Chiu et al. [1], with the purpose of reducing supplier's stock holding cost, an n+1 delivery policy is proposed here in lieu of n multi- delivery plan. Moreover, failure in rework situation is practically considered in the present study. The joint effects of the n+1 multi-delivery policy and failure in rework on the optimal replenishment lot size of such an imperfect EPQ model are investigated.

2. ASSUMPTIONS & MATHEMATICAL MODELING

Reexamine the specific economic lot size problem studied by Chiu et al. [1] which addressed two practical issues: the reworking of defective items and a multi-delivery policy for transporting finished items. For the purpose of reducing supplier's stock holding cost, an n+1 delivery policy is proposed in our study in lieu of their n multi-delivery plan. Moreover, a failure in rework assumption is practically considered in our proposed model. Assumptions of this study are given as follows.

Consider a manufacturing system which may produce x portion of random defective items at a production rate d. It is assumed that defective items will be reworked at a rate P_1, within the same cycle when regular production ends. A θ_1 portion of reworked items fails during the rework process and becomes scrap. Under the regular operating schedule, the constant production rate P is larger than the sum of demand rate λ and production rate of defective items d. That is: $(P\text{-}d\text{-}\lambda)>0$; where d can be expressed as $d=Px$. Let d_1 denote production rate of scrap items during the rework process, then d_1 can be expressed as $d_1=P_1\theta_1$.

The distribution of finished (perfect quality) products is under an n+1 delivery policy. That is an initial installment of finished items is distributed to customer for satisfying demand during producer's production uptime and rework time. Then, at the end of rework, when the rest of the production lot is quality assured, fixed quantity n installments of finished items are delivered to customer at a fixed interval of time. Such an n+1 delivery policy is intended to reduce supplier's stock holding cost.

On-hand inventory of perfect quality items of the proposed model is depicted in Figure 1.

Figure 2 illustrates the expected reduction in stock holding costs (in yellow/shade areas) for the proposed model (in blue) in comparison with Chiu et al.'s model [1] (in red).

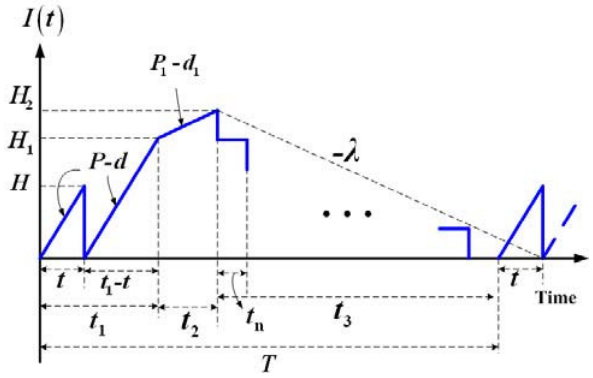


Fig. 1 On-hand inventory of perfect quality items in EPQ model with failure in rework and (n+1) delivery policy

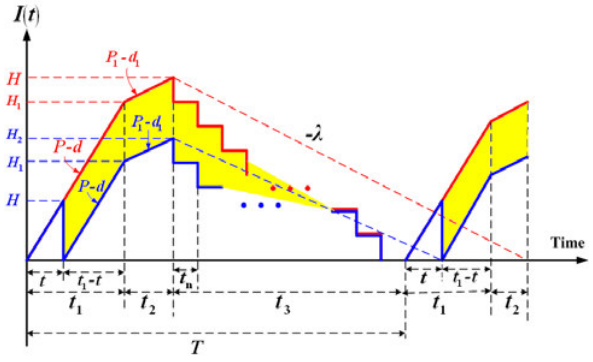


Fig. 2 Expected reduction in stock holding costs (in yellow) of the proposed model in comparison with Chiu et al.'s model [1]

The cost related parameters considered in the proposed model include the following: setup cost K per production run, unit holding cost h, unit manufacturing cost C, unit rework cost C_R, disposal cost per scrap item C_S, holding cost h_1 for each reworked item, fixed cost K_1 per delivery and unit transportation cost C_T. Other notation includes

T = cycle length,
H = the level of on-hand inventory in units for satisfying product demand during manufacturer's regular production time t_1 and rework time t_2,
H_1 = maximum level of on-hand inventory in units when regular production ends,
H_2 = the maximum level of on-hand inventory in units when rework process finishes,
t = the production time needed for producing enough perfect items for satisfying product demand during the production uptime t_1 and the rework time t_2,
t_1 = the production uptime for the proposed EPQ model,
t_2 = time required for reworking of defective items,
t_3 = time required for delivering the remaining quality assured finished products,
Q = production lot size to be determined for each cycle,
n = number of fixed quantity installments of the rest of finished batch to be delivered to customer during t_3,
t_n = a fixed interval of time between each installment of products delivered during t_3,
$I(t)$ = on-hand inventory of perfect items at t,
$I_d(t)$ = on-hand inventory of defective items at t,
$I_s(t)$ = on-hand inventory of scrap items at time t,
$TC(Q)$= total production-inventory-delivery costs per cycle for the proposed model,

E[*TCU*(*Q*)] = the long-run average costs per unit time for the proposed model.

The following expressions can be derived directly from the proposed model and Figure 1:

$$H = (P-d)t = \lambda(t_1+t_2) \tag{1}$$

$$H_1 = (P-d)(t_1-t) = Q(1-x) - \lambda(t_1+t_2) \tag{2}$$

$$H_2 = H_1 + (P_1-d_1)t_2 \tag{3}$$

$$t = \frac{\lambda(t_1+t_2)}{P-d} \tag{4}$$

$$t_1 = \frac{Q}{P} = \frac{H_1+H_2}{P-d} \tag{5}$$

$$t_2 = \frac{xQ}{P_1} \tag{6}$$

$$t_3 = T - (t_1+t_2) = mt_n \tag{7}$$

$$T = t_1+t_2+t_3 = \frac{Q}{\lambda}(1-\theta_1 x) \tag{8}$$

Figure 3 depicts the on-hand inventory of imperfect quality items produced during uptime t_1 and reworking time t_2. It is noted that the maximum level of defective items is dt_1. During the rework process, a portion θ_1 of reworked items fail and becomes scrap.

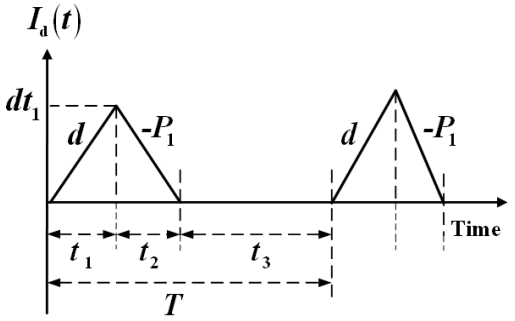


Fig. 3 On-hand inventory of defective items in EPQ model with failure in rework and (*n*+1) delivery policy

TC(*Q*) the total production-inventory-delivery costs per cycle, consists of the variable production cost, the setup cost, variable rework cost, disposal cost, (*n*+1) fixed distribution costs and variable delivery cost, holding cost for perfect quality items during uptime t_1 and reworking time t_2, holding cost for defective items during t_1, variable holding cost for items reworked during t_2, and holding cost for finished goods during t_3 where n fixed-quantity installments of the finished batch are delivered to customers at a fixed interval of time.

$$\begin{aligned} TC(Q) &= CQ + K + C_R[xQ] + C_S[xQ\theta_1] \\ &+ (n+1)K_1 + C_T[Q(1-\theta_1 x)] \\ &+ h\left[\frac{H}{2}(t) + \frac{H_1}{2}(t_1-t) + \frac{H_2+H_1}{2}(t_2) + \frac{dt_1}{2}(t_1)\right] \\ &+ h_1\left[\frac{dt_1}{2}(t_2)\right] + h\left[\left(\frac{n-1}{2n}\right)H_2 t_3\right] \end{aligned} \tag{9}$$

Because defective rate x is assumed to be a random variable with a known probability density function, taking the randomness of x into account, one can use the expected values of x in the related cost analysis. Substituting all related parameters from Eqs. (1) to (8) in *TC*(*Q*), one obtains the expected cost E[*TCU*(*Q*)] as follows.

$$\begin{aligned} E[TCU(Q)] &= \frac{E[TC(Q)]}{E[T]} = \frac{C\lambda}{1-\theta_1 E(x)} + \frac{[(n+1)K_1+K]\lambda}{Q[1-\theta_1 E(x)]} \\ &+ \frac{C_R E(x)\lambda}{1-\theta_1 E(x)} + \frac{C_S E(x)\theta_1\lambda}{1-\theta_1 E(x)} + C_1\lambda + \frac{h_1 Q\lambda[E(x)]^2}{2P_1[1-\theta_1 E(x)]} + \frac{hQ}{2}\cdot \\ &\left\{ \begin{aligned} &\frac{2\lambda^3}{P^3[1-\theta_1 E(x)]}E\left(\frac{1}{1-x}\right) + \frac{4\lambda^3}{P^2P_1[1-\theta_1 E(x)]}E\left(\frac{x}{1-x}\right) - \frac{\lambda^2}{P^2[1-\theta_1 E(x)]} \\ &- \frac{2\lambda^2 E(x)}{PP_1[1-\theta_1 E(x)]} + \frac{2\lambda^3}{PP_1^2[1-\theta_1 E(x)]}E\left(\frac{x^2}{1-x}\right) - \frac{\lambda[E(x)]^2(1-\theta_1)}{P_1[1-\theta_1 E(x)]} \\ &- \frac{\lambda^2[E(x)]^2}{P_1^2[1-\theta_1 E(x)]} + [1-\theta_1 E(x)] - \frac{\lambda[1-2\theta_1 E(x)]}{P[1-\theta_1 E(x)]} \\ &- \left(\frac{1}{n}\right)\left[\begin{aligned} &[1-\theta_1 E(x)] - \frac{2\lambda}{P} - \frac{2\lambda E(x)}{P_1} + \frac{2\lambda^2 E(x)}{PP_1[1-\theta_1 E(x)]} + \frac{\lambda^2}{P^2[1-\theta_1 E(x)]} \\ &+ \frac{\lambda^2[E(x)]^2}{P_1^2[1-\theta_1 E(x)]} \end{aligned} \right] \end{aligned} \right\} \end{aligned} \tag{10}$$

3. CONVEXITY AND THE OPTIMAL SOLUTION

The optimal replenishment lot size can be obtained by minimizing the expected cost *E[TCU(Q)]*. Differentiating *E[TCU(Q)]* with respect to *Q*, the first and the second derivatives of *E[TCU(Q)]* are shown in Eqs. (11) and (12).

$$\begin{aligned} \frac{dE[TCU(Q)]}{dQ} &= \frac{-[(n+1)K_1+K]\lambda}{Q^2[1-\theta_1 E(x)]} + \frac{h_1\lambda[E(x)]^2}{2P_1[1-\theta_1 E(x)]} \\ &+ \frac{h}{2}\left\{ \begin{aligned} &\frac{2\lambda^3}{P^3[1-\theta_1 E(x)]}E\left(\frac{1}{1-x}\right) + \frac{4\lambda^3}{P^2P_1[1-\theta_1 E(x)]}E\left(\frac{x}{1-x}\right) - \frac{\lambda^2}{P^2[1-\theta_1 E(x)]} \\ &+ \frac{2\lambda^3}{PP_1^2[1-\theta_1 E(x)]}E\left(\frac{x^2}{1-x}\right) - \frac{2\lambda^2 E(x)}{PP_1[1-\theta_1 E(x)]} - \frac{\lambda[E(x)]^2(1-\theta_1)}{P_1[1-\theta_1 E(x)]} \\ &- \frac{\lambda^2[E(x)]^2}{P_1^2[1-\theta_1 E(x)]} + [1-\theta_1 E(x)] - \frac{\lambda[1-2\theta_1 E(x)]}{P[1-\theta_1 E(x)]} \\ &- \left(\frac{1}{n}\right)\left[\begin{aligned} &[1-\theta_1 E(x)] - \frac{2\lambda}{P} - \frac{2\lambda E(x)}{P_1} + \frac{2\lambda^2 E(x)}{PP_1[1-\theta_1 E(x)]} \\ &+ \frac{\lambda^2}{P^2[1-\theta_1 E(x)]} + \frac{\lambda^2[E(x)]^2}{P_1^2[1-\theta_1 E(x)]} \end{aligned} \right] \end{aligned} \right\} \end{aligned} \tag{11}$$

$$\frac{d^2E[TCU(Q)]}{dQ^2} = \frac{2[(n+1)K_1+K]\lambda}{Q^3[1-\theta_1 E(x)]} \tag{12}$$

Equation (12) is resulting positive because *K, n, K*$_1$*, λ, Q,* and (1-$\theta_1 E[x]$) are all positive. The second derivative of *E[TCU(Q)]* with respect to *Q* is greater than zero. Hence *E[TCU(Q)]* is a convex function for all *Q* different from zero.

The optimal *Q** can be obtained by setting first derivative of *E[TCU(Q)]* equal to zero. With rearrangement, one obtains

$$\frac{\left[(n+1)K_1+K\right]\lambda}{Q^2}=+\frac{h_1\lambda\left[E(x)\right]^2}{2P_1}$$
$$+\frac{h}{2}\left\{\begin{array}{l}\frac{2\lambda^3}{P^3}E\left(\frac{1}{1-x}\right)+\frac{4\lambda^3}{P^2P_1}E\left(\frac{x}{1-x}\right)-\frac{\lambda^2}{P^2}\\+\frac{2\lambda^3}{PP_1^2}E\left(\frac{x^2}{1-x}\right)-\frac{2\lambda^2E(x)}{PP_1}-\frac{\lambda\left[E(x)\right]^2(1-\theta_1)}{P_1}\\-\frac{\lambda^2\left[E(x)\right]^2}{P_1^2}+\left[1-\theta_1E(x)\right]^2-\frac{\lambda\left[1-2\theta_1E(x)\right]}{P}\\-\left(\frac{1}{n}\right)\cdot\left[\begin{array}{l}\left[1-\theta_1E(x)\right]^2-\frac{2\lambda\left[1-\theta_1E(x)\right]}{P}-\frac{2\lambda E(x)\left[1-\theta_1E(x)\right]}{P_1}\\+\frac{2\lambda^2E(x)}{PP_1}+\frac{\lambda^2}{P^2}+\frac{\lambda^2\left[E(x)\right]^2}{P_1^2}\end{array}\right]\end{array}\right\} \quad (13)$$

$$Q^*=\sqrt{\frac{2\lambda\left[(n+1)K_1+K\right]}{h\left\{\begin{array}{l}\frac{\lambda^2}{P}\left[\begin{array}{l}\frac{2\lambda}{P^2}E\left(\frac{1}{1-x}\right)-\frac{1}{P}+\\\frac{1}{P_1}\left[\frac{4\lambda}{P}E\left(\frac{x}{1-x}\right)+\frac{2\lambda}{P_1}E\left(\frac{x^2}{1-x}\right)-2E(x)\right]\end{array}\right]\\-\frac{\lambda\left[E(x)\right]^2}{P_1}\left[(1-\theta_1)+\frac{\lambda}{P_1}\right]+\left[1-\theta_1E(x)\right]^2\\-\frac{\lambda\left[1-2\theta_1E(x)\right]}{P}-\left(\frac{1}{n}\right)\cdot\\\left[\left[1-\theta_1E(x)\right]\cdot\left[\left[1-\theta_1E(x)\right]-\frac{2\lambda}{P}-\frac{2\lambda E(x)}{P_1}\right]\right.\\\left.+\frac{2\lambda^2E(x)}{PP_1}+\frac{\lambda^2}{P^2}+\frac{\lambda^2\left[E(x)\right]^2}{P_1^2}\right]\end{array}\right\}}}+\frac{h_1\lambda\left[E(x)\right]^2}{P_1} \quad (14)$$

4. NUMERICAL EXAMPLE

This section adopts the same numerical example as in Chiu et al. [1]. Consider an item can be produced at a rate P of 60,000 units per year and this item has experienced a flat demand rate λ of 3,400 units per year. During production process, a random defective rate x is assumed to be uniformly distributed over the interval [0, 0.3]. An annual rate of rework P_1=2,200 is assumed and a portion θ_1=0.1 of reworked items fails during the rework process. Additional variables include: K=\$20,000; C=\$100; C_R=\$60; C_S=\$20 per scrap item; h=\$20 per item per year; h_1=\$40 per item reworked; a fixed cost K_1=\$4,350 per shipment; and C_T=\$0.1 per item delivered. In order to show practical usages of our research results, the following two different scenarios are demonstrated:

Scenario 1: Let total number of deliveries remain 4 (i.e. n=4 as was used in Chiu et al. [1]. For the proposed model, it is (n+1)=4. An initial installment of finished products is distributed to customer during t_1, for satisfying the product demand during production uptime and rework time. Then, at the end of rework, fixed quantity three other installments of finished items are delivered to customer at a fixed interval of time. Also, for the purpose of comparison, we use lot-size solution Q=3,495 (Chiu et al. [1] in calculating the expected production-inventory- delivery cost (i.e. Eq. (10) of proposed model) and obtain E[TCU(3495)]= \$440,221. One notes that there is a reduction in manufacturer holding costs amounts to \$11,276 (see Figure 4), or 11.25% of total other related costs (i.e. E[TCU(Q)]-(λC): total cost excludes the variable production cost).

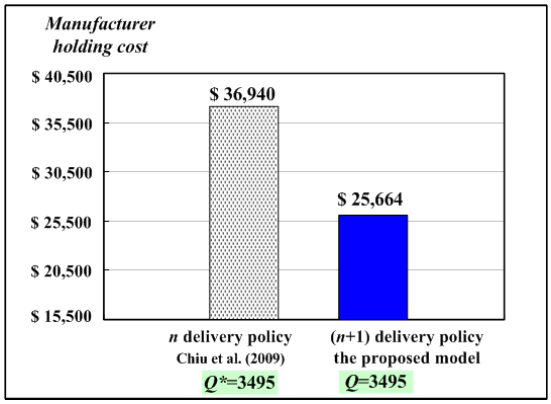


Fig. 4 Comparison of producer's stock holding cost for the proposed (n+1) delivery policy to that of Chiu et al. [1]

Scenario 2: Let total number of deliveries remain 4 (that is (n+1)=4 in our model). By applying Eqs. (14) and (10), one obtains the optimal lot size Q*=4,193 and the expected cost E[TCU(Q*)]=\$439,197, respectively. It is noted that overall reduction in production-inventory- delivery costs amounts to \$12,300, or 12.27% of total other related costs.

5. CONCLUDING REMARKS

Chiu et al. (2009) derived an optimal production lot size for an EPQ model with discontinuous issuing policy and imperfect rework. An n multi-delivery plan for distributing the finished items at the end of the rework process was adopted by them. With the purpose of reducing supplier's stock holding cost, this paper extends Chiu et al.'s model [1] and proposes an n+1 delivery policy in lieu of their n multi-delivery plan, along with a practical assumption considering the failure in rework situation.

Mathematical modeling is employed and the long-run average production-inventory-delivery cost per unit time is derived. Convexity of cost function is proved and closed-form optimal replenishment lot size solution to the problem is derived. A numerical example is provided to show practical usage of our research result and demonstrate its significant savings in producer's stock holding cost.

For future research, one interesting direction will be to investigate the effect of multiple customers on lot size decisions for the same model.

ACKNOWLEDGEMENTS

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Determining production run time with random defective rate and stochastic breakdown

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ABSTRACT

This study derives the optimal run time for a production system with random defective rate and Poisson breakdown. In a real-life manufacturing system, generation of defective items and machine failures are inevitable. With the purpose of addressing these practical issues, this study examines a production system that has random defective items produced, and it also is subject to an equipment failure that may take place randomly. An abort/ resume inventory control policy is adopted when breakdown occurs. Under such a policy, the malfunction machine is under repair immediately and the interrupted lot will be resumed right after restoration of the machine. Mathematical modeling and analyses, along with a recursive searching algorithm are used and proposed in this paper for deriving the optimal replenishment run time that minimizes the long-run average cost for such a practical production system. An example is provided to demonstrate how the proposed solution procedure works as well as its application.

Keywords: Manufacturing; Replenishment run time; Defective rate; Machine failure; EPQ model; Production Planning

1. INTRODUCTION

The economic order quantity (EOQ) model was first introduced [1] several decades ago to assist corporations in minimizing total inventory costs. He employed mathematical techniques to balance the setup and the stock holding costs and derived the optimal order size that minimizes the long-run average cost. In the manufacturing sector, when items are produced in-house instead of being acquired from outside suppliers, the economic production quantity (EPQ) model is commonly used to deal with non-instantaneous stock replenishment rate in order to obtain the minimum production-inventory cost per unit time [2]. Despite their simplicity, the EOQ and EPQ models are still broadly used [2-3].

Conventional EPQ model assumes that all items made are of perfect quality. However, in real-life production systems, due to process deterioration and/or other factors, generation of nonconforming items is inevitable. Practically, these defective items sometimes can be reworked hence overall production costs can be reduced. For example, manufacturing processes in printed circuit board assembly, or in plastic injection molding, etc., sometimes employs rework as an acceptable process in terms of level of quality. Therefore, many studies have been carried out to enhance the EOQ and EPQ models by undertaking issues of imperfect production and reduction of its corresponding quality costs [4-11]. Rahim and Ben-Daya [7] examined the simultaneous effects of both deteriorating product items and deteriorating production processes on the economic production quantity, inspection schedules, and the economic design of control charts. Deterioration times for both product and process were assumed to follow arbitrary distributions, and the product quality characteristic was assumed to be normally distributed. Usages of their models were demonstrated through illustrative examples.

Probabilistic machine failure is a critical reliability factor in production management and it can be very disruptive when occurring, particularly in a highly automated manufacturing environment. Groenevelt et al. [12] examined two production control policies that deal with stochastic machine breakdowns. The first one assumes that the production of the interrupted lot is not resumed (called no resumption-NR policy) after a breakdown. The second policy considers that the production of the interrupted lot will be immediately resumed (called abort/resume or AR policy) after the breakdown is fixed and if the current on-hand inventory is below a certain threshold level. In their article, both policies assume the repair time is negligible and they studied the effects of machine breakdowns and corrective maintenance on economic lot size decisions. Studies have since been carried out to address the issue of machine failures during production [13-21]. Arreola-Risa and DeCroix [14] explored an (s, S) stochastic-demand inventory management system under random supply disruptions and partial backorders. Their analysis yields the optimal values of the policy parameters and provides insight into the optimal inventory strategy when there are changes in the

severity of supply disruptions or in the behavior of unfilled demands. Makis and Fung [15] analyzed the effects of machine failures on the optimal lot size as well as on optimal number of inspections. Formulas for the long-run expected average cost per unit time was obtained. Then, the optimal production/inspection policy that minimizes the expected average costs was derived. Giri and Dohi [19] presented an exact formulation of stochastic EMQ model for an unreliable production system. Their model is formulated based on the net present value (NPV) approach, and by taking limitation on the discount rate the traditional long-run average cost model is obtained. They also provided the criteria for the existence and uniqueness of the optimal production time and computational results showing that the optimal decision based on the NPV approach is superior to that based on the long-run average cost approach. Chiu et al. [20] studied the optimal run time problem with scrap, the reworking of repairable defective items, and machine breakdown under no resumption (NR) policy. Formulas for the long-run expected average cost per unit time was derived. Theorems for convexity and bounds of run time were presented and a simple procedure for searching the optimal run time was provided.

2. MATHEMATICAL MODELLING

Consider that there is a random defective rate x in a production system, and the nonconforming items produced cannot not be reworked; they are scrap and will be discarded soon after the end of production. This system is also subject to machine failure and it may take place randomly. An abort/resume (AR) inventory control policy is adopted when breakdown occurs. Under such a policy, the malfunction machine is under repair immediately and the interrupted lot will be resumed right after the restoration of machine. The repair time is assumed to be constant. To prevent shortage situation from happening, there is a safety stock policy in place to cope with the possibility of machine breakdown occurs in very earlier stage of the production.

The production rate is a constant and is much larger than the demand rate λ. The production rate of defective items d can be expressed as the production rate times the defective rate: $d=Px$. The cost parameters considered in the proposed model include the setup cost K, unit production cost C, unit holding cost h, disposal cost per scrap item C_S, and a fixed cost M for repairing and restoring the machine. Additional notations used are as follows.

- H_1 = the level of on-hand inventory when machine breakdown occurs,
- H_2 = the level of on-hand inventory when machine is repaired and restored,
- H_3 = the level of on-hand inventory when machine is restored and the remaining production uptime is accomplished,
- Q = production lot size per cycle,
- t_1 = the production uptime to be determined for the proposed model,
- t = time before a random breakdown occurs,
- β = number of breakdowns per year, a random variable follows a Poisson distribution,
- t_r = time required for repairing the machine,
- t_2' = time needed for consuming all available good items when breakdown takes place,
- $I(t)$ = on-hand inventory of perfect quality items at time t,
- $I_d(t)$ = on-hand inventory of defective items at time t,
- T' = cycle length in the case of machine breakdown takes place,
- t_2 = time required for depleting all available perfect quality items when machine breakdown does not occur,
- H_4 = maximum level of on-hand inventory in units when production process ends,
- T = cycle length when machine breakdown does not occur,
- **T** = cycle length whether a machine breakdown or not,
- $TC_1(t_1)$ = total inventory costs per cycle in the case of machine breakdown takes place,
- $TC_2(t_1)$ = the total inventory costs per cycle when machine breakdown does not occur,
- $TCU(t_1)$ = the total inventory costs per unit time whether a breakdown takes place or not.

Under regular supply, the basic assumption for EPQ model with random defective rate and shortages should be that the production rate of perfect quality items must always be greater than the sum of the demand rate and the production rate of defective items. Therefore, one should have $(P\text{-}d\text{-}\lambda) > 0$. Let t denote the time before a breakdown taking place and t_1 stands for the production uptime to be determined by this study in order to minimize the long-run average production-inventory cost. It is also assumed that during production uptime t_1 machine failure may occur randomly, if the time to breakdown $t < t_1$, then a random breakdown occurs during the production uptime t_1. On the other hand, if $t >= t_1$, then machine failure does not happen during t_1. Hence, the aforementioned two situations are studied separately.

EPQ model with random defective rate and stochastic breakdown

First, the production time t before a machine breakdown taking place is smaller than the uptime t_1. The abort/resume policy is adopted when random breakdown takes place. Under such a policy, production of the interrupted lot will be immediately resumed when the breakdown is fixed. The on-hand inventory level of perfect quality items when a breakdown occurs during t_1 is illustrated in Figure 1.

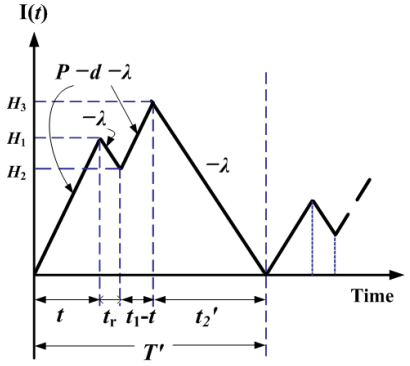


Fig. 1 On-hand inventory of perfect quality items in EPQ model with random defective rate and stochastic breakdown

The cycle length T' contains production uptime t_1, the time required for repairing the machine t_r and the time needed for depleting all on-hand perfect quality items t_2' (as shown in Eq. (1)). The following solution procedure used by this paper is similar to what was presented by Chiu et al. [30]. From the assumption of the proposed model and Figure 1, one can obtain the following formulations directly

$$H_1 = (P - d - \lambda)t \tag{1}$$

$$H_2 = H_1 - t_r\lambda = (P - d - \lambda)t - g\lambda \tag{2}$$

$$H_3 = H_2 + (P - d - \lambda)(t_1 - t) \tag{3}$$

$$T' = t + t_r + (t_1 - t) + t_2' \tag{4}$$

$$t_1 = \frac{Q}{P};\ \ \therefore\ Q = t_1 P \tag{5}$$

where $t_r = g$, g is the assumed fixed repair time and $d=Px$.

It is noted that the nonconforming items produced during production time t (before a breakdown takes place) is dt, and total defective items produced during production uptime t_1 can be obtained as shown in Eq. (6). All imperfect quality items are assumed to be scrap items here. The time needed for depleting all on-hand perfect quality items t_2' can also be expressed as shown in Eq. (7).

$$d \cdot t_1 = x \cdot Q = x \cdot t_1 \cdot P \tag{6}$$

$$t_2' = \frac{H_3}{\lambda} = T' - t_1 - t_r \tag{7}$$

$TC_1(t_1)$ – the total production-inventory cost per cycle (Eq.(8)) for the case of machine breakdown taking place (under AR policy) during uptime t_1, consists of the variable production cost, the setup cost, a fixed cost for repairing the machine, the variable disposal cost, and holding cost for both perfect quality items and nonconforming items during the production uptime t_1.

$$TC_1(t_1) = C \cdot t_1 \cdot P + K + M + C_S \cdot t_1 \cdot P \cdot x + h\left[\frac{H_1}{2}(t) + \frac{H_1 + H_2}{2}(t_r) + \frac{H_2 + H_3}{2}(t_1 - t) + \frac{H_3}{2}(t_2') + dt(t_r) + \frac{dt_1}{2}(t_1)\right] \tag{8}$$

Because the proportion x of defective items is assumed to be a random variable with a known probability density function, to take the randomness of defective rate into account, one can use the expected values of x in the inventory cost analysis. Substituting all related parameters from Eqs. (1) to (7) in $TC_1(t_1)$, and with further derivations one obtains the expected production-inventory cost per cycle $E[TC_1(t)]$ for the case of EPQ model with random defective rate and stochastic breakdown as follows.

$$E\left[TC_1(t_1)\right] = K + M + \left\{CP + C_s PE[x] - hPg + hPgE[x]\right\} \cdot t_1 + (hPg)t + \left\{\frac{h}{2}\frac{P^2}{\lambda}\left[1 - 2E[x] + E[x^2]\right] - \frac{hP}{2} + hPE[x]\right\} \cdot t_1^2 \tag{9}$$

EPQ model with random defective rate but no breakdowns

In this situation, production time t before a machine breakdown taking place is greater than the production uptime t_1. One can obtain the production uptime t_1 as shown in Eq. (2) and the level of on-hand inventory of perfect quality items H_4 as follows.

$$H_4 = (P - d - \lambda)t_1 \tag{10}$$

It is noted that total scrap produced during production uptime t_1 are the same as shown in Eq. (6). Time t_2 required for depleting all on-hand perfect quality items and the cycle length T are.

$$t_2 = \frac{H_4}{\lambda} = T - t_1 \tag{11}$$

$$T = t_1 + t_2 \tag{12}$$

Total production-inventory cost per cycle $TC_2(t_1)$ (see Eq.(13)) for this case, consists of the variable production cost, the setup cost, the variable disposal cost, and the holding cost for both perfect quality items and nonconforming items during production uptime t_1.

$$TC_2(t_1) = C \cdot t_1 \cdot P + K + C_S(t_1 \cdot P \cdot x) + h\left[\frac{H_4}{2}(t_1) + \frac{H_4}{2}(t_2) + \frac{dt_1}{2}(t_1)\right] \tag{13}$$

Taking the randomness of defective items into account and substituting all related parameters from Eqs. (10) to (12) in $TC_2(t_1)$, one obtains

$$E\left[TC_2(t_1)\right] = K + \left[CP + C_s PE[x]\right] \cdot t_1 + \left\{\frac{h}{2}\frac{P^2}{\lambda}\left[1 - 2E[x] + E[x^2]\right] - \frac{hP}{2} + hPE[x]\right\} \cdot t_1^2 \tag{14}$$

3. INTEGRATING CASES WITH/OUT BREAKDOWN

Because $E[TC_1(t_1)]$ and $E[TC_2(t_1)]$ for the cases of EPQ models with and without random breakdowns have been derived, respectively. Due to stochastic machine breakdown and random scrap rate, the cycle length of the proposed EPQ model is not a constant. The renewal reward theorem is employed to cope with the variable cycle length. Let $f(t)$ denote the probability density function of random production time t before breakdown occurs and let $F(t)$ be the cumulative density function of t. Then the expected production-inventory cost per unit time $E[TCU(t_1)]$ (whether a breakdown takes place or not) is:

$$E\left[TCU(t_1)\right] = \frac{\left\{\int_0^{t_1} E\left[TC_1(t_1)\right] f(t)\,dt + \int_{t_1}^{\infty} E\left[TC_2(t_1)\right] f(t)\,dt\right\}}{\mathrm{E}[\mathbf{T}]} \tag{15}$$

and

$$\mathrm{E}[\mathbf{T}] = \int_0^{t_1} E[T'] f(t)\,dt + \int_{t_1}^{\infty} E[T] f(t)\,dt \tag{16}$$

Further, substituting for $E[TC_1(t)]$, $E[TC_2(t_1)]$ and $E[\mathbf{T}]$ in $E[TCU(t_1)]$ (i.e. Eq. (15)) one obtains the expected inventory cost per unit time $E[TCU(t_1)]$ as follows.

$$E\left[TCU(t_1)\right] = \frac{\left\{\begin{array}{l}\int_0^{t_1}\left\{\begin{array}{l}K + M + \left\{CP + C_s PE[x] - hPg + hPgE[x]\right\} \cdot t_1 + (hPg)t \\ + \left\{\frac{h}{2}\frac{P^2}{\lambda}\left[1 - 2E[x] + E[x^2]\right] - \frac{hP}{2} + hPE[x]\right\} \cdot t_1^2\end{array}\right\} f(t)\,dt \\ + \int_{t_1}^{\infty}\left\{\begin{array}{l}K + \left[CP + C_s PE[x]\right] t_1 \\ + \left\{\frac{h}{2}\frac{P^2}{\lambda}\left[1 - 2E[x] + E[x^2]\right] - \frac{hP}{2} + hPE[x]\right\} \cdot t_1^2\end{array}\right\} f(t)\,dt\end{array}\right\}}{\frac{P\left[1 - E(x)\right] t_1}{\lambda}} \tag{17}$$

Because the number of machine breakdown per unit time is assumed to be a random variable that follows a Poisson distribution with the mean equals to β per unit time. Therefore, the time between breakdowns obeys the exponential distribution, with the density function $f(t) = \beta e^{-\beta t}$; and its cumulative density function $F(t) = 1 - e^{-\beta t}$. Solving the integration of mean-time-to-breakdown of the expected $E[TCU(t_1)]$ one obtains

$$E\left[TCU(t_1)\right] = \frac{\lambda\left\{C + C_S E[x] - hg\right\}}{\left[1 - E(x)\right]} + \frac{hP\left[1 - 2E[x] + E[x^2]\right] - h\lambda + 2\lambda hE[x]}{2\left[1 - E(x)\right]} \cdot t_1 + \frac{\lambda}{\left[1 - E(x)\right]}\left\{\frac{K}{Pt_1} + hgE(x)\left(1 - e^{-\beta t_1}\right) + \left[\frac{M}{P} + \frac{hg}{\beta}\right]\frac{\left(1 - e^{-\beta t_1}\right)}{t_1}\right\} \tag{18}$$

In order to determine the optimal production run time t_1*, two theorems are proposed here. Let $v = M\beta + hgP$ and $w(t_1)$ denote

$$w(t_1) = \frac{2\left[K\beta + v \cdot \left(1 - e^{-\beta t_1}\right)\right]}{\left[Pt_1^2 hgE(x)\beta^2 + v(2 + \beta t_1)\right]\left(\beta e^{-\beta t_1}\right)} \tag{19}$$

Theorem 1: *E[TCU(t₁)] is convex if* $0 < t_1 < w(t_1)$.

The first and the second derivative of $E[TCU(t_1)]$ are

$$\frac{d\,E\left[TCU(t_1)\right]}{dt_1}=\frac{hP\left[1-2E[x]+E[x^2]\right]-h\lambda+2\lambda hE[x]}{2\left[1-E(x)\right]} + \frac{\lambda}{\left[1-E(x)\right]}\left\{\begin{array}{l}\dfrac{-K}{Pt_1^2}+hgE(x)\left(\beta e^{-\beta t_1}\right) \\ +\left[\dfrac{M}{P}+\dfrac{hg}{\beta}\right]\left[\dfrac{-\left(1-e^{-\beta t_1}\right)}{t_1^2}+\dfrac{\beta e^{-\beta t_1}}{t_1}\right]\end{array}\right\} \quad (20)$$

$$\frac{d^2\,E\left[TCU(t_1)\right]}{dt_1^{\,2}}=\frac{\lambda}{\left[1-E(x)\right]}\cdot \left\{\begin{array}{l}\dfrac{2K}{Pt_1^3}+hgE(x)\left(-\beta^2 e^{-\beta t_1}\right) \\ +\left[\dfrac{M}{P}+\dfrac{hg}{\beta}\right]\cdot\left[\dfrac{2\left(1-e^{-\beta t_1}\right)}{t_1^3}-\dfrac{2\beta e^{-\beta t_1}}{t_1^2}-\dfrac{\beta^2 e^{-\beta t_1}}{t_1}\right]\end{array}\right\} \quad (21)$$

From Eq. (21), because the first part of the second derivative of E[$TCU(t_1)$] is greater than zero, it implies:

$$\text{if } \left\{2K+2\left(M+\frac{Phg}{\beta}\right)\cdot\left(1-e^{-\beta t_1}\right)\right\}> \left(\beta e^{-\beta t_1}\right)\cdot t_1\cdot\left\{Pt_1^2 hgE(x)\beta+\left(M+\frac{Phg}{\beta}\right)\cdot(2+\beta t_1)\right\} \quad (22)$$

Because $\left(\beta e^{-\beta t_1}\right)\cdot\left\{Pt_1^2 hgE(x)\beta+\left(M+\frac{Phg}{\beta}\right)\cdot(2+\beta t_1)\right\}>0$ and recall that $v=M\beta+hgP$; so

$$\frac{\left[2K\beta+2v\cdot\left(1-e^{-\beta t_1}\right)\right]}{\left[Pt_1^2 hgE(x)\beta^2+v\cdot(2+\beta t_1)\right]\left(\beta e^{-\beta t_1}\right)}> t_1 \quad (23)$$

Therefore

$$\frac{d^2\,E\left[TCU(t_1)\right]}{dt_1^{\,2}}>0$$

$$\text{if } 0<t_1<\frac{2\left[K\beta+v\cdot\left(1-e^{-\beta t_1}\right)\right]}{\left[Pt_1^2 hgE(x)\beta^2+v(2+\beta t_1)\right]\left(\beta e^{-\beta t_1}\right)}=w(t_1) \quad (24)$$

Hence, the proof of Theorem 1 is completed.

In order to minimize the expected cost E[$TCU(t_1)$], Eq. (24) must be satisfied. To search for the optimal value of t_1* that yields minimum cost, one can set the first derivative of E[$TCU(t_1)$] equal to 0. That gives

$$\frac{d\,E\left[TCU(t_1)\right]}{dt_1}=\frac{hP\left[1-2E[x]+E[x^2]\right]-h\lambda+2\lambda hE[x]}{2\left[1-E(x)\right]} + \frac{\lambda}{\left[1-E(x)\right]}\left\{\begin{array}{l}\dfrac{-K}{Pt_1^2}+hgE(x)\left(\beta e^{-\beta t_1}\right) \\ +\left[\dfrac{M}{P}+\dfrac{hg}{\beta}\right]\left[\dfrac{-\left(1-e^{-\beta t_1}\right)}{t_1^2}+\dfrac{\beta e^{-\beta t_1}}{t_1}\right]\end{array}\right\}=0 \quad (25)$$

$$\because \frac{1}{\left[1-E(x)\right]}>0$$

$$\therefore \left\{\begin{array}{l}\dfrac{hP\left[1-2E[x]+E[x^2]\right]-h\lambda+2\lambda hE[x]}{2} \\ +\lambda\left\{\begin{array}{l}\dfrac{-K}{Pt_1^2}+hgE(x)\left(\beta e^{-\beta t_1}\right) \\ +\left[\dfrac{M}{P}+\dfrac{hg}{\beta}\right]\left[\dfrac{-\left(1-e^{-\beta t_1}\right)}{t_1^2}+\dfrac{\beta e^{-\beta t_1}}{t_1}\right]\end{array}\right\}\end{array}\right\}=0 \quad (26)$$

Let $\varphi=hP\left[1-2E[x]+E[x^2]\right]-h\lambda+2\lambda hE[x]$, so Eq. (26) becomes

$$\frac{\varphi}{2}+\lambda\left\{\begin{array}{l}\dfrac{-K}{Pt_1^2}+hgE(x)\left(\beta e^{-\beta t_1}\right) \\ +\left[\dfrac{M}{P}+\dfrac{hg}{\beta}\right]\left[\dfrac{-\left(1-e^{-\beta t_1}\right)}{t_1^2}+\dfrac{\beta e^{-\beta t_1}}{t_1}\right]\end{array}\right\}=0 \quad (27)$$

For the purpose of finding the optimal production run time t_1*, let t_{1L}* and t_{1U}* denote the bounds of optimal run time t_1*:

$$t_{1U}^*=\sqrt{\frac{2\lambda(v+K\beta)}{\varphi P\beta}} \quad (28)$$

$$t_{1L}^*=\text{the positive root of}\left\{\frac{-v\pm\sqrt{v^2+2\left[\varphi P\lambda^{-1}+2hgE(x)P\beta\right]K}}{\varphi P\lambda^{-1}+2hgE(x)P\beta}\right\} \quad (29)$$

Theorem 2: $t_{1L}^*<t_1^*<t_{1U}^*$

Recall Eq. (27), in order to have the first derivatives of E[$TCU(t_1)$]=0, one must have:

$$\left\{\varphi\left(Pt_1^2\beta\right)+2\lambda\left\{\begin{array}{l}-K\beta+hgE(x)\left(Pt_1^2\beta^2 e^{-\beta t_1}\right) \\ +\left[M\beta+hgP\right]\left[-1+e^{-\beta t_1}+t_1\beta e^{-\beta t_1}\right]\end{array}\right\}\right\}=0 \quad (30)$$

Substituting $v=M\beta+hgP$ in Eq. (30), one has

$$(\varphi P\beta)t_1^2+2\lambda\left(e^{-\beta t_1}\right)\cdot \left\{\left[hgE(x)P\beta^2\right]t_1^2+(\beta v)t_1+v\right\}-2\lambda(K\beta+v)=0 \quad (31)$$

or

$$\left[\frac{1}{2}\left(\varphi P\lambda^{-1}\right)+\left(e^{-\beta t_1}\right)\left[hgE(x)P\beta\right]\right]t_1^2 +\left[\left(e^{-\beta t_1}\right)v\right]t_1+\left[v\beta^{-1}\left(e^{-\beta t_1}-1\right)-K\right]=0 \quad (32)$$

then

$$t_1^*=\text{the positive root of}\left\{\frac{-\left(e^{-\beta t_1}\right)v\pm\sqrt{\left(e^{-\beta t_1}\right)^2v^2-2\left[\left(\varphi P\lambda^{-1}\right)+2\left(e^{-\beta t_1}\right)\left[hgE(x)P\beta\right]\right]\cdot\left[v\beta^{-1}\left(e^{-\beta t_1}-1\right)-K\right]}}{\left(\varphi P\lambda^{-1}\right)+2\left(e^{-\beta t_1}\right)\left[hgE(x)P\beta\right]}\right\} \quad (33)$$

Also, Eq. (31) can be rearranged as follows.

$$2\lambda\left(e^{-\beta t_1}\right)\left\{\left[hgE(x)P\beta^2\right]t_1^2+(\beta v)t_1+v\right\}=2\lambda(K\beta+v)-(\varphi P\beta)t_1^2 \quad (34)$$

$$\therefore\ \left(e^{-\beta t_1}\right)=\frac{2\lambda(K\beta+v)-(\varphi P\beta)t_1^2}{2\lambda\left\{\left[hgE(x)P\beta^2\right]t_1^2+(\beta v)t_1+v\right\}} \quad (35)$$

Since $e^{-\beta t_1}$ is the complement of the cumulative density function $F(t_1)=1-e^{-\beta t_1}$ and $0\le F(t_1)\le 1$, $0\le e^{-\beta t_1}\le 1$. Let δ_L and δ_U denote the bounds for $e^{-\beta t_1}$ then from Eqs. (31) and (33) one obtains:

$$t_{1U}^*=\text{the positive root of}\left\{\frac{-(\delta_L)\cdot v\pm\sqrt{(\delta_L)^2\cdot v^2-2\left[\left(\varphi P\lambda^{-1}\right)+2(\delta_L)\left[hgE(x)P\beta\right]\right]\left[v\beta^{-1}\left((\delta_L)-1\right)-K\right]}}{\left(\varphi P\lambda^{-1}\right)+2(\delta_L)\left[hgE(x)P\beta\right]}\right\} \quad (36)$$

t_{1L}^* = the positive root of

$$\left\{\frac{-(\delta_U)\cdot v \pm \sqrt{(\delta_U)^2\cdot v^2 - 2\left[\left(\varphi P\lambda^{-1}\right)+2(\delta_U)\left[hgE(x)P\beta\right]\right]\left[v\beta^{-1}\left((\delta_U)-1\right)-K\right]}}{\left(\varphi P\lambda^{-1}\right)+2(\delta_U)\left[hgE(x)P\beta\right]}\right\} \quad (37)$$

and $t_{1L}^* < t_1^* < t_{1U}^*$.

Further, because $0 \le e^{-\beta t_1} \le 1$ and if we let δ_L=0 and δ_U=1, then Eqs. (36) and (37) become Eqs. (28) and (29).

Hence, the proof of Theorem 2 is completed. □

Upon accomplishment of finding bounds for the economic production run time t_1*, this study proposes a recursive searching algorithm based on limits of $e^{-\beta t_1}$ (see Appendix) to locate t_1*. Although the economic production run time t_1* cannot be expressed in a closed form, the proposed algorithm successfully pinpoints the optimal value of t_1* that minimizes the long-run average production-inventory cost for such an EPQ model.

4. NUMERICAL EXAMPLE

Suppose a manufactured item has a flat demand rate of 4,000 units per year and this item can be produced at an annual rate of 10,000 units. The production system has experienced a random defective rate x which follows the Uniform distribution over the interval [0, 0.1]. All defective items are considered scrap and will be discarded in the end of production uptime.

Furthermore, the production equipment (machine) is subject to a stochastic breakdown that follows a Poisson distribution with mean β=0.5 times per year and an Abort/resume (AR) policy is used when a random breakdown takes place. To prevent shortage situation from occurring, there is a safety stock policy in place to cope with the possibility of machine breakdown happens in very earlier stage of the production. Additional parameters used in this example include

h = \$0.6 per item per unit time,
K = \$450 for each production run,
C = \$2 per item,
C_S = \$0.3 disposal cost for each scrap item,
M = \$500 repair cost for each breakdown.
g = 0.018 years, a constant time needed to repair and restore the machine,

For convexity of E[$TCU(t_1)$] (i.e. Theorem 1 or Eq. (24)), using both upper and lower bounds of t_1* in Eqs. (28) and (29) one finds out that Theorem 1 holds. That is: t_{1U}*=0.535<$w(t_{1U}$*)=1.989 and (2) t_{1L}*=0.291<$w(t_{1L}$*)=1.647. Applying Eqs. (28) and (18), one obtains t_{1U}*=0.535 (years) and E[$TCU(t_{1U}$*)]=\$9,844; and through the computations of Eqs. (29) and (18), one has t_{1L}*=0.291 (years) and E[$TCU(t_{1L}$*)]=\$ 9,730.

Because the expected cost function $E[TCU(t_1)]$ is convex and the economic production run time t_1* falls within the interval of [t_{1L}*, t_{1U}*] (based on Theorems 1 & 2), then by using the proposed recursive searching algorithm (presented in Appendix) one can find the optimal run time t_1*. As a result, one notes that in this example (β=0.5) the optimal run time t_1*=0.336 years and the optimal expected costs per unit time E[$TCU(t_1$*)]=\$9,719. The behavior of E[$TCU(t_1)$] with respect to production run time t_1 is depicted in Figure 2.

Further analysis shows that when β approaches to 0 (i.e. 1/β approaches to ∞, meaning the chance of breakdown is equal to zero), the economic production run time t_1*=0.332 years and the expected cost E[$TCU(t_1$*=0.332)]=\$ 9,625.

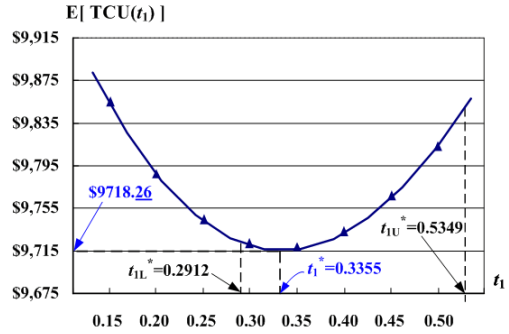


Fig. 2 Behavior of E[$TCU(t_1)$] with respect to production run time t_1

5. CONCLUSIONS

For practitioners who are in the production management field and are interested in applying the aforementioned research results, two conditions must be satisfied. First, we must have $(P\text{-}d\text{-}\lambda)>0$ to prevent stock-out situation from occurring. That is the production rate of perfect quality items must always be greater than the sum of demand rate and production rate of defective items - a basic assumption of the proposed model. The second condition: $0<t_1<z(t_1)$ must be satisfied (see Theorem 1) to assure that the long-run expected cost function $E[TCU(t_1)]$ is convex. Hence, the minimum cost exists. One notes that the proposed solution procedure for searching the economic production run time is valid only if the above-mentioned conditions are satisfied.

Probabilistic machine failures and random defective rate are common and inevitable reliability factors that trouble production managers and practitioners most. When breakdowns taking place unexpectedly, abort/resume policy is a practical and commonly used inventory control policy to deal with such a disruption of production situation. This paper studies the joint effect of random defective rate and stochastic breakdown (under AR policy) on the economic production run time decision for such a specific EPQ model. Upon accomplishment of this study, a complete solution procedure has been established (which includes mathematical modeling and analyses, proofs of theorems, a recursive searching algorithm, and a numerical example) to show that the economic replenishment run time for the proposed EPQ model is derivable. For future study, examining the effect of backlogging on the optimal run time for the same model will be an interesting topic.

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APPENDIX

A proposed recursive searching algorithm for finding t_1*.

As stated in section 3, although the economic production run time t_1* cannot be expressed in a closed form, it can be located through the use of the following searching algorithm based on the existence of bounds for $e^{-\beta t_1}$ and t_1*. Recall Eq. (35)

$$\therefore \left(e^{-\beta t_1}\right) = \frac{2\lambda(K\beta+v)-(\varphi P\beta)t_1^2}{2\lambda\left\{\left[hgE(x)P\beta^2\right]t_1^2+(\beta v)t_1+v\right\}} \quad (35)$$

Because $e^{-\beta t_1}$ is the complement of cumulative density function, hence $0 \le e^{-\beta t_1} \le 1$.

Let $\alpha(t_1) = \dfrac{2\lambda(K\beta + v) - (\varphi P\beta)t_1^2}{2\lambda\left\{\left[hgE(x)P\beta^2\right]t_1^2 + (\beta v)t_1 + v\right\}} \quad \therefore\ 0 \le \alpha(t_1) \le 1$

This study presents the following recursive searching algorithm for locating the economic production run time t_1^*:

(1) Let $\alpha(t_1)$=0 and $\alpha(t_1)$=1 initially and compute the upper and lower bounds for t_1^*, respectively (i.e. to find the initial values of [t_{1L}^*, t_{1U}^*]).

(2) Substitute the current values of [t_{1L}^*, t_{1U}^*] in $e^{-\beta t_1}$ and calculate the new bounds (denoted as δ_L and δ_U) for $e^{-\beta t_1}$. Hence, $\delta_L < \alpha(t_1) < \delta_U$.

(3) Let $\alpha(t_1) = \delta_L$ and $\alpha(t_1) = \delta_U$ and compute the new upper and lower bounds for t_1^*, respectively (i.e. to update the current values of [t_{1L}^*, t_{1U}^*]).

(4) Repeat steps 2 and 3, until there is no significant difference between t_{1L}^* and t_{1U}^* (or there is no significant difference in terms of their effects on E[$TCU(t_1^*)$]).

(5) Stop. The optimal production run time t_1^* is obtained.

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The Use of RFID Technology in Intermodal Transport

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ABSTRACT

Intermodal transport is one of the most revolutionary and important phenomena in the 21st century regarding transport. This type of transport represents freight transport ″from door to door″ using at least two branches of transport without the change of freight unit. Recently in intermodal transport there is a greater use of radio-frequency identification – RFID technology that enables electronic monitoring of intermodal freight during the entire transport time, loading trucks or wagons with freight, loading ships with the same freight to the port of unloading and transport continuation to the destination. The results of its use for private companies are reflected on monitoring the flow of freight and the higher market delivery speed, higher productivity and efficiency (which inevitably causes production process improvement), while for the countries it is important to improve national security, reduce traffic congestion etc. With regard to given facts, this paper shows the importance of RFID technology for the development of intermodal transport and it answers some of the crucial questions regarding its application.

Key words: Intermodal transport, trucks, wagons, liners, radio-frequency identification, freight unit, fare reduction.

1. INTRODUCTION

Greater amount of goods that is transported daily in intermodal transport has doubled in the last few years. Two million containers are transported by sea daily, as key intermodal manipulative units, which proceed to the destination by the following means of transport: river, maritime, land and air transport. In the midst of the development, higher safety and capacity standards are being set as a challenge. It is noticeable that present ports, railway stations, truck terminals, concerning carrying capacity, or different means of transport, have reached their maximum or are going to reach it, so the main answer to the flow of goods acceleration lays in jo b optimization during freight manipulation. Although RFID technology is an ideal solution for every type of intermodal transport, today, in the 21st century, a traditional way of transport is still being used for transport supervision, which results in the fact that very often neither the sender nor the receiver knows where the shipment is at a certain time. This fact opens up the doors to many negative consequences – theft, smuggling, various forms of criminal activity. A logic question emerges – why does it represent a problem for world companies, in the century of progressive development, to introduce RFID technology in the business activities of a shipping company? There are numerous positive effects of RFID technology and only one negative, and there is a solution even to that problem. Namely, RFID presents a financial challenge in the beginning; it is very expensive, but it is also cost-effective over the long term, without the loss of goods and with no criminal activity. The purpose of this paper is to become familiar with basic elements and ways to apply RFID technology, as well as with problems that arise in intermodal freight unit transport. The paper consists of five parts. It describes the basic elements of intermodal transport system, intermodal unit development system and intermodal freight unit. Furthermore, it presents the overview of RFID technology together with the work frequency and the possibilities of applying the EPC (Electronic Product Code), possibilities of RFID implementation with sensors and basic implementation costs. It analyzes the influence of RFID on the automatization of the trans-shipment process in the port and, in the end, it gives an example of a company that tested RFID technology in real working conditions in intermodal transport.

2. BASIC ELEMENTS OF INTERMODAL TRANSPORT SYSTEM OVERVIEW

Intermodal transport is a complex system of the transport chain with the freight unit in its center that consists of smaller units connected in an entirety of certain dimensions that do not change during the transportation. Intermodal transport unit represents a container, a changeable truck chest and a semi-trailer. Its use enables transportation cost reduction, freight homogeneity and massiveness. In Figure 1 the flow of goods in intermodal transport is demonstrated.

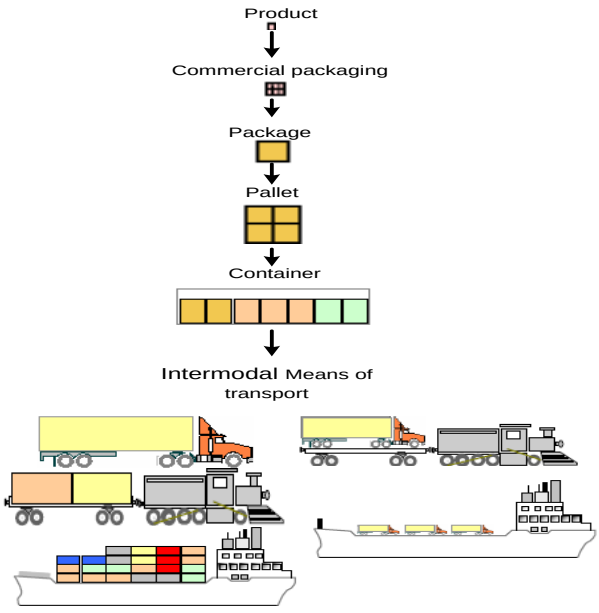


Figure 1: Flow of goods in intermodal transport

In Figure 2 the flow of the product in the development of the intermodal transport unit is presented.

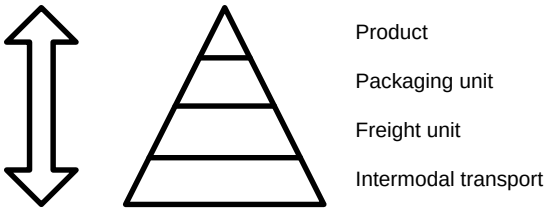


Figure 2: Intermodal unit development system

The most common means of transport in intermodal transport is surely the container ship, because ¾ of world trade is carried by sea. With the development of technology, container ship capacity grows as well, which is shown in the Table 1.

Table 1: Container ship characteristics through history

Generation	Year	Capacity (TEU)
I	1960 – 1970	750 – 1000
II	1970 – 1980	1000 – 1500
III	1980 – 1990	1500 – 3000
IV	1990 – 1995	3000 – 5000
V	1995 – 2000	5000 – 7000
VI	2000 – 2002	7000
VII	2002 – 2004	7000 – 8000
VIII	2004 – 2006	8000 – 10000
IX	2006 – 2008	10000 – 12000
X	2008 – 2009	12000 – 1400
XI	2009 -	15000-

3. RFID TECHNOLOGY

3.1. RFID technology overview

Radio-frequency identification is a method of automatic identification that enables storing and remotely retrieving data via radio waves using RFID transponders and readers. RFID transponder is a computer chip that enables the transportation of an identification number and each one is equipped with an antenna. Passive RFID transponder does not have its own power-supply, but receives energy from radio-frequency reader emission (smaller signal range, smaller resistance etc.). Semi-passive transponder has a battery that feeds the chip, but uses the reader energy for communication. Active transponder has its own battery; bigger resistance, bigger range (up to 100m), wider applicability. RFID reader also has an antenna that enables it to communicate (reading and writing data) with transponders in range. RFID-middleware represents a program interface that receives the data from the reader and then filters them by previously determined rules, sending them, if necessary, to the belonging information system (a company's database). Figure 3 demonstrates the mentioned structure.

The reading and data transfer speed is connected to the frequency. The higher the frequency is, the quicker the transfer. RFID frequencies together with application fields are presented in Table 2.

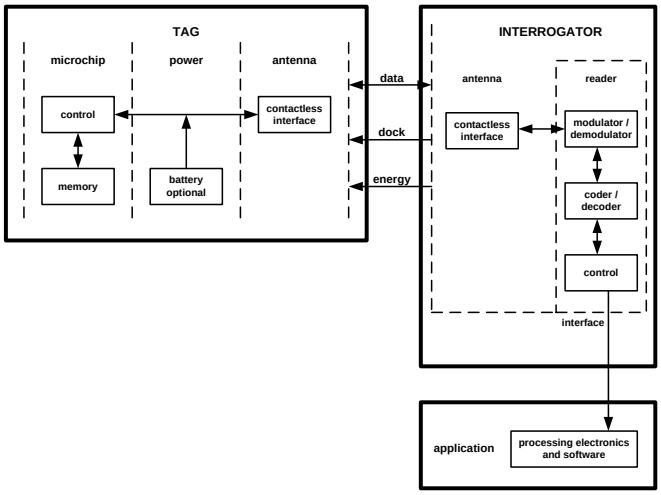


Figure 3: RFID system overview

Table 2: RFID frequencies

frequency band	system characteristics	example applications
Low (LF) 100–500 KHz (typically 125–134 KHz worldwide)	Short read range (to 18 inches) Low reading speed Relatively inexpensive Can read through liquids Works well near metal	Access control Animal identification Beer keg tracking Inventory control Automobile key/anti-theft systems
High (HF) (typically 13.56 MHz)	13.56 MHz frequency accepted worldwide Short to medium read range (3–10 feet) Medium reading speed Can read through liquids/works well in moist environment Does not work well near metal Moderate expense	Access control Smart cards Electronic article surveillance Library book tracking Pallet/container tracking Airline baggage tracking Apparel/laundry item tracking
Ultra High (UHF) 400–1,000 MHz (typically 850–950 MHz)	Long read range (10–30 feet) High reading speed Reduced likelihood of signal collision Difficulty reading through liquids Does not work well in moist environments Experiences interference from metals Relatively expensive	Item management Supply chain management
Microwave 2.4–6.0 GHz (typically 2.45 or 5.8 GHz)	Medium read range (10+ feet) Similar characteristics to UHF tags, but with faster read rates	Railroad car monitoring Toll collection systems

3.2. RFID technology in intermodal transport

Intermodal transport unit holds a unique identification number. Manually written numbers as well as their control during the transport are subject to errors. With the introduction of RFID technology, container identification number, as the main freight unit in intermodal transport, is stored on an RFID tag not leaving any room for error. The tag holds a unique identification numbers named Electronic Product Codes (EPC) - the code that resides on an RFID tag that is unique to each product. The code contains manufacturer and product information as well as an individualized serial number which is shown in figure 4. EPCs are maintained by EPC global.



Figure 4: EPC code example

When implementing RFID technology in each segment of intermodal transport, all manipulative devices have to be equipped with RFID readers, thus enabling automatic container identification as well as all manipulative activities performed with it. RFID readers can be placed on cranes, vehicles etc.

With the implementation of active transponders with sensors and GPS, instant supervision of key information in container transport is enabled. Sensors analyze given data boundaries and the change that is not within given boundaries can be automatically sent to authorized organization. Some of the basics magnitudes whose value is measured when implementing sensors in RFID technology are:

- Position – using the GPS system it is possible to determine the momentary position of the containers;
- Temperature – if measured, it can be discovered whether the container was opened, the presence of fire, electronic devices, person;
- Chemicals – the presence of poison, explosives and radioactive material is tested;
- Air pressure – in the case the container is hermetically closed, its damaged condition or opening are automatically discovered;
- Sound – whose measuring can reveal whether the device is used inside and is a person talking inside;
- Movement – if something is moving in the container etc.

3.3. Basic costs of RFID technology implementation

As it has already been mentioned, it is possible to implement more types of sensors in the container, i.e. intermodal unit; however, this raises the question of profitability. It is a fact that in transport of goods, there is no economic excuse for using more types of sensors. It is applicable only in transport of goods of extremely high value, transport of military equipment etc. The basic costs of RFID technology implementation is shown in Table 3. Components provided are divided into:

- passive tags,
- active tags,
- UHF readers, and
- Middleware.

Actual cost and what is cost dependency about is shown, respectively.

Table 3: Price of basic parts of RFID technology

Component	Actual cost	Cost depends on
Passive tags	20-40 cents (in more advanced versions, it can be up to several USD)	Antenna Frequency Memory size Packaging
Active tags	10-50 USD	Battery Chip Packaging
UHF readers	500-3,000 USD	Intelligence and frequency of the readers
Middleware	Depends on applied field	Depends on applied field

3.4. RFID technology architecture intermodal transport

In Figure 5, RFID technology architecture in intermodal transport in combination with GPS and sensors is shown. With a suitable way of implementing RFID technology in intermodal transport, an intermodal transport company is enabled to monitor the product in the entire transport chain, from its packaging in intermodal unit to its arrival to the destination. If damage, breaking in the container or any opening happens, data base will automatically be uploaded and each dysfunction that occurs will be pointed out. Except for the investment problems at the beginning, there is also the problem of piling data that constantly upload the server (data base), however this is solved by an advanced version of middleware which filtrate gathered data.

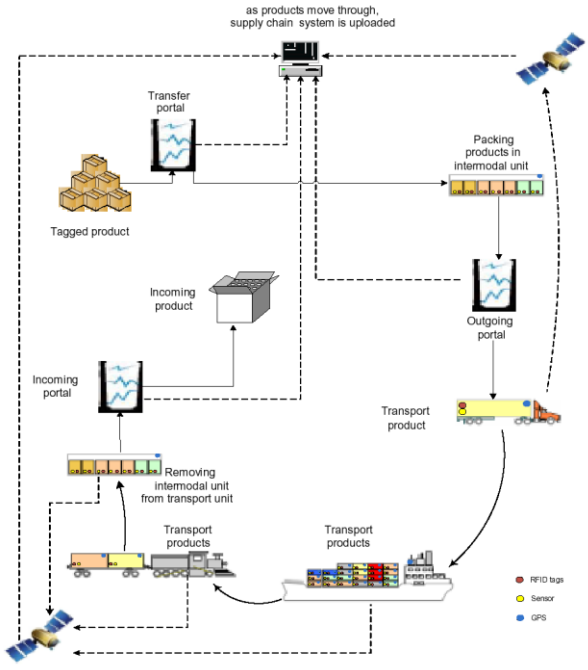


Figure 5: Architectural proposition of implemented RFID technology in intermodal transport

3.5. RFID influence on automatization of transport process in intermodal nodes

It is a fact that the longest possible freight hold-up or loss of time happens during loading/unloading of the ship or land vehicles (wagons or trucks), i.e. intermodal node (place where two branches of transport are intertwined or certain freight manipulative actions take place). In Figure 6. an intermodal node is shown.

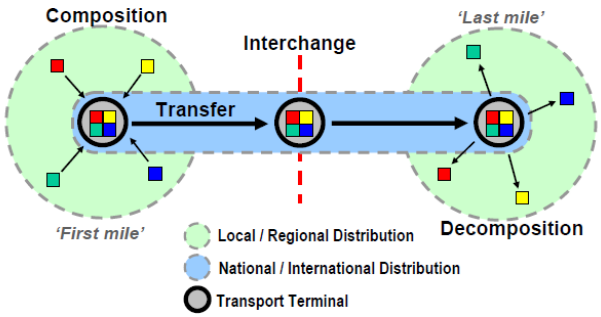


Figure 6: Intermodal node

Using RFID technology, we have the possibility to monitor the freight in ports or goods and port terminals and consequently the possibility to influence the delivery. Monitoring the flow of freight is significant in order to optimize port transport process for instance and, consequently, to ensure market supply in due time, i.e. planning the course of production process in production companies (e.g. car industry, shipyards etc.), especially organizations that deal with transport (different transporters). Introducing RFID technology to the mentioned freight processes, we have the possibility to directly influence trans-shipment time reduction in intermodal node with the following consequences: reduced cost, higher efficiency, bigger profit etc.

One of the most interesting intermodal nodes is surely the seaport. RFID technology enables the reduction of total amount of time of port occupancy. Total amount of time of port moorings occupancy can be demonstrated with the following equation:

$$T_{uvzv} = T_{var} + T_{vib} + T_{vpob} + T_{vni} \quad [\text{hours}] \qquad (1.)$$

where:

T_{uvzv} – total amount of time of moorings occupancy;
T_{var} – administrative action time upon ship´s arrival to the berth;
T_{vib} – time needed to unload the ship;
T_{vpob} – time needed to prepare the ship to leave the berth;
T_{vni} – time when there is no unloading.

In the previously mentioned relation, the use of RFID technology can directly influence the T_{vib} variable accelerating the time needed to unload the ship because of the automatic identification of the intermodal unit.

4. TESTING RFID IN ACTUAL WORKING CONDITIONS

One of the first world companies to introduce and test RFID technology in intermodal transport was the shipping company Horizon Lines in September 2006. The integration of RFID together with WEB management system enabled an incomparable visibility of the containers from the loading time until they reached the final destination. The test was performed during transport under extreme conditions in the area of Alaska on 40 degrees Celsius below zero. This experiment eliminated the fear that a certain company upon introducing this technology would become and has proven the functionality and cost effectiveness of RFID technology. With regard to the positive test results, in January 2007, the company introduced an active RFID solution, enabling their clients to monitor the freight movement in any transport phase. Precisely because of the investment in the research and development in intermodal transport and because of constant efforts to improve the technology, Horizon Lines, Inc. have successfully managed to reduce total costs when processing the transport data and have also become extremely popular and appreciated in their area of expertise. On March 7, 2008 they were selected in top 100 logistic IT providers.

"What we did was an ocean-container shipping industry first," said Ken Privratsky, vice president and general manager of Horizon Lines. "We've set a precedent, on a national and international level, for providing greater visibility of deliveries and more efficiency in supply-chain operations. Using RFID technology, we are enabling our clients to better utilize the assets that they have."

5. CONCLUSION

Dealing with the mentioned thematic, the following advantages of RFID system in intermodal transport have been noted:

- each intermodal manipulative unit has its own unique identification number;
- it enables to read and write data from a distance up to several meters;
- it is possible to simultaneously read more identification number tags;
- it is possible to encrypt data on a transponder;
- automatic use of RFID enables the acceleration of manipulative processes and the reduction of human action;
- transponder is resistant to light reflection and it is not disturbed by the complete lack of light;
- there are no negative environment consequences (detergents, water, paint, ice etc.) that put obstacles in the way of radio-wave communication;
- national security is improved;
- possibility of timely theft or freight damage detection;
- possibility of on-line monitoring of the momentary freight position etc.

Based on these facts, it is obvious that the benefits of using RFID technology in intermodal transport are numerous, in the private as well as the public sector because of the possibility to monitor the flow of freight (goods) to better organize the

working process in the ports, transport of goods and the technological production process. Introducing RFID technology in intermodal transport, the initial investment would be significantly high, but all the participants in the chain of transport would profit in the long term.

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Performance of Service Delivery in Mental Health Care Systems: a case of Third Cybernetics Evolution in the NHS, England.

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ABSTRACT

A welfare state has a responsibility, by virtue of its 'social contract' with its citizens to provide health and social services to the citizenry. The state delegates that responsibility to a number of actors, each of which has its own strategy-as-practice as one among many. To ensure coherence, it is important to manage their performance collectively, including inputs from the patients groups.

This process of management turns out to be difficult, especially that of the mental healthcare services because of lack of communication among the actors. The author will be looking at a possible solution to this problem based on the assumption that it is possible to change the way the actors act by bringing them together to share their purposes and common actions through the notion of dialogism as way of maintaining plurality of logics: different voices (polyphonic), styles (stylistic), space-time conception (chronotopic), interanimating discourse (architectonics) and the dynamic interplay of different dialogues (polypi). It is this process of plurality of logic that the researcher termed, the Third Cybernetics Evolution as a way of sequential processes from the First Cybernetics through the Second Cybernetics to the Third Cybernetics. It is argued that implementing these, allows for improved communication among actors, as a way of achieving high quality service delivery via increase in their interactions.

Keywords: Third Cybernetics Evolution, Mental Healthcare System, NHS, Storytelling, Communication, and Dialogism.

INTRODUCTION

The state through its agent, the NHS, is responsible for ensuring that the health needs of the citizenry are adequately met. The government therefore provides the resources in terms of equipment; facilities and personnel needed to deliver the service to the patients. The government in the process of resourcing the NHS sets targets through the Department of Health for health and social service providers. But for the healthcare system to be effective in meeting the local needs and expectations, it has to involve the inputs of the clients and patients. According to some clients interviewed in Lincolnshire, the system is not performing because some of their colleagues had to go back to the hospital after their medical treatment because the system has no adequate provision for social integration and social needs of the patients. It is argued that where such provisions exist, the government decide what is needed and the criteria for measuring the performance without considering local needs of the citizens which may be different from one locality to another. The clients (patients) claimed that where the system seems to give attention to their needs, the government thinks the system is not performing because it is not meeting the targets set and hence closes down such hospitals or departments in the hospitals even when the citizens protest.

It is being argued that mainstream mental health care research tend to be clinically dominated, reflecting the linear and hierarchical approaches of medical professionals who based their analysis on quantitative and experimental testing with less attention to qualitative research approach. One of the focuses of the paper therefore is to give attention to qualitative research in mental health services by giving audience to service users, carers, the family and the community through the Actors-Dialogism-System.

Mental health problems account for significant proportions of diseases in UK. However, access to treatment though available is not being fully utilised because of a number of issues in which reorganisation of the service is urgently needed. The issues of mental healthcare have become important because of its significant burden on the government and the community. Mental healthcare is argued accounts for nearly 12% of the global burden of disease and will hit the target of 15% of disability adjusted life years lost to illness by 2020 (WHO, 2003) [25].

The economic and social costs to the state and the community have increased with the development of science and medicine. Before the 17th century, issues of mental disorders were attributed to spiritual explanation and this consequently informed its treatment. However, with the development in science and medicine, secular explanations were given to the mental disorder as a physical state of the mind leading to the confinement of such people in secured places.

During the first part of the 18th century however, the dominant view of mental disorders being incurable and the justification of being sub-humans and so their status, living conditions and physical restraints to places of confinement changed. The pressure from society and humanitarian groups about the

human rights of people with mental disorders led to a call for reforms in the treatment of mental patients and as a result the introduction of moral treatment programmes. This led to deinstitutionalisation or de-hospitalisation of the service delivery aimed at creating the opportunity to implement some of the ideas developed on social network (social capital) and community support system as alternatives outside psychiatric institutions. However, the way mental healthcare service delivery is organised determines the effectiveness of the interventions and the ultimate fulfilment of the objective of the service. The quality of the service determines whether the service increases the likelihood of one achieving the desired outcome of becoming employable, independent, self organised and part of the community. The quality of the service delivery is important because it ensures that service users receive the care and support they require; it also ensures that there is improvement in their daily life activities and living; it provides acceptable and relevant clinical and non clinical care to reduce the impact of mental health problems; and to make efficient and effective use of resources available to them (Murray and Lopez, 1996) [21].

In the UK, the government's policy on community care services was strongly developed with the Third Sector in mind. This is evidenced in the Community Care Act (Department of Health, 1990) [12] which embraces the full involvement of the Third Sector in mental healthcare services in particular. Despite this policy, however, communication and therefore the collaboration between the statutory and the voluntary organisations to improve the quality of the service is weak (Simpson, 1996) [22] and problematic, (Adams, 1990) [1]. The weakness of this collaboration has been attributed to lack of understanding of each other's objectives, missions or vision and organisational practices, methods and significantly, differences in respect of their structures, resources and their value systems (Wilson, 1994)[24]. There is also an issue of confidence and trust by the professionals of the formal sector about the capabilities of semi skilled personnel of the Third Sector. Gratham (1995) [15] surveyed 55 general practitioners in his area and found that only 18 per cent had made some referral to the Alzheimer's disease Society. Some professional even see any sharing of skills, knowledge and experiences with the non-professional as a threat to their profession (Gussow and Tracy, 1976) [17]. The paper aims at proposing a method of resolving the problem of communication and for that reason collaboration through participatory communication of all actors. We will now look at the methodology used in this research to identify the problem of limited communication among actors of the system.

METHODOLOGY AND DESIGN

The study is intended to expand on the understanding of how to improve performance or improve the quality service through the interaction of the stakeholders in health service delivery, particularly in mental healthcare delivery system. The mental healthcare service is looked at as a system with boundary and sub-systems. The sub-systems being the actors within the delivery service system with each sub-system representing a system in its own domain. The activities engaged by the actors beyond the boundary of the mental healthcare system represent the environment. A phenomenological method is used in this research because it is one of the methods which help to identify phenomena through the perspectives of the actors in the situation. In human interactive situations like the mental healthcare service delivery, the method enables the researcher to gather in depth information and perceptions through qualitative methods of interviewing and focus group discussions.

Phenomenology could be looked at as a philosophy, but also as a research method for gathering and analysing data (Goulding, 1999) [14]. As a method, phenomenology allows for the discovering of people's 'world views' thus capturing their subjective experiences. Using the phenomenological methods of interviews and focus groups' discussions, the experiences of the participants were organised by means of storytelling and interwoven with living story method. The living story theory which is the bedrock of living story method was used. The living story theory is defined as the emergence, trajectory, and morphing of living story from ante-narrative-conception to the end of decomposition of a story (Boje, 2007b; Boje, 2008) [10, 11]. A living story is a story which lies in-between dead and alive narratives and between forgotten and revitalised story. It is hence a critical ante-narrative where a living story method traces and pre-deconstructs an ongoing interweaving living story narrative and ante-narrative to become self-deconstruct. In the process of deconstructing stories some stories die and others rejuvenate or emerge and better still some revolve. The living story method is hence interplay of dead (ended) narratives with living emergent stories. It tells the emergent stories in the context of fragmented dead narratives.

In all eighteen (18) managers from the Lincolnshire Partnership Foundation Trust (LPFT), Lincoln County Council (LCC) and various voluntary organisations in Lincolnshire that have contractual agreement with the Trust were interviewed, also two focus group discussions were conducted and secondary data from the BBC news and newspapers were analysed.

The data collected were transcribed and analysed by reading and analysing the data in depth to search for differences and patterns in relation to the research questions of the study. Each interview was used to probe into issues from the previous interviews which were not clear in order to create a 'rich picture' of the research problem (lack of adequate communication among the actors). This was to-and-from process, with interpretations being continuously revised and the context broadened using the notion of 'Ideal interpreter'.

Interpretivism is assumed to be mental content judgement-dependent; that is the facts about propositional attitude of people is exactly what is being captured by the judgement of the Ideal Interpreter (Johnston, 1993a) [18]. However, for Dennett and Davidson (sited in Wright, 1989) [26], the Ideal Interpreter is a third-person who interpreters someone else. The interpreter can also be a first- personal account where the interpreter is taken to be the subject of interpretation. Dennett's and Davidson's version of interpreter is however, formulated on the thesis of bi-conditional: that X belief Q, therefore if there is an informed Ideal Interpreter, the Ideal Interpreter would be disposed to attribute to X the belief that is Q. There is however, a problem with this line of argument of interpretivism. There is no a priori guarantee that the Ideal Interpreter will find answers to all the meaning of the subjects' beliefs particularly those that are linguistically expressed. It is therefore necessary that some sufficient conditions are held as a constraint to strengthen this identified weakness of interpretivism, that is there is an appropriate informed Ideal Interpreter who would be disposed to attribute X the belief that Q. Interpretivism presupposes therefore that facts or believes given by the Ideal Interpreter will be the facts participants believe in an ideal situation. For this reason, it indicates reasons specifically to the participants' meaning of their experiences as per the research as opposed to general considerations about judgement-dependent accounts.

For the purposes of this research, the Ideal Interpreter is assumed to have a sufficient database of non-intentional and intentional sources of information, knowledge and experience to interpret the subjects' meanings, believes, experiences and desires. The Ideal Interpreter uses daily life application of intentions in addition to scientific minded observations and experiences of non-intentional in order to arrive at the best possible meanings of the participants experiences and believes in order to resolve the problem of limited communication .It is argued that interaction among the actors through participatory communication will help to achieve the ultimate level of collaboration that will improve the quality of the service delivery system.

ACTORS' COLLABORATION: WAY FORWARD TO IMPROVE THE QUALITY OF SERVICE

It is proposed that to improve the quality of service, collaboration among all interested parties of the mental healthcare delivery system is necessary in order to meet the needs and expectations of clients. One can say therefore that the collaboration among the stakeholders is not happening because of communication problems among the actors of the service delivery system. This has been identified as the research problem and confirmed from the data collected and analysed from interviews conducted among managers and directors from the Lincolnshire Partnership Foundation Trust (LPFT), Lincoln County Hospital (LCH), Lincoln County Council (LCC), voluntary organisations and some service users from the Lincolnshire county, (the above mentioned institutions are some of the actors of the mental health care system). There are a number of possibilities to resolve the problem identified that is lack of communication among the actors:

One possibility is to focus on information overload in the organisation of the NHS. It is proposed, by increasing the level of interaction among all the interested parties via the use of participatory communication after a suitable destabilisation of the existing communication system, the quality of service will be improved.

Another possibility is the proposal to use the method of 'information overload', i.e. an intentional increase in information through the communication channels of the NHS, as a way to support a suitable destabilisation of the interaction among all the interested parties to stimulate self-organised improvement.

The third possibility, the one that is the paper's focus is the possible improvement in the organisation of the mental healthcare system within the NHS. It is proposed therefore that the use of 'information overload' a process to achieve participatory communication is necessary in order to increase the level of interaction among all the interested parties and also to stimulate self-organisation of the system using the dialogism approach. It is when the level of interaction in the decision making process is increased and more attention given to the beneficiaries of the system through the supporting groups' representatives that the system may attain optimum performance and meet clients' needs, expectations and in fact satisfy the needs of all stakeholders, that is achieve 'complete collective satisfaction'.

As a way of resolving the problem of lack of communication, there is the need for collaboration because after medication and discharge from hospital, service users may need the social support mainly provided by the Third Sector. The fact is that the majority of mental health patients preferred to work with and receive help from the non-professionals than from the mental health professionals (Barker et al, 1990) [6]. Research has proven that for mental health problems in particular, the benefit of social support cannot be swept under the carpet especially at the time of discharge from hospitals and that social networks has been very influential in the improvement of quality of life of service users. (Green et al, 2002) [16].

Consequently it is therefore important that collaboration is encouraged among all stakeholders to incorporate each actor's aims, objectives or vision (complete collective satisfaction). This is necessary because no single organisation can meet the needs and expectations of mental health service

users on its own so a multi-agency model (actors-dialogism-system) should be explored via collaboration. This involves the training of self help groups, sharing information, service evaluation and feedback to improve services delivery. It is also important to incorporate other methods used by the Third Sector staff to strengthen the collaboration between the Third Sector and the formal sector (Simpson, 1996) [22]. It is important to note that in evaluating the performance of the service delivery in mental healthcare, in order to improve the quality, one needs to go beyond the medical model, diagnosis of symptoms, treatment and side effects of disease; this involves input/output system of treatment and measurement. This system of input/output is what the researcher calls the First Cybernetics. However, total treatment of mental problem should include the social well being of patients (service users), this in a collective measurement is referred to as Health-Related Quality Of Life (HRQOL). The HRQOL generally includes the domains of physical functioning, psychological, well being (e.g. level of anxiety, depression, fear of recurrence); and social functioning of the patients. The process of going beyond the medical model, therefore the input/output approach to an open system is termed the Second Cybernetics.

Cybernetics at the level of input/output approach is about the study of negative feedback, which is self-stabilising loops that lead to a regulation of a system in order to generate a state of equilibrium (Ashby 1957)[2]. Cybernetics is usually related to external and centralised control of black boxes and goal-oriented behaviours, which have to do with systems sustaining complex interactions with their environment over time (Beer, 1966 p.257) [7], this is a Second Cybernetics system or approach.

The concept of negative feedback is crucial for achieving stability and adaptation. Negative feedback is a necessary corrective action, which when implemented produces a specific outcome by modifying a course of action. The consequence of this arrangement is that, the input of the loop is affected by its own output. Hence, a satisfactory outcome can be achieved following a negative feedback process, indicating whether the system has achieved its goal or fallen short, by providing backward information on the resulting outputs, in order to be used for the manipulation of the inputs of the system (Ashby 1957 p.53-54) [2]. This process is the First Cybernetics process of a system according to Boje, (2008) [11].

Moreover, maintaining the stability and adaptation of a system involves developing a capacity to handle fluctuations in the input and environmental disturbances over time (Beer, 1979 p.57-69) [8]. This capacity can be achieved by having a feedback adjuster, a device that manipulates the input patterns of a black box, in terms of the readings taken from the output patterns and by holding an adequate representation inside the inputs/outputs correlation in order to manage the output variety. A feedback adjuster allows for self-regulation and single-loop learning. It permits the detection of errors and allows corrective action to be taken within the range set by the representation of the variety of the input/output relationship.

The First Cybernetic approach as described above is not very suitable for a complex system like the mental healthcare system. The reason for this, is that, as adaptation and stability is achieved; the system is bound to dissipate (dysfunction) with time, because of the continuous changes and constant increase of the variety in its environment, which may exceed the capacity of the input/output cybernetic system. This is in line with the reverse interpretation of the Ashby's Law of Requisite Variety. Therefore one needed to go beyond this level of abstraction to the Second Cybernetic system which is open system. It is an open system because it receives its feedback not only from within the system but also from the system's environment. Again being an open system means the system does not only exchange energy with its environment but also matter from the environment. However, in both the First and Second Cybernetics approaches of improving performance or quality of service, there are elements of linearity and hierarchical which in themselves create problems.

The mental healthcare system, as a human institution with different people with different needs and preferences, it is expected that the capacity of its meta-system transition (co-ordinated process) will not be able to cope with the variety of needs and preferences from both inside and outside the system and therefore dissipation is bound to happen. This is what has resulted in various forms of reforms all aimed at resolving the problems associated with increase variety of needs and preferences by the various actors. One cannot avoid the dissipation because all the actors have their own different goal-oriented values which are not static, but grow together with a diversifying environment, which is also different from the government.

The possible way to resolve the problem in order to achieve the desired high quality of service delivery (complete collective satisfaction) is to move to a higher level of co-operation among the actors where the relationship between them or the functional imperative is neither a linear nor hierarchical but spiral relationship of Polypi Dialogism. The Dialogism consists of 4 notions namely the Polyphonic, Stylistic, Chronotonic and Architectonic with the fifth notion, Polypi playing a co-ordination role. This is the Third Cybernetics proposed by this paper as the possible best way of resolving the problem of communication in order to improve the quality of service delivery via increase in interaction. The next section explains these notions in detail.

DIALOGISM

A polyphonic is a set of written, visualised or orally told stories by all the stakeholders of a system as opposed to mono vocal narrative or written strategy by an expert or a dominant actor (Boje, 2008) [11]. It

is a construction by many embodied voices, logics and perceptions. It could be visual arts, photos, décors, drama or oral storytelling that communicates through interaction. It involves getting stakeholders to engage in storytelling through the sharing of ideas, experiences, knowledge and skills such that each and every one's voice and logic get enunciated and subjected to questioning until a form of understanding is reached on the particular issue and how to deal with it.

However, the interaction or communication in the process of the sharing is not necessarily a function of producing a consensus but usually results in open situation where the issue is being accepted or rejected. The actors in the process therefore reach a point, which bifurcates into further alternatives. The process of bifurcation itself is a process of reducing complexity of the issues that come to the 'floor' of the dialogue into simple terms and meanings.

The Stylistic is a dialogue; it is an orchestration or a sense making of an image or dialogism among various means of dialoguing or communicating namely oral telling of stories, print and video media, internet, gesture-theatrics, décor and other architecture modes of image expressions

For Weick (1995) [23] sense making could be a way of looking at stylistic on the basis of the public sense making control. Sense making in this sense is about the act of or the process of placement of items into frameworks, comprehending, redressing and constructing meanings from the frame such that interacting with it generates mutual understanding and patterning. This form of framing and reframing (producing and reproducing) is a stylistic feature. It also determines the style of delivery of the services and where necessary the revision of the style to meet certain moral obligations.

Chronotopic dialogism can be described as a holographic relation of centring (centripetal of chronotopes) and amplifying (centrifugal of chronotopes). Holographic is storytelling that runs from one dimension to multiple complexities. Storytelling is holographic, in the sense that it can interrelate to more than one complexity. Storytelling is infectious and that can be tracked across space-time.

Architectonic dialogism is focuses mainly on the interaction of several societal discourses that affects organisation's performance. The three basic discourses are the ethics, aesthetic and cognitive which are answerable to one another. Kant (1993) [19] and Bakhtin (1981) [5] described architectonics as societal discourses. However, each of them has his own divergent views on this notion. Kant invented the 'cognitive architectonic'. For him architectonic is the art of constructing a system. He argues that reason cannot permit our knowledge to remain in an unconnected and rhapsodistic state, but requires that the sum of one's cognitions constitute a system. Kant sees architectonic as cognitive notion deeply implicated in the construction of systemicity. Bakhtin preferred the term 'consummation' to construction and was careful not to assume a monophonic or mono logic or mono language system. He looked at a system as 'systemicity', that is unmergedness and unfinalisability of the system. This is the way forward for the proposed mental healthcare system, where there is no room for homeostatic state or dissipation because the process of 'polypi' is 'unmerged' 'and unfinalised'.

Polypi is the inter-dialogism of Polyphonic, Stylistic, Chronotopic and Architectonic. It is a multi-dialogue complexity, where the four (4) notions of dialogism collide. The Polypi is therefore a coordination system of the above dialogisms discussed. The above process of dialogism (Polypi) is the Third Cybernetics revolution being proposed to resolve the problem of communication identified among the actors of the mental healthcare system. It is argued that implementing these, allows for improved communication among actors, as a way of achieving high quality service delivery via increase in their interactions.

CONCLUSION

A typical and recent familiar example of narrative and emergent stories of dialogism is the death of Michael Jackson, the pop star. A network of organisations constructed narratives along side stories of Michael Jackson's death; even now stories about his death continue to emerge. In the narrative and emergent stories of his death, the Polypi of dialogism is contentious: Polyphonic logics struggle to converge or agree; the multiple stylistics of verbal, written and posters or pictures contrast; the multiple Chronotopes of varying temporalities and partialities diverge, and the ethical discourse of architectonic, questions reverberates into many other discourses. It indicates therefore that the complexity of the narratives and emergent stories of Michael Jackson's death is unmerged and 'unfinalised' if one wants to get to the bottom or top of the story.

Dialogism is a complex notion; it is a weave of many storytellers and listeners who together co-construct the meanings of a dynamic issue. This reduces living story into complete collective meaning as opposed to ante-narrative elements of amplification transformation (Boje, 2008) [11].

The contribution of this paper to knowledge is to propose that although linearity or hierarchical approaches to knowledge creation is making impact in society, the impact will be great and more beneficially however, if the interaction among the actors is a spiral relationship on the collective level by way of collaboration to resolve problems identified collectively in order to achieve 'complete collective satisfaction' particularly in the service delivery system, like the mental healthcare service.

In the case of mental health care delivery system 'Complete collective satisfaction' is achievable only if strategy-as-practice in the mental healthcare system moves from the level of abstract

categorisation such as planning or reforms to the level of collaboration. This means that the way forward is therefore the re-organisation of the system which now is exclusive to the NHS or government (target setting) to a level of multifunctional and interdependent interaction, where consideration is given the environment: other service providers, clients, financiers, the public and in fact all stakeholders.

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Organizational Culture and Strategy: the nature of relationships between constructs in Institutions of Higher Education in Brazil

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ABSTRACT

The main objective of this study is to analyze the nature of the relationships between organizational cultures and the strategies used at the Institutions of Higher Education in the state of Rio Grande do Norte, Brazil. Noting the importance given to organizational culture in relation to the formulation of strategies this study arose from the need to initiate a discussion on new parameters and guidelines of the strategies in the management of higher education institutions, identifying the organizational culture is related to typologies of generic strategies used by these organizations. The reach this goal it was used an explicative study of quantitative nature applied to 31 Institutions of Higher Education to enable the identification of the relationships between the cultural styles and the strategic typologies used by the researched Institutions. To analyze the data it was used the canonical correlation predictive model and quantitative analysis. The results of the present study indicates the existence of an entrepreneur cultural style and a prospective strategic typology predominating in most of the researched Institutions. Finally this study confirms the relationships between organizational cultural styles and the typologies of the organizational strategies of the researched Institutions.

Keywords: Organizational Culture. Organizational Strategy, culture ande strategy. Institutions of Higher Education.

1 INTRODUCTION

In seeking to gain competitiveness and increase efficiency, the present study highlights the current period of expansion experienced by higher education organizations in the country. It is observed, according to data from INEP (2009), that there was a significant increase in the number of Higher Education Institutions (HEIs) in the country between the years 1997 and 2007 totalling a number of 2281 Higher Education Institutions nationwide.

Contextualizing this to the numbers of Higher Education Instituitions in the state of Rio Grande do Norte - RN, according to data from INEP (2009), in 2000 this state registered a total of 8 HEIs with the Ministry of Education - MEC. These numbers of HEIs in the state of RN according to data from E-MEC (2010) increased to 45 Higher Education Institutions that develop their activities in the classroom as well as in distance education. This increase in the number of HEIs in the state of RN followed the national trend of expanding higher education in Brazil.

Thus, it is important to affirm the need for HEIs, operating in the state of RN, to seek differentials in managerial efforts of conduct in order to provide educational services that have low costs of operation and are also effective in generating results. Mintzberg and Rose (2003) argue that higher education institutions, "are organizations that continually respond to environmental demands because they have many internal agents capable of independent responses which react to the interests, demands and pressures of the community that surrounds it. "

For this reason, it is necessary that the managers of these HEI get to know their cultural patterns so that they are capable of developing strategies which can integrate the power of the internal needs of the organization with the external demands of their environment (Vizeu, Gonçalves, 2010)

Within this context, this study seeks to answer the following central research question: What is the relationship between organizational culture and strategies of Higher Education Institutions in the State of Rio Grande do Norte?

As an objective this study seeks to: establish the causal relationships between culture and organizational strategies adopted by the HEIs of RN.

With this understanding therefore, the different levels of the culture of the organization express a set of values that have been constructed throughout the company's history which were developed by the process of internal and external adaptation. The culture has deep roots that, in some ways, represent the organization's DNA (Dutra, Fleury and Fleury, 2006).

Porter (1986), emphasizes the importance of adding the knowledge of beliefs and other cultural characteristics to management tools applied as business strategies. He also affirms that to add the knowledge of the culture surrounding the organisations is both fortuitous and desirable for the establishment of organisational conditions appropriate to better administrate the changes arising from strategies, their impacts and resonances.

In this way, Schein, (2009) recognizes the importance of corporate culture on organizational management. This author highlights the influence of cultural elements in the way the company operates, the way people behave, and in the establishment of organizational strategies.

Based on the previously proposed aspects of the discussion related to culture and organizational strategy Mintzberg;

Ahistrand and Lampel (2000) allow for the creation of a relationship based on structural typologies of organizations relating them to the cultural styles proposed by Mendes and Paz (2008) and the typologies of generic strategies of Miles and Snow (2003).

Thus, it is observed that the relationship between culture and strategy is perfected in the organizational form which defines the configuration of structure and of power. Thus, Mintzberg (2003) presents seven forces that are delineated in organizational configurations that include: leadership ,efficiency, proficiency, focus, innovation, cooperation and competition. The imbalance between these forces allows for the formation of the six organizational configurations proposed by the author: simple structures, mechanized bureaucracy, professional bureaucracy, a divisional form, ad-hocracy and a hybrid approach called the missionary configuration.

Of the six configurations identified, four types have the capacity to demonstrate the theoretical relationship between cultural styles and strategic types. These were conducted and analysised for results that will be identified by an empirical intervention in this study. Table 01 presents in each type of organizational configuration a cultural style and a strategy typology adequate for that culture.

Organizational Configurations Mintzberg	**Ad-hocracy**	**Machine Bureaucracy**	**Professional Bureaucracy**	**Missionary**
Cultural Styles Paz e Mendes (2008)	Entrepreneurial	Bureaucratic	Affiliative	Individualistic
Generic Strategies Miles e Snow (2003)	Prospective	Defensive	Analyzer (Prospective or Defensive)	Reactive

Table 1: Organizational Settings: combining cultures and strategies
Source: Danjour (2010)

As observed in Table 1 the organizational settings and their cultural styles and respective typologies of generic strategies are identified. For construction of the table there was a perception by Mintzberg; Ahistrand and Lampel (2000) claiming that "the typology of Miles and Snow is reduced to two basic forms (which seem to correspond to the machine's organization and ad-hocracy) with the third being a hybrid, and the fourth a collection of inadequate responses." Based on the prior alignment made by Mintzberg it sought to relate the cultural styles proposed by Mendes and Paz (2009) with the strategic typology of Miles and Snow (2003).

Thus, Ad-hocracy seconded by Mintzberg (2003) has a structure that is highly organisational and rather informal. It has a team of staff specialists divided into small project teams and makes investments in training and has groupings of staff based on market requirements. This structure enables the alignment of the entrepreneurial style of organizational culture with the prospective strategy typology.
Mechanized Bureaucracy in turn, is charactarised by a large amount of rules and procedures and by organizational communication which is developed in a formal way. The decision-making is predominantly centralized and routine operational tasks have highly specialized staff. This configuration identifies a bureaucratic cultural style and defensive generic strategy typology.

The professional bureaucracy presents itself as a hybrid form, ie a transitional stage between the mechanized bureaucracy and ad-hocracy or vice versa. Thus this organizational configuration is characterized by an emphasis on staff training processes, horizontal specialization of labor and decentralization of decisions both vertically and horizontally. Therefore, this configuration allows a direct affiliative cultural style. This cultural style is in favor of implementing an analyzer strategic typology and can also present either predominantly or secondarily prospective strategic typologies or defensive strategies.

Finally, the missionary configuration has its own characteristics which are dominated by a system of beliefs and values that unite individuals on the basis of an ideology. This structure is characterized by: the absence of direct supervision, a lack of a standardization of work and a lack of a technical structure. It has a minimum of hierarchy, an intermediate line and a virtual absence of formalization. This form identifies itself as a cultural style associated with the individualistic typology configuration and attempts to create emotional bonds with people in the organization and its ideologies. Also tied to this cultural style is the reactive strategy (Mintzberg, 2003).

2. METHODS

As for its objectives, the research is classified as explanatory. According to Collis and Hussey (2005) this kind of research "aims to understand phenomena and to discovering and measuring causal relations between them." With regards to procedures, this study is classified as being an analytical survey, which according to Collis and Hussey (2005), is a positivist methodology that, from a representative sample of the population, allows inferences and "determines whether there is any relationship between different variables" thereby requiring the researcher to identify the independent and dependent variables of the study. Finally, the study is quantitative in nature with respect to the classification of generic strategies, the organizational culture typology and the establishment of possible relationships between these variables.

The study population was composed of 32 managers from 32 higher education institutions that have their physical headquarters in the state of Rio Grande do Norte. By covering all higher education institutions that have their physical headquarters in the state of Rio Grande do Norte, the present study was classified as a type census and did not use just one sample.

The data in this study was collected through questionnaires, with a total of 74 questions on a Likert Scale. This instrument was divided into 30 questions drawn up based on the model proposed by Mendes and Paz (2009) – called a Scale of styles of organizational functioning – EEFO and validated with accuracy rates of Cronbach's alphas ranging from 0.79 to 0.83 , aimed at identifying cultural typologies. The other 44 questions were developed based on the theoretical model of Miles and Snow (2003), adapted from the instrument developed by Conant and

Monkwa Varadajan (1990) to assess the existing generic strategies in the organizations studied and validated with accuracy rates of Alfa Cronbach exceeding 0.7.

Questionnaires were administered in person to 23 managers of HEIs that have headquarters in the Metropolitan area of Natal and by mail to the other 09managers whose HEI headquarters are outside the Metropolitan area of Natal.

Analyses performed in this study was to identify the relationship between organizational culture and the types of strategies present in IFRN. With this in mind, we used multivariate canonical correlation analysis. For Hair Jr. (2009) canonical correlation is a "multivariate statistical model that facilitates the study of interrelationships among sets of multiple dependent variables and multiple independent variables." For purposes of this study, the dependent variables considered were types of generic strategies namely: prospective, defensive, reactive and analyzer. The independent variables considered were the styles of organizational culture, namely: entrepreneurial, affiliative, individualistic and bureaucratic.

Finally, the results with the implementation of canonical correlation are confirmed using the correlational statistical technique of Pearson's seconded by Collis and Hussey (2005) which made it possible to identify and confirm the extent of the strength of association between each pair of factors of culture and organizational strategy. The last analysis performed in this study tried to correlate cultures and strategies found in HEIs with a theoretical proposal presented in Table 1's theoretical framework, identifying unconformities and conformities in relation to the proposed model.

3. RESULTS AND DISCUSSION

The analysis conducted in the study sought to identify by means of the canonical correlation technique and Pearson's correlation, the relationships that exists between the types of organizational culture proposed by Mendes and Paz (2009) and the proposed strategic typologies by Miles and Snow (2003).

For the choice of canonical functions that will be interpreted, Hair Jr (2009) proposes to examine three fundamental criteria:

" (1) the level of statistical significance of the function,
(2) and magnitude of the canonical correlation and
(3) redundancy measure for the percentage of variance explained from the two data sets "

With this in mind, we observe that the canonical analysis allows the researcher to measure the strength of associative relationships between two sets of variables. Thus, we chose the function significant at 1% and identified a p-value of 0.0004 and the other factor observed was the R canonical of 0.8825, indicating a strong positive and significant correlation. When squared, this coefficient represents the amount of variance in a linear composite of the canonical function assigned to another compound of the same function and this is the canonical R^2. Thus, one can say that 77.88% of the variance in a linear composite of the first function is influenced by a variation in another compound that composes it.

Looking at the influence percentage of 77.88% that the second compound linear (cultures) exerts on the first compound (strategies) presents in the first instance, that it can be confirmed that there is a significant degree of influence of organizational culture in the strategic position of the HEIs studied. In this way, the influences will be identified when analyzing the canonical loads and Pearson correlation.

From the identification of function to be analyzed, canonical loads or canonical structural correlations were identified. According to Hair Jr (2009) the index "measures the simple linear correlation between an observed variable in the original set and the dependent or independent statistical variable canonical ensemble". Therefore, because it is a predictive analysis technique, it will be conducted by observing a scale ranging from -1 to 1, in which the measurements closest to 0 indicate a weak influence on a determined factor, and the measurements closer to -1 or 1 indicate a strong influence determining the relationship of one factor to another. Based on the analysis criteria used by Puente-Palacios (1995) the present study considered a canonical load equal or greater than 0.4 to the interpretations of all correlations.

Therefore it is observed that in the first group the four dependent variables that are strategic typologies proposed by Miles and Snow (2003) can be identified as Y1 respective, Y2 defensive, Y3 analyzer and Y4 reactive. The second group consists of four independent variables that are the cultural styles proposed by Mendes and Paz (2009) that can be identified as X1entrepreneurial, X2 affiliative, X3 individualistic and X4 as bureaucratic.

When analyzing the canonical charges it is observed that the style of entrepreneurial culture (0.8922) strongly and positively influences the forward-looking strategy (0.9573) while still exerting a moderate and positive influence on the analyzer strategy(0.4188).

The affiliative cultural style (0.6871) shows a strong positive influence on prospective strategic typology (0.9573), also exerting a moderate and positive influence on the analyzer strategy(0.4188).

However, the individualistic cultural style (-0.7866) has a strong negative influence on the prospective strategy (0.9573) and a moderate and negative influence on the analyzer strategy typology (0.4188).

The last cultural style, in which was analysed a canonical load, was the bureaucratic style (0.7887) that exerted a strong negative influence on the prospective strategy (0.9573) and a moderate negative influence on the analyzer strategic typology (0 , 4188).

As a way of reaffirming the results identified in the predictive model of canonical correlation, we analyzed the Pearson correlation between the cultural styles and strategic typologies of the HEIs of RN. Unlike the canonical correlation analysis, Pearson's correlation identifies just the significance of the correction with the p-value visualization and the identification of the strength of correlation and therefore it is not possible to affirm the existence of multiple influences among the factors, as was done in discussions of the canonical correlation.

Thus, considering a significance level of 1%, there is a strong positive correlation between the entrepreneurial and affiliative cultural styles with the prospective strategy typology and a strong negative correlation between the prospective strategy and

the bureaucratic and individualistic cultural styles . These results reaffirm the identified in the analysis of canonical loads and reaffirm the existence of relationships between culture and organizational strategy.

Other indices of Pearson correlations, significant at 5%, which reaffirm the relationships found in the canonical correlation analysis, were correlations between the bureaucratic cultural style and the analyzers and reactive strategies, showing a moderate and negative correlation between the bureaucratic cultural style and the analyzer strategy, and a moderate and positive correlation between the bureaucratic cultural style and the reactive strategy.

We also identified that the sum of the percentages found for each cultural style and organizational strategy for HEI formed a 84% compliance with the theoretical model proposed in table 1of the theoretical reference and only 16% did not comply with the theoretical proposal .

Thus, we identified a significant percentage of agreement between the theoretical proposals in figure 2 with the results found in this present study that reaffirm the results of the canonical correlation.

However, it is important to reaffirm the posture that is predominantly innovative, flexible and focused on the learning process, identified in HEIs in the state of RN. One way it identified itself was as a 48.4% prevalence of entrepreneurial culture associated with prospective strategy in HEIs, as well as with affiliative cultural style strategies and prospective analyzer which contributed to this analysis.

In relation to the percentage of non-conformities identified in Figure 3, it can be justified as a possible lack of understanding by the Administration regarding the possibility that the cultural style present in their organization aids in the development of a typology that enables an organization to better match its environment.

Finally, it is important to highlight that the alignment identified between the three analysises performed for this present study contribute to the identification of the relationships between cultural styles of Peace and Mendes (2009) and the competitive strategies of Miles and Snow (2003).

4. CONCLUSION

After the analysis and discussion of results, you can make some conclusive considerations and achieve the overall objective proposed by this study that sought to link the cultural styles of Peace and Mendes (2009) with the generic strategy typologies of Miles and Snow (2003).

By studying the cultural styles present in the HEIs you can identify the predominance of three of the four cultural styles proposed by Mendes and Paz (2009). The cultural styles that stood out were the entrepreneurial and affiliative styles. These results demonstrate a cultural openness of these HEIs and the level of maturity of its employees perceived through their policies that foster growth and innovation in their respective institutions.

Regarding strategic typologies studied that were adopted by HEIs, we observed the occurrence of the four strategies proposed by Miles and Snow (2003). Among these strategies the predominance of the prospective and defensive strategies was clear. This result demonstrates the predominance of two groups of HEIs each with different characteristics. On one side you have organizations that are positioned in an innovative way to focus on the learning process and a second large group of HEIs that are more conservative, with centralized decision-making and focus on the efficiency of internal processes.

Finally, the results of the predictive analysis of canonical correlation indicated a strong relationship between cultural styles and strategic typologies. These results confirmed the correlation that shows, beyond the influence of culture in relation to strategies, the influence of the strategy on culture, demonstrating causality between the two dimensions that can identify the statistical model. Other statistical analysis in the study to demonstrate the relationship between culture and strategy were the Pearson correlation and comparison between the theoretical proposal presented in this study with the findings in the survey that indicated 84% compliance.

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DEMATERIALISING JUDICIAL EXPERTISE: COLLABORATIVE TOOLS, CHANGE MANAGEMENT

From “ink and feather” to mouse click and collaborative space: an operation of modernization and change management inside the public service of Justice

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1 Judicial expertise in France

1.1 What is it

Judicial expertise in France is part of civilian litigation devoted to provide the court or tribunal with an opinion answering questions related with:

- Technical assessment,
- Quest for technical evidence,
- Opinions upon technical subject after controversial examination by expert of materials submitted by litigants, cross examination by litigant of the preliminary expert’s opinion, before he delivers his opinion.

1.2 How does it work

The hereafter scheme describes relations between actors.

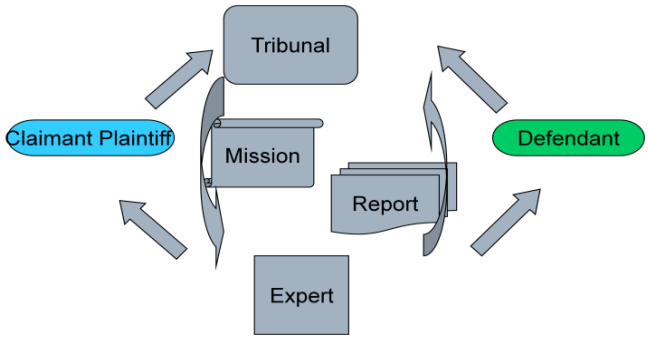


Figure 1 Scheme of relations inside a legal civilian expertise mission

Controversial debate lying upon documents and hearings is the common rule.
Some figures: in civilian expertise, 80% of the expertises never go back to the court; that means that litigants reach an agreement on the basis of expert’s opinion.

1.3 Trends for improvement

Inside judicial world, as elsewhere in public services, strong pressures have developed to cut expenses and improve management ; they has led to a deep move toward quality management, improving costs, time span and accuracy of answers to tribunal technical questions.
So in a constraint context, two drivers where dug out at the end of 2009:

- Improve the flows of document and decision process among courts and tribunals,
- Answer to consumer driven expectancies on the ground of judicial expertise.

At the beginning of 2010, the French Justice Department decided:

- To dig out the use of collaborative tool formerly suggested among the Experts community, but not deployed because of a lack of commitment among the hereafter listed actors.
- To induce Experts and Courts to start with local bars an experiment opening the track for further extension of dematerialization.

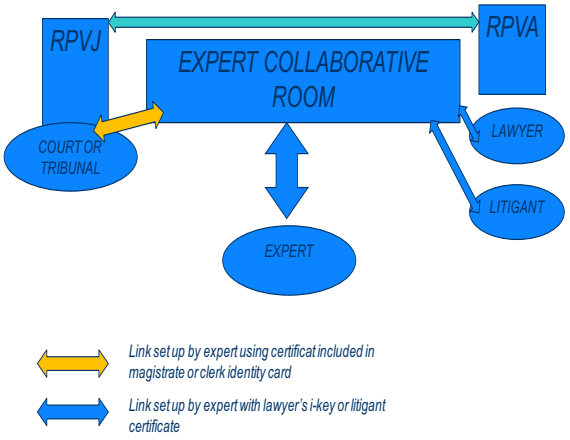


Figure 2 Scheme of relations in a dematerialized expertise

2 Key success factors:

2.1 Content and conditions of a dematerialization project

A dematerialization project has to answer functions, documentary and of communication, and surmount fears. These **4 functions** attached to a document are:
- creation, of document
- exchange and sharing
- preservation
- cohabitation with traditional supports.

The legislation tackled this question since the beginning of 2000s: the French civil code plans now the equivalence between the digital document and the paper document under certain conditions reminded below.

6 fears, have to be addressed by supports of dematerialization, tools and organizations and collaborative work they can be expressed as follows:
- identity of the authors and the issuers, how to be sure of the origin
- integrity of documents: how to be sure of the fact that the document is not distorted or altered,
- confidentiality: the document is accessible only to those for whom it is intended,
- proof of the exchanges: this proof joins in the field of the expertise of justice the proof of the respect for the principle of the controversial,
- perpetuity: the digital documents have to meet during an appropriate long term the expectations over time of users: consultation, copy,
- traceability: this traceability includes the proof of the exchanges, it also includes all the elements of organization, distribution, addresses and their modifications, modification in the lists of the litigants and their counsels associated with the relevant procedure.

To support the answers to these apprehensions, a cardinal element: the certificate, which allows to identify the actors of the procedure, the authors of documents or interventions and to authenticate the documents which they emitted. The certificate is the condition of a secure use by concerned parties of the secure space of expertise.

3 Actors

3.1 Tribunal and court

Inside Tribunal and courts, judges and clerks are committed with expertise; two kinds of services inside the tribunal:
- "Service du contrôle" (expertise management, supervision and funding)
- « Juge du fond » (Decision Chamber of the Tribunal).

Since March 2011, they are receiving identity card including an electronic certificate, parallel to that of experts.

3.2 Bars and Lawyers

Since four years, lawyers are supposed to be equipped with an i-key including a certificate which allows them to use a special VPN "RPVA" ("Réseau privé virtuel avocats" - Lawyers virtual private network -).

As several steps of procedure – including lodging an appeal – will require in a compulsory way use of digital procedure, actual use of information technologies is likely to grow since that very 2011 year ; out of 50000 lawyers in France, 5000 owned in 2010 such an electronic certificate, in June 2011, their number raised to 25000.

3.3 Judicial experts and their professional associations

Selected after a specific process judicial experts are enlisted according to definite specialties and sub specialties (Building, accountancy, Health and medical service, physical prejudice, environment…).

Notwithstanding the full right of Courts and Tribunal to appoint as a judicial expert for a determined mission, whoever they decide, in fact, those appointments take their origin in the lists (mainly individuals, but other organizations, private firms, may be enlisted as expert - chemical analysis firms, DNA analysis,…) set up by Courts of Appeal or the "Cour de Cassation". Most of those experts register in a non government association, "compagnie d'experts", existing in every Court of Appeal. Those associations grouped themselves 80 years ago in an association "Conseil national des compagnies d'experts de justice" which is an association of public interest according to French law.

4 The dematerialization project

That project is two prongs :
- expert identity card, including the expert's name and photo, that identity card is a document allowing entrance in Justice rooms or penitentiary precincts, it also bears the electronic certificate which is mandatory in secure exchanges with participants in expertise,
- collaborative tool "OPALEXE" operated by private company CERTEUROPE[1], which is registered as "confidence third party", and allows exchange of documents.

4.1 Experts identity card

In order to manage that identification, the deployment of experts' identity cards is managed by the Conseil national and its affiliate « compagnies ».

For this identification the national council of the companies of judicial experts (CNCEJ) is going to assure, with the person issuing cards and certificates, CERTEUROPE(provider CERTEUROPE), who already assured the delivery of certificates the experts who made the demand(request), and the multidisciplinary companies, the implementation and the distribution(broadcasting) for the experts registered on a list of a card(map) carrying(wearing) their identity and their photography and including a certificate allowing the authentication of his author regarding:
- issuing documents
- preliminary action for further exchanges of documents: opening of secure collaborative space, opening and if relevant, locking accesses on the secure spaces of exchange of documents,
- expert's identification during the physical access to judicial premises or secured cells or jails (mainly for medical experts).

This card delivery goes through the mention, by the president of the concerned regional company, on the file of identity card order passed on to the person receiving benefits CERTEUROPE(provider CERTEUROPE), giving evidence that the expert is registered well on the list of the experts near the Court of Appeal.

This role of the regional company is a necessary link of the chain of security of the production of the cards of expert and the associated certificates.

[1] CERTEUROPE is the French « confidence operator » selected by French council of the companies of judicial experts.

Experts' card is issued for 3 years and the requests for renewal are made in conditions comparable to those existing for the credit cards.

4.2 Collaborative tool

In summary the expert will have the control of the opening of the secure space, the creation of the accesses to the authorized persons - court, litigants and their counsels, co-expert ...-and the deposit on this secured space of documents which are send either to parties, their counsels and\or to the court.

The organized functions include a novation, the mode of communication between the magistrates and the experts; the chancellery displays the implementation of identity cards for magistrates' identification according to a calendar parallel to that planned for the experts within the framework of this project to allow this digital communication develop in the best conditions of security.

The used tool assures the information of the addressees, and allows them to download files and documents.

5 Project content Change management

5.1 General outlook

Using tools - expert's card including an electronic certificate, a secure space of expertise OPALEXE - which are well known and already used besides legal community, let us think in of " team rooms " used in a large number of industrial or technological projects, the project is, beyond its technological aspect, a project of change management.

Several drivers of that change management are so planned:
- **training**, in the use of the secure space, with the various stages, of creation of the space, the opening of the accesses to the participants (left and their advice(councils), court) o in the more general employment(use) of certificates and in the signature of the electronic documents, o at the presentation(display) of the management of the most frequent particular cases (not represented parts(parties), granting by the expert of certificates software)
- **ergonomics** of tools, with an experience feedback at the conclusion of the prefiguration developed in Bordeaux,
- **organization,** with a particular attention carried upon in the possibilities of faster communication between the jurisdictions and the experts,
- **feedback** and the sharing of experience, with an attentive glance on all the actions of dematerialization in progress in legal fields,
- **electronic document management** with naming conventions and as the case may be, an recourse to the use of metadata, what can establish(constitute) one of the shutters(sectors) of training initiatives.

5.2 Organization

The planned agreements were so signed:
- Agreement Chancellery - National Council : aims, ways and means, steps, mutual contributions,
- Agreement National Council - CERTEUROPE : technical support, third party confidence, collaborative tools management and service,
- Agreement of authority of delegated recording, between regional Experts Companies and CERTEUROPE, starting with Bordeaux Court of Appeal.

5.3 Training: the main workload

The contents and the volume of training is split here after :
- 4 hours of specific training for 6 instructors,
- A half-day of training on the general

presentation(display) and the orientations (3 hours),
- A half-day of training(formation) in the employment(use) of OPALEXE (3 hours),
- One half-day of training(formation) on the peripheral domains (management of mailbox, electronic signature, naming,) (3 hours)
- 5 at 6 half an hour of use of the first " test secure collaborative tools" for actions of simulation.
It represents approximately 12 hours of training for every individual expert.
- The indispensable individual appropriation is not included: from 3 to 5 hours according to personal experience.

So formation for 80 people required 1000 hours training.

5.4 Calendar

The calendar develops upon a one year time span to reach a point opening the gate to a nationwide deployment.
- 11/03/2010: raising awareness of volunteers experts willing to become group-instructors
- 12/09/2010: steering committee to the Court of Appeal
- 12/17/2010: raising awareness(sensitization) of the experts and command(order) of cards(maps)
- 06/01/2011: training(formation) of the experts and the discount(delivery) of the certificates
- 03/14/2011: opening of the space OPALEXE (reality)
- 03/21/2011: training of the magistrates step 1
- 05/12/2011: steering committee to the Court of Appeal
- 06/14/2011: magistrates' training step 2 and raising awareness among lawyers
- 07/07/2011: new steering committee
- In October, 2011: first evaluations.

6 Conclusion

First results have confirmed the former economic outlooks:

Average expertise is currently improved on economic stand points:
Less hardcopies,
Less registered letters fees,
The return on investment is higher for building, construction expertise (15% savings), then accountancy and figure matters (10% savings), third with medical and disable people handicap assessment (less than 5% savings).

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Date : 2011.06.27 23:48:39 +01'00'

New Algorithms for Predictive Scheduling with Determined Terms of Milestone Achievement

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Abstract - *In this paper, we have proposed new algorithms for the problem of predictive production scheduling, with the Resource-Constrained Project Scheduling Problem (RCPSP). Those algorithms are adjusted for making robust the activity sequences characterised by specific unsurpassable times of completion of particular tasks related to milestones. The calculation procedures presented here provide protections against exceeding the milestone completion times, although they also make the schedule robust in the locations that are most exposed to interference. Also, the activities whose possible delays would cause the largest instability costs are better protected. The algorithm operations are comparable owing to the defined robustness measures: the predictive scheduling objective functions.*

Keywords: predictive scheduling, project scheduling problem, robust scheduling

1 Introduction

During the execution of production orders, workers often determine the terms of completion of particular production stages. The clients, however, agree with the contractor on the dates of checking the progress of works, known as the milestones. Consequently, the client is assured of the timely completion of the given project. In order to keep the agreed dates, the contractors must take into account the interference that may occur during the production processes, e.g. machine failures, mistakes made in activity duration estimation etc.

The approach in which we take into account the correctness of the task execution during task sequencing is called either predictive scheduling or proactive scheduling. Under the predictive approach, robust schedules are developed, based on the anticipation of possible production disruptions [3]. Despite making the sequence robust, some unexpected interference may occur, causing a default in the agreed terms of milestone attainment. In such cases, it is necessary to apply the reactive scheduling process to reduce the costs of instability.

In this paper, we are describing the problem of predictive production scheduling, with limited accessibility to the resources (*RCPSP*) and the assumption of timely execution of the project milestones. We have defined the objective function and proposed suitable algorithms for particular scheduling stages.

2 Project execution stages

In dynamic production systems, the project execution is composed of several stages, presented in Fig. 1 [6]:

- Planning: determination of tasks, their durations and resource consumption; establishment of sequence relationships between the activities, establishment of the terms of completion of the whole project and of its particular stages, or of the milestones which determine the schedule of activities developed during the scheduling process;
- Scheduling: definition of the commencement and completion times of the activities that make up the given project, with the allocation of specific resources to each activity; in this stage, predictive scheduling is carried out, both nominal and robust;
- Execution and Control: monitoring of primarily timely implementation of the agreed project stages, with concurrent preservation of the predictive schedule stability; at this stage, reactive scheduling is carried out, in response to any production interference;
- Evaluation: after the project completion, the sequence assessment is carried out, e.g. by ex-post comparison to an optimum schedule.

The scheduling stage is of special importance. The development of a production plan and its accurate performance allows for staged accounting with the project owners, improves the production organisation, allows for coordination of internal resources of the business, resource flow between the tasks and orders and timing of material supplies, as well as enhances the procedures of contractor engagement, contract awarding etc.

The above items indicate that predictive scheduling is essential for the production process organisation. In the first stage of the process of nominal scheduling, an initial schedule is developed, taking into account the efficiency criteria, supplemented with the provision of robustness during robust scheduling.

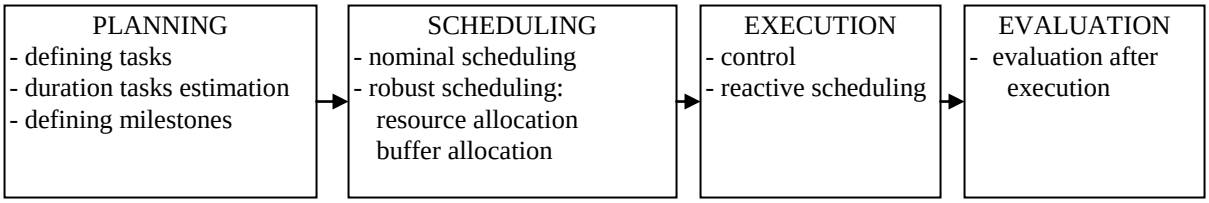


Fig. 1. *Subsequent stages of project execution*

3 Problem formulation

The project scheduling problem with limited availability of resources (*RCPSP*), consists in finding of such time vectors for the commencement of particular tasks (operations and activities) that the resource requirements at each moment is not larger than the available quantity of resources (this quantity is constant, regardless of the load experienced in preceding stages), with the fulfilment of properly defined optimisation criteria [5].

The project schedules in the activity networks will be represented by a non-cyclical, coherent and simple directed graph $G(V, E)$, in which V means a set of nodes corresponding to activities and E is a set of arcs which describe the sequential dependences between the activities. The set V is composed of n activities, numbered from *1* to n, in a topological order, i.e. the predecessor has always a lower number than the successor. As an auxiliary measure, we add two fictitious operations 0 and $n+1$, with zero durations ($d_0 = d_{n+1} = 0$), representing the project start and finish, respectively.

For an *RCPSP*, with determined terms of completion of some of the tasks, the constraint conditions can be defined as follows [6]:

- The finish-start and zero-lag precedence relationships occur between the activities: the subsequent operation may start immediately after the completion of the previous one (precedence constraints):

$$s_i + d_i \le s_j \qquad \forall (i, j) \in E \tag{1}$$

- In each moment of time t, the resource consumption does not exceed the available quantities (resource constraint):

$$\sum_{i:i \in S} r_{ik} \le a_k \qquad \forall t, \forall k \tag{2}$$

- For some activities, unsurpassable term of completion is determined (time constraints related to the milestones):

$$z_i \le \delta_i \tag{3}$$

where:

s_i – the time of starting the operation i (decision variables)
d_i – time of the operation i completion,
a_k – quantity of available resources of the type k,
r_{ik} – the activity i requirement for the type k resource,
z_i – planned time of completion of the activity i,
δ_i – unsurpassable time of the operation i completion, determined only for the activities related to the milestones, that concerns in particular the project completion time δ_{n+1}.

The model determined by equations (1)-(3) uses the milestone system, or the system of critical points that are decisive for the project completion. A timely completion of subsequent stages, or reaching the milestones, will ensure meeting the deadline of work completion. However, the delays usually cause penalties or liquidated damages, while timely project completion may be associated with the payment for the given project stage.

Subsequent critical points related to the tasks whose completion is attached to a specific date ($\delta_j \neq 0$) are marked with km_i. For each i, let the set KM_i contain all the activities whose completion is required for the execution of the given milestone km_i. The total time necessary for the completion of all the activities tkm_i from particular sets KM_i may be determined by (4):

$$tkm_i = \sum_{j \in KM_i} d_j \tag{4}$$

Let pb_i mean the level of protection for a km_i, calculated with equation (5):

$$pb_i = \frac{rezerwa_i + \sum_{j \in KM_i} FS_j}{tkm_i} \tag{5}$$

where: $rezerwa_i$ – the difference between the unsurpassable time of completion δ_j (determined for the km_i) and the earliest possible time of completion of all the tasks belonging to the set KM_i,

FS_j – time margin after the activity j.

The protection level pb_i thus definition will be used in the objective function for predictive scheduling.

4 Nominal scheduling

At the nominal scheduling stage, the initial schedule is developed. The schedule can be either imposed after making calculation in a commercial software package, or determined by own calculation procedure. Nominal sequencing does not contain any buffers; it is not resistant to possible production interference; and it does not take into account the changeability and uncertainty of the production system parameters.

The nominal schedule is most often determined by the application of the algorithms for a deterministic problem. Classical algorithms for solving an *RCPSP* problem may not be used in the case under consideration. The milestones system is used here, while the defined objective function, proportional to the time consumption, should ensure protection against possible breach of the completion dates of particular project stages, taking into account a proper protection level.

The proposed objective function, taking into consideration the observance of the times of completion of all the project stages, is a weighted total of the levels of milestone protection pb_i:

$$\max\{\sum_{i=1}^{m} pb_i \cdot wm_i\} \tag{6}$$

where: wm_i – weight assigned to the milestone km_i.

The value of the weight wm_i depends on the current protection of the milestone km_i, and it is determined on the basis of the ascending milestone sequence with reference to pb_i. For example, the value may be determined in the following way:

- for the milestone with a minimum protection level pb_i, we assume: $wm_i = m$;
- for the milestone with k-th pb_i, $wm_i = m - k$;
- for the milestone with a maximum pb_i, $wm_i = 1$.

The weights wm_i assigned to the milestones wm_i can also be determined in a different way; however, the following condition should be fulfilled: larger weights wm_i for less protected milestones km_i.

Owing to the objective function determined by formula (6), we obtain the following:

- equal distribution of the protection buffers based on the levels pb_i, attained by proper establishment of the weights wm_i;
- distribution of the time margin, in proportion to the duration of the milestone tkm_i: the larger the tkm_i value, the larger buffering of the milestone km_i.

In the case of the *RCPSP* problem, when developing a schedule, we apply the decoding procedures, or the so-called Schedule Generation Schemes (*SGS*), which generate the sequence, based on a priority list (or activity list), taking into account the availability of the resources and the sequence interdependence. For a deterministic problem, the following are used [7]:

- *serial SGS*: in each iteration, the first non-sequenced activity from the activity list or the priority list is started at the earliest possible commencement time upon fulfilment of the sequential and resource constraints;
- *parallel SGS*: iteratively in subsequent moments of the time t (at the decision-making points), all the non-sequenced activities are started; the ones which may be started in the sequence arranged on the activity list or the priority list upon fulfilment of the sequential and resource constraints.

Below we present new algorithms that use the *SGS* procedures when generating a nominal sequence for the defined *RCPSP* problem, with timely achievement of the milestones.

Priority-List Based Scheduling

A priority list of activities is created, and it is used to generate the sequence, with the application of schedule generation schemes (*SGS*).

Algorithm 1

Step 1. Calculation of the $zapas_i$: the difference between the contractual unsurpassable date of completion δ_j of the closest milestone for the activity i and its earliest possible time of completion, taking into account only duration times of the tasks that precede the activity in the activity network.

Step 2. Calculation of the priority of each activity execution based on formula (7).

$$pr_i = \delta_j \cdot zapas_i \tag{7}$$

Step 3. Creation of the activity priority list, in accordance with the ascending pr_i values. Based on that list, the schedule will be determined.

Algorithm 2

Step 1. Determination of the milestone attainment sequence based on the δ_i value; the auxiliary list $LKM = \{km_2, km, km_1, ..., km_l$ (*project completion time*) $\}$ is created.

Step 2. Determination of the sequence on the priority list in the sets of subsequent milestones KM_i, e.g. applying either the priorities which are characteristic for the deterministic problem *RCPSP*, i.e. the Latest Starting Time (*LST*) list: sorting of the activities in the non-descending order of their latest possible starting times (the best rule for the deterministic *RCPSP* problem), or the priority rules taking into

account the cost of instability (related to the resource consumption of the tasks).

Step 3. Generation of the schedule, using the *SGS*, based on the priority list determined in Steps 1 and 2.

Meta-Heuristic Algorithms

The application of meta-heuristics, e.g. of Simulated Annealing (*SA*) and Tabu Search (*TS*) may improve the solution obtained with the use of scheduling on the basis of a priority list. The algorithms *TS* and *SA*, which search through the activity list, maximise the objective function determined by formula (6).

5 Robust scheduling

Robust scheduling is intended to create a sequence which, due to its properties, is resistant to interference that may appear in the production process [1]. Two approaches are distinguished here [4]:

- schedule quality robustness, where we intend to fulfil the efficiency criteria;
- solution robustness of the whole schedule, where we intend to implement all the sequencing details, in accordance with the plan.

For the defined problem of timely milestone attainment, the schedule quality robustness is reduced to the protection for keeping the agreed terms of completion of particular project stages. The objective function, determined by formula (6), is a proper measure of the schedule quality robustness. Consequently, the initial schedule, obtained during the nominal scheduling process, need not be robust with respect to the sequence quality.

In the solution robustness approach, we intend to implement all the sequencing details, in accordance with the plan. The proposed measure of the schedule robustness has the form of equation (8).

$$M = (\sum_{i=1}^{n}(\sum_{j=1}^{k} r_{ij} \cdot d_i) \cdot \sum_{j=1}^{FS_i} a^{-j} + - \sum_{i=1}^{n+1} f_i \cdot \max(0, z_i - \delta_i)) \quad (8)$$

where: a – the parameter affecting the buffer allocation ($a > 1$),

f_i – the marginal cost for exceeding the latest term of completion of the activity i, determined only for the activities related to the milestones,

FS_i – free slack, time buffer for the activity i.

The application of the robustness maximisation measure M as the objective function of robust scheduling leads to a uniform distribution of the time buffers in the schedule, with special protection of the starting time of the activities that are the most resource and time consuming (the larger the value of the parameter a, the more uniform the buffer distribution). Also the dates of completion of the milestones are taken into account by determining the f_i liquidated damages assigned to the time unit related to the delay of the completion of the activity i.

Robust scheduling is composed of the robust resource allocation and of robust buffer allocation:

- Robust resource allocation: proper assignment of the resources for the performance of particular activities to develop the schedule which is highly resistant to interference. The algorithms are most often reduced to the minimisation of the number of additional sequential interdependencies resulting from resource allocation, e.g. *ISH*, *ISH*^{2}, *MABO* [7].
- Robust buffer allocation: placement of time buffers before the tasks to make the schedule robust or resistant e.g. to a periodic unavailability of resources or changeability of activity duration. Buffer allocation takes place upon determination of the assignment of resources to tasks.

What is especially essential in scheduling is proper buffer allocation. The time buffers should be entered in vital locations of the nominal schedule that are the most exposed to interference or charged with the largest instability cost. We have proposed below our algorithms for robust buffer allocation applicable to the problem under consideration and to the objective function determined by formula (9), taking into account the schedule robustness quality measure, formula (6).

Algorithms of Robust Buffer Allocation

Algorithm 3

This algorithm implements the time buffers in front of particular activities, in the sequence of susceptibility to interference, taking into account the weight of sequential interdependencies in the resource flow network. The buffer placement method also depends on the duration of particular milestones tkm_i. The schedule is buffered in such a way that allows for as proportional as possible protection of timely completion of all the project stages.

In this algorithm, the coefficient wb_i (formula 10) is calculated. The coefficient is used for determining the sequence of entering the buffers in front of the activities. The determination of the coefficient wb_i is possible after an analysis of the planned times of commencement and duration of all the tasks that precede the activity i in the resource flow network. We calculate the corrected time of completion of all the activities j from the set P_i^*, or the set of the activities which precede the activity i, directly or indirectly. The correction Δd_j of the task duration j is calculated in accordance with formula (9).

$$\Delta d_j = \alpha \cdot d_j \cdot r_j \quad (9)$$

$$wb_i = \frac{\sum_{j \in P_j^*} r_i \cdot (s_j + d_j + \Delta d_j - s_i)}{b_i + 1} \qquad (10)$$

where: b_i – time buffer before the activity i;

α – the parameter which can take into account the peculiarity of a given process, i.e. the machine failures, or the coefficient of the actual activity duration.

When determining the robustness measures, we make the following assumptions:

- The more resources are involved in the activity, the more susceptible is the activity to interference.
- The longer the activity, the larger possibility of its prolongation since longer tasks indicated a larger absolute changeability.
- The interference of the activity start time in case of a more resourceful activity causes a larger instability cost (or disorganisation of larger quantities of resources).

The algorithm operation consists in the addition of unit buffers during a single loop course until the whole schedule is completed. Before each course is carried out, modified coefficients pb_i are calculated, in accordance with formula (11).

$$pb_i^{'} = \frac{rezerwa_i}{tkm_i} \qquad (11)$$

A buffer will be inserted for the milestone with a minimum pb_i. To find the buffered task, the wb_i values are calculated for the activities belonging to the set KM_i. Next, the insertion of the unit buffer in front of the activity representing the largest wb_i is checked. If the schedule performance time with that buffer does not exceed the times of completion of the key activities, the buffer will be inserted, the schedule is modified and the wb_i and pb_i values are calculated for a new schedule. A new calculation cycle is carried out with the updated wb_i values. However, when the buffer insertion exceeds the time of milestone attainment, the activity will be added to the list of the tasks which are not buffered. If it is not possible to insert a buffer for the given milestone km_i, the milestone will be omitted in the subsequent runs of the algorithm, that is all the activities belonging to the KM_i will remain unprotected. The course of the algorithm is continued until either all the activities stop to be buffered or when the coefficient wb_i assumes the zero value.

Algorithm 4

This algorithm inserts buffers after the activities, protecting a timely commencement of succeeding activities. In the first place, the longest tasks are buffered (with the assumption that longer tasks are characterised by a larger absolute changeability). In each iteration, a new schedule is generated based on the modified duration times. The duration changes are staged. At each stage, the activity duration time is changed by the maximum dk_i, calculated in accordance with formula (12), of one unit on the condition that the dk_i is at least equal to 1.

$$dk_i = \alpha \cdot d_i - b_i \qquad (12)$$

where: α – the parameter, an iteration step.

Sequencing is evaluated at each step by the use of the objective function determined by formula (8). In subsequent steps, the best solution is recorded. The algorithm will finish its operation when all the activities cannot be buffered any more due to the exceeded time of any of the pre-determined milestone, with taking into account the modified task durations.

Algorithm 5

This algorithm is based on the Critical Chain and Buffer Management Method (*CC/BM*) [2] related to the Theory of Constraints (*TOC*). The critical chain is defined as a set of the activities that determine the total time of the project completion, taking into consideration the sequential relationships and the resource constraints. In case of unlimited resources, the critical chain definition is equivalent to the critical path definition. In the CC/BM method, instead of adding the protection margins to particular tasks, common buffers are created. They are inserted in the strategic places of the project; however, only the time of the whole project completion must be observed, not the times of completion of particular tasks.

In the buffer management method, it is proposed to implement an additional time margin at the end of the project's critical chain, or the so-called Project Buffer (*PB*), as well as insert additional buffers for the activities outside the chain, or the so-called Feeding Buffers (*FB*). The insertion of the additional buffers in the locations where the activities outside the critical chain are connected to the chain provides protection against interference in the course of the critical activity execution. Due to the fact that various resources may be required for the execution of particular processes belonging to the critical chain, the availability of such resources also outside the planned times is the condition for the continuity of the process performance. Signalling of earlier requests for critical resources is possible due to the Resource Buffers (*RB*) that are available in advance with respect to the critical-chain activities.

In the case of the problem with defined milestones, for each checkpoint km_i, critical chains are calculated. Next, for each km_i, the size of the protection margin $rezerwa_i$ (equivalent to the *PB*) is determined. The margin can be calculated as a certain fraction k of the duration of all the activities from the KM_i. The buffering level k is determined on the basis of schedule analysis. After determination of the

milestone buffer sizes, *FB's* and *RB's* are determined for particular critical chains. A drawback of that approach is the provision of robustness only for the schedule quality. The solution obtained during nominal scheduling is corrected, while further milestone attainment time protection is reduced to the protection of the tasks belonging to the critical chains.

6 Conclusions

In this paper, we have proposed new algorithms for the problem of predictive production scheduling, with the Resource-Constrained Project Scheduling Problem (*RCPSP*). Those algorithms are adjusted for making robust the activity sequences characterised by specific unsurpassable times of completion of particular tasks related to milestones. The calculation procedures presented here provide protections against exceeding the milestone completion times, although they also make the schedule robust in the locations that are most exposed to interference. Also, the activities whose possible delays would cause the largest instability costs are better protected. The algorithm operations are comparable owing to the defined robustness measures: the predictive scheduling objective functions.

Presently, our works concentrate on testing of the algorithms described here. The preliminary research results indicate the correctness of our procedures and the increased robustness of our schedules.

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The Bullwhip effect as a consequence of information dissipation within the supply chain system

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ABSTRACT

Supply chains represent complex and dynamic systems that incorporate autonomous firms interacting with one another to fulfill a common goal, while insuring their own ones. These firms' behaviors are considered to be non-linear and sometimes unpredictable. This makes information transfer in the supply chain complex and causes instability when information transferred is incomplete or incorrect. This instability is characterized by the Bullwhip Effect that represents concretization of entropy, namely the degree of disorder within a system. In this paper we develop a new analytical approach assuming that the bullwhip effect is a consequence of the entropy of the supply chain system that is represented by information dissipation.

Keywords — Supply chain system, entropy, information dissipation, bullwhip effect.

INTRODUCTION

In this last century, firms evolve in an extremely complex environment, constituted by open markets, globalization of sourcing, advancements in and intensive use of information technologies, decreasing product lifecycles, and increased demand. This complexity is intensified by consumers who are becoming increasingly demanding in terms of product quality and service. These pressures have led companies to focus on their core business, resulting in outsourcing of less profitable activities. Most of these companies have opted for specialization and differentiation strategies, resulting in rapid new market growth and intensified flow between all actors. The intensity and ever increasing complexity of these flows has further destabilized the environment in which companies evolve. Globally the system has become extremely volatile, making planning and predicting quite difficult for all actors concerned. Streamlining processes and flows through the value creation system has also become rather problematic as a result. To cope with this complexity, firms have adopted new business models around the concept of networks.

According to systems theory, supply chains can be considered as dynamic and complex systems composed of autonomous firms that interact with one another contributing to fulfilling a common goal. These firms' behaviors are actually non-linear, varying between cooperation and conflict. Firms create value by cooperation and capture it by competition. Zouaghi and Spalanzani [13] characterized this type of system as ago-antagonistic, in which bipolar strategies can be considered constructive, even if conflicting. One of the most important characteristics of this kind of system is its dissipative structure meaning that a supply chain is subject to information loss over time [2]. Dissipations in supply chain systems are due to several non-linearities emerging from different activities, such as demand forecasting, inventory management, transport management, production management, replenishment, warehousing, to mention but a few.

SUPPLY CHAIN SYSTEMS, ENTROPY AND INFORMATION DISSIPATION

Changing dynamics between the supply chain and its environment challenges management approaches inherited from Cartesian linear analytical thought. Linear thinking concerning demand forecasting and local optimization is no longer adequate when faced with increasing complexity of supply chains due to the factors seen above such as globalization, information technologies, etc. Unlike the Cartesian reductionist view, systems thinking sees the supply chain as a whole, representing more than the sum of its parts. Put simply, the supply chain has been defined by David et al. [4] as "a system of people, activities, information, and resources involved in creating a product and then moving it to the customer". Stevens [11] defines it as "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed-forward flow of materials and the feed-backward flow of information". Put otherwise, we can say that a supply chain is a system composed of a set of companies that interact with each other by way of different kinds of flows (material, financial, information, knowledge and

relational) to serve a common goal, which is customer satisfaction, within an uncertain environment.

Walker et al. [12], define uncertainty as "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system". This uncertainty can be materialized in a supply chain by demand uncertainty, production uncertainty and delivery uncertainty [3]. This uncertainty renders difficult supply chain system behavior predictability and thus lucid decision making. If we broaden our vision, we can say that a company's decision-making is a process requiring availability of reliable, exhaustive and real-time information and knowledge. The lack of these elements often results in decisions being made locally, without a global vision, and not taking into account the majority of potential knowledge issues that could optimize supply chain operations.

Moreover, supply chain dynamics oscillate between two main states: Order and Disorder. Basically, organization of the supply chain system is the ordering of existing disorder. Initially, the supply chain exists whether managed or not. So, the better a supply chain is managed, the less entropy subsists. Entropy is the effect of system disorder. For example, the more companies (as sub-systems) focus on local optimization at the expense of global optimization, the greater the entropy over the entire supply chain system. This entropy is principally generated by antagonistic subsystem behaviors due to nonlinear supply chain dynamics.

As we have seen above, the supply chain represents a complex system which is dynamic in nature. This is mainly due to complex, dynamic interactions undertaken between different subsystems which embody supply chain members. This complexity creates conditions conducive to the emergence and spread of different types of disturbances. These disturbances may have varying degrees of intensity depending on their causes and their initial conditions. While uncertainty remains the main cause, sources of disturbance in the supply chain system can be intrinsic or extrinsic. Extrinsic ones come from the environment in which the supply chain evolves, like for instance, the unpredictability of market demand. The second source of disturbance is intrinsic and derives from the supply chain itself, like planning or execution of logistics operations such as transportation, production and inventory management for example. Davis [5] distinguishes defines three categories of uncertainty in a supply chain, namely supply uncertainty, process uncertainty and demand uncertainty.

Most companies configure their supply chain to achieve "regular operational conditions". However, this is not always possible because "regular operational conditions" are distorted by disturbances, consequently producing dissipations within the supply chain. As defined in hard sciences, dissipation is energy loss in dynamic systems over time resulting from phenomena creating a disturbance. When applied to non-linear or chaotic systems dynamics, Prigogine and Stangers [9], cited by Saint-Amand [10], state that dissipative structure "reflects the association between the idea of order and the idea of waste and was purposely chosen to express the new fundamental fact: the dissipation of energy and matter, usually associated with ideas of performance loss and evolution towards disorder, becomes, far from equilibrium, a source of order". So, when joining order and disorder, entropy is manifested in complexity [10].

There are two main dynamics in which flow evolves (Table1). In the first, a system is stable and disturbances can be controlled, so actions can be performed to reduce small perturbations which have arisen over time. Here, flows are laminar and their cadence is regular, and their evolution in time and space is linear and predictable. The second dynamic is only visible if disturbances exceed a certain threshold. Thus, the initially laminar flow suddenly becomes a turbulent one after a short transition period. The disturbances are amplified and give rise to instabilities that make flows nonlinear and dissipative. The dissipation of flow is manifested by the non-spatiotemporal predictability of its evolution. The transition from laminar flow to nonlinear or chaotic flow depends on the speed of shift and acceleration of disturbances. All this depends on the initial conditions which determine the transition from a laminar flow to a turbulent one.

Dynamics	**Laminar**	**Transient**	**Turbulent**
Disturbances	quasi non-existent	sparsely intense	considerable
Flow	quasi clocked	non linear	chaotic
Stability and regularity	stable and regular	stable and irregular	unstable and irregular
Dissipation	insignificant	substantial	very important

Table1: Systems dynamics and their characteristics

Supply chain stability mainly depends on flow dynamics. Making the analogy between flow dynamics in fluid mechanics and supply chains can be interesting as it helps one understand how these dynamics evolve over time. Thus, we can equate the supply chain to a pipe in which the fluid flow represents physical and information flows. So, as they are laminar, flows evolve in a stable, steady and linear way in time and space. When extrinsic and intrinsic disturbances caused by different sources of uncertainty (demand forecasting, planning and execution of business processes) appear and cannot be mitigated, the supply chain dissipates flows to maintain a certain level of stability. The Bullwhip effect illustrates this well by showing how uncertainty related to market demand amplifies disturbances in the supply chain by increasing inventory levels, disrupting production and distribution, and by creating a disjuncture between the information flow and the physical flow of products that become as a result asynchronous in the form of supply chain information system dissipations. We will now characterize these dissipations in greater detail.

THE BULLWHIP EFFECT: CONSEQUENCE OF INFORMATION DISSIPATION WITHIN THE SUPPLY CHAIN SYSTEM

When overlaying features seen above on a supply chain outlook, we find that most of them fit this organizational configuration. The first one deals about the definition of ago-antagonistic couples. The analysis of supply chain as hybrid governance structure permit to identify some ago-antagonistic strategies, like for example lean versus agile strategy; integration versus outsourcing or hierarchy versus market governance; reactive versus proactive strategy and cooperative versus competitive strategy. To illustrate this point we can present some ago-antagonistic couples in the supply chain. Leanness and agility can be a good example. These two strategic positions are opposite, but their combination has constructive effects. Assimilating leanness and agility gives us what is called leagility which is a bipolar strategy. This one join the fact of having a schedule level by eliminating non-value added time and at the same time, best cope with changing demand by extra reduction of value-added time through production technology breakthroughs [8]. Another example concerns integration as opposed to outsourcing. Once articulated, these two contrasted strategies produce positive effect. Actually, the search of light integration by matching vertical integration and strategic outsourcing extends a company's product portfolio and success, which in turn allows the development of a competitive

To understand supply chain system complexity and dynamics, we will focus on information and physical flow to better anticipate its behavior. To illustrate this, we will first refer to the case of Procter & Gamble (P&G) diapers [7], to show that the market is not volatile, and final consumer demand is stable and characterized by low uncertainty; and that supply variations subsist and are accented along the supply chain. Despite this stability, stock levels are amplified in the supply chain from downstream to upstream.

This amplification phenomenon, known as the Bullwhip Effect, represents supply chain system instability mainly due to information asymmetry between companies. This asymmetry emerges and grows as inequality in terms of availability, access and sharing of information increases between companies. The Bullwhip Effect is not always the consequence of extrinsic demand uncertainty, but it embodies the intrinsic information entropy of dynamic, complex systems. Entropy is a measure of the level of informational disorder between supply chain system actors. In other terms, it characterizes the information loss within the system. Generally, entropy grows if nothing is done. This means that information loss is a growing phenomenon but may be regulated by negative entropy, called negentropy. The more entropy is present, the more rigid and inflexible the system becomes. Information loss and system rigidity represent sources of instability. Consequently, information quality, quantity and the mode of sharing it constitute important elements that contribute to making the supply chain system more stable.

Since the emergence and development of information technologies, companies have heavily invested in Electronic Data Interchange (EDI) solutions and extranets to coordinate their activities and create effective collaboration mechanisms within the supply chain. These solutions can ensure information transfer; however, they cannot certify the qualitative and quantitative accuracy of the information transferred. Indeed, sources of inaccuracy in the shared information are multiple. We can invoke human error while inputting data in a store, potentially leading to asynchrony in physical and accounting inventories, which are often transferred through EDI. We can also add to this inaccuracy due to synchronization delays between inventory movements, database updates and the time between receiving and recording goods. Other sources of instability are product "losses" in stores (loosing track of merchandise) [6], that lead to asynchrony between inventory information transmitted to partners and real inventory status. Companies regularly inventory merchandise in an effort to cope with information quality and quantity loss (two key factors in supply chain management), even though this technique remains ineffective [1].

Information loss is a source of uncertainty in the supply chain system and is characterized by a lack of upstream and downstream process visibility. In an effort to protect themselves against stock-outs, companies in the supply chain produce in "batch" with fairly long and quite variable lead times thus increasing the level of local stocks due to a localized optimization orientation, amplifying thereby the Bullwhip Effect.

Throughout the rest of the article we will make the assumption that demand is known and stable. We do this to isolate the environment effect on the supply system and focus only on entropy that characterizes the intrinsic complexity of the supply chain system. As said earlier, entropy is a measure of the informational disorder within a system. In the case of a supply chain, this entropy takes the form of informational disorder which is amplified as one moves along the chain from downstream to upstream. Indeed, entropy measures the probability of loosing information during transfer within the supply chain information system. This can manifest as missing information, lost wealth or accuracy, or speed of availability.

In Figure1 we show that entropy exists in all complex systems. It is responsible for disorder and the loss of informational quality and quantity that is contained in a system existing between actors. Entropy reduces inventory evolution visibility and negatively impacts all production, distribution and warehousing activities in the system, increasing uncertainty. Lack of visibility leads to significant intrinsic uncertainty, and as a result the system loses its flexibility and increases its rigidity. Companies generally use mass production (batch) to cope with situational risks, and therefore increase their inventory levels. The rigidity of the system results from the loss of visibility that increases from upstream to downstream in direct proportion to the overall system dynamic. This explains inventory fluctuation levels that increase as one goes up the supply chain.

Figure1 represents supply chain system entropy in its current state. We show that loss of information causes system rigidity.

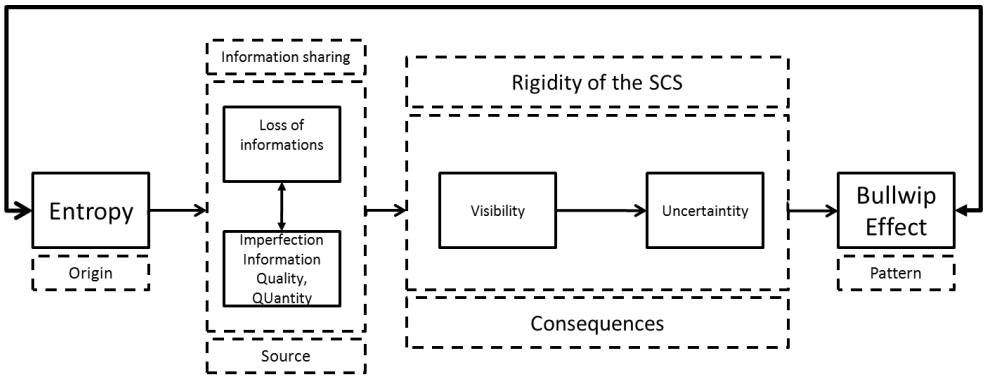


Figure1: Concretization of entropy in the supply chain system

CONCLUSION

As we have seen in this paper, supply chains represent complex, dynamic systems mainly due to the interactions carried out between diverse subsystems aka: supply chain members. We have seen that the dynamics fluctuate between order and disorder. Fundamentally, organization of a supply chain system is the creation of order out of current disorder by effective management. Admittedly, supply chains exist whether managed or not. So, the better a supply chain is organized, the lower the levels of subsisting entropy. This entropy is manifested in supply chain system disorder, and is principally generated by incompatible subsystem behaviors due to non-global management orientation. It is concretized by information dissipation or loss. The impact of this information loss remains a source of uncertainty inherent in the supply chain system. It is characterized by a lack of upstream and downstream process visibility, the amplification of which is described in the Bullwhip Effect.

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The Effect of Computer Anxiety on Enneagram

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ABSTRACT

The primary objective of this study is to ascertain the effect of computer stressors on the users' anxiety level and their Enneagram personality type. A set of questionnaire was developed in lieu of this. The data obtained were analyzed using the One-way Analysis of Variance. An important finding from this study revealed that the Enneagram types were affected by the computer stressors. The findings also revealed that the levels of anxiousness experienced by the Enneagram types vary. The differences in the levels were attributed to the components of the Enneagram. This is a pioneer study that applied Enneagram in rationalizing the effects of computer anxieties on users.

Keywords: Enneagram, computer anxiety, stressors, personality

INTRODUCTION

Frustration with technology is a major reason why individuals cannot use computers to reach their goal, hesitate to use computers or avoid computers altogether [23]. Many factors account for the cause of frustration among users, for example the design of the system, sufficient training and documentation and tech support [21]. Frustration may occur from typical keyboard typing errors to atypical ones like system crashes. Negative feelings such as frustration and anxieties caused by a computer have been recognized as a psychological phenomenon and works as a negative moderator for stress [27]. While good interface designs, up-to-date hardware, clear user documentations and sufficient trainings may assist in reducing the anxiety of the users for a particular incident, there is room for other methods that could impact the users' frustration. Thus, by examining the root causes of these frustrations from the psychological point of view, i.e. the personality type, developers may be able to approach their designs more effectively.

The fundamental question that this paper attempts to answer is how do individuals with different personality type perceive the effects of computer stressors? Individuals may have different views on how a computer stressor affects them – one individual might feel slightly anxious by it, while the other is severely anxious and yet another is not affected at all. The attempt to fill this gap is mainly influenced by the lack of prior studies linking personality typing methodologies, in particular, the Enneagram to computer stressors [25, 36].

LITERATURE REVIEW

Many researchers had studied on the relationship between computer anxiety and personality type. Anthony, Clarke and Anderson [1], as well as Korukonda [20], found positive correlation between anxiety and the Five-Factor Model. Anthony et al. [1] reported a positive correlation between computer anxiety and Neuroticism, whereas Openness had a negative correlation with anxiety. For individuals with low scores on Openness, Anthony et al. predicted these individuals were hesitant towards using the computer technology due to their tendency to avoid the unfamiliar and may feel challenged by the constantly changing environment of computers. However, an earlier research conducted by Hudiburg, Pashaj and Wolfe [17] indicated no direct relationship between the stressors and any of the five personality dimension with the exception of Openness. The mixed and somewhat contradictory findings of Anthony et al. [1] and Hudiburg et al. [17] prompted Korukonda [20] to examine the above mentioned relationship. Using 242 students from a private university in Western New York, Korukonda [20] found a strong positive correlation between Neuroticism with computer anxiety, whereas negative correlations were found between Openness and Extraversion with computer anxiety. The findings provided a stronger support and extended the conclusion of Anthony et al.'s [1] study.

Another type of personality typing methodology, Holland Types, was used to determine the levels of computer anxiety by Bellando and Winer [2]. Holland Types is used to determine an individual's career interests using six general career personality types. The six types, depicted in a hexagon, are: Realistic, Investigative, Artistic, Social, Enterprising and Conventional. Bellando and Winer's [2] study revealed two of the Holland types, Artistic and Social, had a significantly higher computer anxiety, while the remaining four types reported no significant differences.

In the proposed Computer Frustration Model by Bessiere, Newhagen, Robinson and Shneiderman [5], computer anxiety was included as one of the individual (dispositional) factors, alongside with other computer variables (experience, self-efficacy and attitude). Another individual (dispositional) level factor proposed was the psychological factor. However, to our knowledge, there was no study that links computer anxiety and psychological factor, especially in the personality traits of the users.

Although the Enneagram had been integrated into modern sciences, in particular to businesses and management applications, yet the Enneagram's application had been limited in the area of computing. Specifically, Enneagram had not been used to gauge the anxiety level of computer users and the type of stressors causing it. Thus, the gaps presented here lead us to this study.

RESEARCH FRAMEWORK

A research framework is proposed to test the influence of personality type on a computer user's anxiety level. Figure 1 represents the diagrammatically visualized research framework.

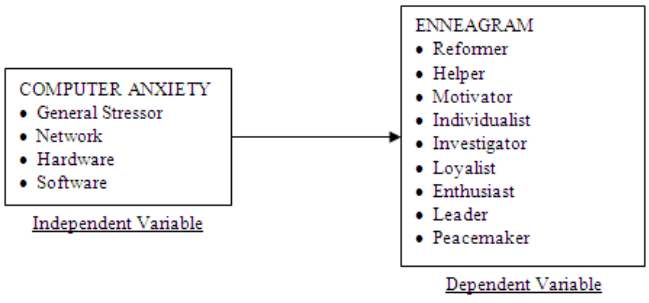


Figure 1. Research framework.

Based on the literature review conducted on computer anxiety, the computer anxiety component was extracted out to serve as the independent variable. The independent variable measures causes of the computer anxieties as it influences how a user perceives and reacts toward the anxiety. A factor analysis was conducted and 15 stressors were proposed based on common problems that a user encounters while interacting with computer stressors. The results of the factor analysis, along with other tests which include the Kaiser-Meyer-Olkin (KMO), the Bartlett's test of sphericity and the fit measures of the Confirmatory Factor Analysis (CFA) test, lead to the extraction of three factors from the analysis, and was renamed to *Software*, *Network*, and *Hardware* group. Table 1 highlights the results of these tests.

Statistical Test	Results
Factor analysis	Alpha coefficient: 0.831 (Software), 0.820 (Network), 0.794 (Hardware)
Kaiser-Meyer-Olkin (KMO)	0.886
Bartlett's test of sphericity	0.000
Confirmatory Factor Analysis (CFA) test	Chi-square = 330.831, p-value = 0.000, Ratio = 3.803, AGFI = 0.823, CFI = 0.878, PCFI = 0.727, RMSEA = 0.095

Table 1. Summary of statistical tests and their results.

Another group was formed and named to *General Stressor* to test the overall effect of the stressors on the personality types. This group contains all 15 stressors and as such, the previous three groups mentioned earlier fall under the *General Stressor*'s subset.

The Enneagram serves as the personality typing tool and will serve as the dependent variable. The Enneagram was chosen in this study over other personality typing methodologies due to several reasons. In order to measure what stressors could cause anxiety in an individual, we need to know the basic characteristics of that individual so as to better understand the true reason for the way that individual behaved. The Enneagram measures the underlying motivation of an individual, rather than on behaviours, unlike other personality typing methodologies (MBTI®, KTS, The Big Five and Global 5-SLOAN) [9, 35]. Along with that, it also delves into the negative side of the individual's personality to shed some light on the individual's faults and what he or she needs to change to address the faults [8].

While other personality typing methodologies distinguishes an individual based on their behaviours, there remains the question that two individuals may behave similarly, but for different reasons. Behaviours are influenced by social norms, hence, an individual may behave differently depending on factors such as the situation and the culture that he or she is in at that moment. Thus, behaviours may change from time to time, but the underlying motivation for behaving in that particular way remains. Measuring an individual's personality type using the Enneagram then, is said to be better, as the individual's main Enneagram type will not change [33].

We believe the Enneagram is the basic point for all other personality type measurements. As it measures motivation,

the Enneagram can be used to complement other personality type measurements, thus contributing further to understanding the nature of human beings. For example, studies had been done to correlate the Enneagram with the Jungian [19] typology [11, 12, 14, 29, 31] and also with the MBTI [9, 10, 13, 14, 18, 38]**.** This serves to strengthen our choice of adopting the Enneagram in our study.

RESEARCH METHOD

A questionnaire with three sections was developed with regards to the concepts above. Questions in Section A were in the form of either open or close ended questions, while the rest of the sections' questions were developed using close-ended format. Section A solicits respondents' standard demographic and social connotation information, working experience and experience of using the computer, daily hours using the computer and the level of proficiency on the usage of computers. These questions were administered based on the importance given in the Computer Frustration Model [5]. The data in this section were a mixture of nominal ordinal and interval in nature.

Section B contains 36 questions adapted from the scientifically validated Riso-Hudson Enneagram Type indicator (RHETI) test [28, 34] to determine the Enneagram personality type of the respondents. The RHETI is in the form of forced-choice questions which respondents have to choose from. Each choice will lead to different personality type scores and the total score will determine the most likely personality type of a respondent.

Section C contains 15 short statements which characterize a variety of stressors in working with computers. The statements were administered to evaluate the impact of the stressors on the respondents' anxiety level. The stressors administered in this section were based on the extensive research done by numerous researchers [15, 16, 22, 23, 24, 26, 32, 34]. The partial semantic autonomy scale [7] was adopted to measure the extent of respondents' anxiety level. A five-point scaling was employed for our study following similar scaling by Weil, Sears and Rosen [37]. The scaling are: 'not at all severe', 'slightly severe', 'moderately severe', 'severe' and 'extremely severe', denoted by points 1 to 5.

The population of interest in this study was working professionals from states across the Peninsular of Malaysia. The target respondents were those working professionals who are using the computers in their daily tasks. The target respondents however, did not include those under the age of 18 and above the age of 60. Those below the age of 18 are assumed to be still schooling, while those above the age of 60 are assumed to have retired, since the majority of retirees in Malaysia are 56 and above.

Respondents were not biased against gender, race, status or occupation. However, respondents are chosen to be those whose job scope requires them to use the computers for at least a portion of the workload. This is to prevent bias results for the computer anxiety level due to jitters of not having the experience in managing the computers.

The data collection was of cross-sectional in nature. The questionnaires were distributed via three main methods. The methods are outlined in Table 2, along with the total number of questionnaires distributed and returned, the rate of return and the valid number of questionnaires for each method. The final sample, after data filtration was done, was a total of 310 with the overall response rate of approximately 39.56% to be used for the statistical analyses.

Method	Total Number Distributed	Total Returned	Rate of Return	Valid Number
Hand-delivered	350	145	41.43%	128
Mail	300	97	32.33%	84
Web survey	255	116	45.49%	98

Table 2. Summary of data collection.

RESULTS AND DISCUSSION

The effects of computer stressors on individuals with different personality types using the Enneagram typing along with the motivations behind the differences of the perceived anxiety levels will be investigated. The breakdown of the respondents according to their Enneagram personality types is depicted in Table 3.

Personality Type	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Reformer	30	9.7	9.7	9.7
Helper	69	22.3	22.3	31.9
Motivator	37	11.9	11.9	43.9
Individualist	27	8.7	8.7	52.6
Investigator	20	6.5	6.5	59.0
Loyalist	32	10.3	10.3	69.4
Enthusiast	38	12.3	12.3	81.6
Leader	20	6.5	6.5	88.1
Peacemaker	37	11.9	11.9	100.0
Total	310	100.0	100.0	

Table 3. Number of respondents according to their personality type.

The difference in the sample size for each Enneagram type, in particular Helper, Investigator and Leader may be attributed to the respondents' misidentification of their basic types. Average Helpers, like women, have well-

intentions toward others. They tend to desire being closer to others, forming friendships, giving support, being needed, overbearing and are not fond of others taking them for granted. Women, who are actually Peacemakers, also have a tendency to misidentify themselves as Helpers [30]. Peacemakers, when out of touch from their instinctual strengths, retreat into their inner self i.e. their minds and emotional desire, which mimics Helpers' identity.

Misidentification of the personality types can also be attributed to similarities of the traits in the nine types. For example, Investigators may confuse themselves as Reformers, as both types correspond to Jungian thinking types – Reformers to the extroverted and the Investigators to the introverted thinking type [29]. Investigators, especially females, also might confuse themselves as Individualists. Since Individualists are more feeling-oriented and Investigators are more intellectual, having deep feelings would make Investigators assume that they are Individualists [30]. Leaders can be confused with Motivators or Enthusiasts. These three types are all aggressive types – Motivators towards their goals and to others, Enthusiasts towards their environment, while Leaders are the mixture of both Motivators and Enthusiasts [29].

Although similar traits may be observed between the Enneagram types which lead to misidentification, however, the key point to these similarities is the differences in their motivations, i.e. why they may behave in a particular manner. However, apart from misidentification, another possible reason for the lowest number of respondents for types Investigator and Leader is that the administration of the questionnaire was random. As such, we could not know in advance the respondents' Enneagram type. It is possible that coincidentally, the individuals we approached as our respondents were not of types Investigator and Leader.

Since we are investigating whether the nine Enneagram types' means on the computer stressors differ significantly from one another, the One-way ANOVA test was selected to evaluate the effects. The test was evaluated for *General Stressor* and the three groups of stressors – *Network*, *Software* and *Hardware*. For each of the tests, it assesses whether means of the *General Stressor*, *Network*, *Software* and *Hardware* is significantly different among the nine personality types. The results for the tests are presented in Table 4.

All F-values obtained were lesser than the F critical of 1.9384. Hence, the p-values were rejected for *General Stressor*, *Network*, *Software* and *Hardware* respectively. In light of the non-significant analyses, the independent samples t-test was conducted for each of the four analyses as a complementary to the ANOVA. An independent samples t-test is used when comparing the means on a dependent variable for two independent groups. The One-way ANOVA's F-tests are equivalent to the t-tests, therefore leading to the same answer [3] and confirming the validity of running the t-test as a complementary test to the ANOVA. Since the possibility of obtaining a significant mean difference is higher for personality types with the highest and lowest mean, these two personality type groups were selected as the independent groups in each of the dependent group (*General Stressor*, *Network*, *Software* and *Hardware*).

	One-way ANOVA test		Mean		Independent Samples t-test	
	F-value	p-value	Group 1	Group 2	t-value	p-value
General Stressor	0.931	0.491	Reformer = 2.7778	Enthusiast = 3.1544	-2.606	0.011
Network	1.413	0.190	Reformer = 3.0444	Enthusiast = 3.5658	-2.889	0.005
Software	0.905	0.512	Motivator = 2.5180	Leader = 2.8917	-1.798	0.078
Hardware	0.451	0.889	Motivator = 2.6847	Enthusiast = 2.9737	-1.364	0.177

Table 4. Summary of the one-way ANOVA, mean and independent samples t-test.

The F statistics for Levene's test is used to test if the spread of the groups differs. Since the F-test for all four t-tests were not significant ($p > 0.05$), the two groups in each test were assumed to come from populations with equal variances. The two-tailed t-test yielded significant results for *General Stressor* and *Network*, indicating the significant effects between personality types and anxiety levels. Enthusiasts appear to have higher mean when compared to Reformers, in both analyses, indicating a higher level of anxiety.

Enthusiasts' anxiety level is higher than Reformers as they have problems with anxiety. They are anxious due to their inability to cope with the situation. Specifically, Enthusiasts' are anxious and fearful about their ability to cope with their inner environment – their grief, loss and anxiety [29]. As such, they seek for solace in the outer environment to avoid dealing with their anxieties. At the point of anxiousness, Enthusiasts search for activities and experiences that keep them occupied and momentarily repress their anxiety. By occupying themselves, they feel in control of their pain and anxiety. Dealing with anxieties draw them inward, making them more anxious, hence they get involve with more experiences.

However, the more activities they devote themselves to, the less they are in touch with whatever experiences they are having at that moment, thus increasing their anxiety. This is due to several reasons. Due to the lost of touch and enjoyment of the experiences, Enthusiasts tend to overdo their activities even more, becoming more anxious and dissipate themselves more. As anxiety increases, Enthusiasts minds will be occupied about the future [29], for example thinking about the next activity that they should do to repress their anxiety even though they have just began on a present activity, without giving themselves

a chance to fully experience the activity that might be able to quell their anxiety. These behaviors are evident when Enthusiasts disintegrates into Type One (Reformers) regardless of the level of anxiety Enthusiasts are feeling (for example moderate level in the *General Stressor* group or almost severe level in the *Network* group), Enthusiasts would always feel that they are missing out on something better and resenting themselves from truly enjoying the present experience. According to Riso and Hudson, until Enthusiasts allow themselves the chance to deal with their inner environment, they will always have problems with anxiety and develop a pattern of thinking and behaving as a defense against it.

Reformers, disintegrating into Type 4 (Individualists) when they are anxious, have lower anxiety level compared to Enthusiasts as they tend to repress their anxiety in pursuit for perfection. In particular, they want others to see them as rational and balanced people. Because Reformers always see themselves as less than ideal, "they constantly measure not only the distance between themselves and their ideal, but also the distance between their present perfection and their past imperfection" [29]. Hence, no matter how rational they were in the past while dealing with anxieties, Reformers would still compare themselves with their ideal, repressing their present anxiety more to improve on their past imperfection like controlling their actions and responses in front of others. However, even though they attempt to keep their repressed feelings in check as much as possible, they are not as successful as they want themselves to be, thus explaining why Reformers still do experience anxieties from time to time. Though they long to be free of anxieties, yet Reformers feel guilty for letting their guard down and become even stricter with themselves. The higher the level of anxiety Reformers tries to repressed, the more self- conscious they are with society, forcing them to get their acts together as cover-ups in others' eyes. As such, even though Reformers may be experiencing heighten anxiety, they would not let their feelings be transparent.

CONCLUSION

Based on our findings, it was evident that when different personality types were exposed to a same stressor, they perceive a stressor at different levels of anxiety. The research identified two personality types – Enthusiasts and Reformers, which were affected by a set of *General Stressor* and *Network* stressor. Enthusiasts were more likely to be anxious in stressful conditions than Reformers, due to their traits discussed and how these types disintegrate into their respective types in the Direction of Disintegration. Enthusiasts, regressing into Reformers, tend to feel they are missing out on something greater, thus further occupying themselves which increases their anxiety. Reformers, on the other hand, regressing into Individualists, would like to be perfect in everything, including being able to control their emotions and hence tend to repress their anxiety. Thus, with such results, it can be summed that an effect exists between the personality types and the anxiety levels of users.

Although a limited number of personality types exhibited significant effect, nonetheless, the results obtained implies a possibility that an individual's personality type influences his or her anxiety level. We believe that a more comprehensive set of stressors to measure the different stressor categories along with a standard and larger sample size for each of the nine personality types would enable a possibility of other personality types to have significant differences in their level of anxiety. Although our present research was limited in such aspects, nevertheless, the small but significant results are undeniable.

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The systemics of supply chain complex behavioral interactions

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ABSTRACT

In supply chains, which are organizational systems that integrate complex behavioral interactions, partners adopt bipolar strategies that join paradoxical and constructive behaviors to evolve in nowadays environment. This enables them, on one hand, to converge towards common interests through the development of cooperative actions and strategies; and on the other hand, to deviate on their own interests by adopting competitive maneuvers. This dynamics generates an ago-antagonistic system where both of these two concepts, namely cooperation and competition, simultaneously drive the supply chain. In the present article, this system is analyzed by using ago-antagonistic systems theory in order to have a new apprehension of the supply chain approach.

Keywords — Supply chain, ago-antagonistic system, bipolar strategies.

INTRODUCTION

Defined as hierarchical, dynamic and process oriented networks, supply chains are composed of a set of companies, linked by upstream and downstream flows and diverse level relationships, established in order to satisfy customers through superior coordination and integration, but also greater flexibility and responsiveness. These organizational structures can be presented as inevitable phenomena arising from a need for coordination and flexibility among a set of companies. In this sense, supply chains exist, whether managed or not [6].

The Transaction Costs Theory (TCT), initiated by Coase [15] and developed by Williamson [11] allows us to understand the governance structure that drives firms. Transaction costs represent the sum of three main features of exchange between firms, specifically the costs of coordination between different actors, risks relating to operations and risks of opportunism [16]. Clemons et al. [16] state that coordination costs reflect the costs of information exchange (product, demand, inventory, production capacity ...), those related to the integration of this information in the decision-making process, and costs related to delays due to communication problems. Risks relating to operations are risks of misinformation or voluntary information withholding. Finally, the risks of opportunism include risks relating to the lack of bargaining power or its loss. From this basic principle, companies can choose from two forms of governance: an internalization of their activities leading to hierarchy governance, or outsourcing some of them by a market one. The first alternative mainly revolves around integration mechanisms, such as monitoring, procedures or authority. While the second alternative, is mainly a sub-contract option.

Although, are to bring to light structures that do not have a typical form of governance, those which are midway between market and hierarchy. These structures are mainly characterized by network configurations that have a particular form of organization. Supply chain is a particular kind of network. It is a hierarchical, dynamic and process oriented network that require both cooperation and competition efforts. This hybrid form of governance structure, integrate advantages of both other forms of governance, namely the market and the hierarchy, reducing at the same time, their disadvantages. In other words, companies remain legally independent, retaining their identity, their culture and their capabilities, and also a structural flexibility, while being in close collaboration with other companies in pursuing their common goals.

Cooper et al. [17] define supply chain management as an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user. The principal objective of SCM is to maximize the value created, not just for one company but for the whole supply chain, including the end customer. Mentzer et al. [11] (p.18) defines it as '*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole*'. Concisely, SCM is material, informational and financial flows management from the first supplier to end customer. Therefore, supply chain process integration and re-engineering should concern efficiency and effectiveness of all processes across its members [18].

The integration of the supply chain is neither evident nor automatic. Lambert and Cooper [19] stipulate that it is necessary, first, to identify activities and key members to integrate, while recognizing that an excessive integration could be detrimental to the performance of the supply chain. Then, since the drivers for integration are situational and different from process link to other, the levels of integration differ from link to link, and also vary over time. Finally, the integration of the supply chain also depends on certain organizational factors

such as: trust, commitment, interdependence, organizational compatibility, vision, leadership and top management support [11].

Some researchers stress on the necessary sense of balance between the practice of a lean management and an agile one [20]-[21]-[22]. Naylor et al. [20] state that leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule. While agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. Fabbe-Costes [22] affirms that on one hand, the practice of lean management helps integrating the supply chain by the adaptation of all its actors, to ensure cost reduction and improved service level in operational process logic. On the other hand, agile management generate flexibility (static and dynamic) and adaptability of processes, organizations and supply chains to cope with instability, turbulence, uncertainty and risks in the environment. Likewise, agility has been defined as the ability of an organization to quickly respond to changes in demand, both in terms of volume and variety [23].

In supply chain management, integration and outsourcing are both important. This has lead academics and professionals to combine lean and agile approaches, producing the concept of 'leagile' management [20]. Leagile is adopted by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the market place [24]. The decoupling point is the point that separates activities based on customer orders from those founded on planning and forecasting [25].

Today, two paradigms drive the supply chain at the same time. Cooperative paradigm identifies the supply chain as a whole that is greater than the sum of its parts, not as a fragmented set of entities, against which each member acts for its own [7]. This approach mobilizes concepts such as integration, coordination, collaboration, information sharing, convergent interests and common competitive advantage. The other paradigm focuses on the need of competition between members. Based respectively on works of Smith [8], Nelson [9], Schumpeter [10] and Williamson [11]; Lado et al. [12] affirm that competition generate economic efficiencies by enabling companies to optimally allocate scarce resources, providing the impetus for innovation and entrepreneurship, and reducing transaction costs between them. Furthermore, companies that constitute the supply chain are partially characterized by self interests and individual rationality. All this allow the supply chain to be agile and flexible. These conditions are necessary to cope with a disruptive and unstable environment, and provide the possibility for change and innovation. So, how do these opposite or different behaviors and strategies interact with one another? And how do it generate positive outputs?

To answer these questions, we focus on ago-antagonistic approach within supply chains, to underline the importance of both of these concepts that are paradoxical and complementary at the same time, and which constitute its principal motive. Such an approach will be analyzed and justified through ago-antagonistic systems theory [13], which study phenomena associating bipolar strategies and opposite or different behaviors. After that, we will analyze supply chain with the ago-antagonistic system (AAS) theory, and finish with examples from supply chain management empirical literature to illustrate our arguments.

WHAT IS THE AGO-ANTAGONISTIC SYSTEM THEORY?

After world wars, the general systems theory has come to explain a large range of phenomenon by integrating different sciences (Hard and Social sciences) in the same paradigmatic framework, challenging by the way physics and biology conformism (Von Bertalanffy and Sutherland, 1974). However, even if this theory claims to a large framework, converted scientists from hard sciences gave it back quite rigid. The notions of complexity, self-organization, homeostasis, teleonomy, and so on, became incontrovertible foundations of this so called "general" systems theory. Nevertheless, the combination of complexity and simplicity, self-organization and hetero-organization, homeostasis and homeorhetic in the same systemic framework doesn't exist.

Therefore, a so called Ago-Antagonistic Systems (AAS) came to allow greater flexibility in apprehension of lots of phenomena. AAS approach associate concepts that were typically opposed. The notion 'ago-antagonistic' is composed of the term 'antagonistic', which is employed to indicate the conflictuality of the couple's poles (opposite or only different), and 'agonistic', which means that this conflictuality has a positive and non-destructive impacts (Bernard-Weil, 2003). Accordingly, it implicates bipolar strategies by combining cooperation and conflict in the same occurrence (Bernard-Weil, 2002a).

Bernard-Weil (2002b; 2003) states that this theory is based on eight key features. The definition of an ago-antagonistic couple presents the first feature. It does mean that the system is concerned about three major things: a couple of forces, a regulator and a receiver. The second feature is about the dissipative structure of the AAS, which is specified by the equilibration against a standard view. More precisely, an AAS has two equilibrium states: natural equilibrium or pathological equilibrium. In other terms, the equilibration can be asymptotic, oscillating around the equilibrium point or chaotic. The third feature tells us that the ago-antagonistic combination of elementary ago-antagonistic models bring out an ago-antagonistic network. Indeed, the network structure agrees dialectics view of hierarchy and autonomy, and at the same time underlines that acting on one part of the network can impact the whole network. The forth one is that the AAS is governed by the constituent division. This feature admits that one pole acts for its own interest while performing a common goal. The fifth feature is that the AAS integrate dichotomies in the same logic, viz. a series of properties usually incompatible with each other, like for example synchronic and diachronic, open and closed, simple and complex, hierarchical and autonomous, and so on. The sixth one highlights the notion of pathological homeostasis of an AAS, that allows recognizing strategies, yet unusual, AAS theory may lead. The last but one feature stresses on existing wrong ago-antagonistic couples like good and evil for example, despite their apparent opposition. The last one is somewhat difficult to understand. It deals about the complicated apprehension of the meta-model of the ago-antagonistic model. Every model, even those claiming to universality, requires a meta-model (Bernard-Weil, 1999), and the one of ago-antagonistic model is not yet acknowledged.

To better apprehend this approach, we present the MMRAAC (Mathematical Model for the Regulation of

Agonistic Antagonistic Couples) developed by Bernard-Weil [28]:

First, we have to specify the fact that two conditions allow a normal functioning, that is maintained by a homeostatic homeorhetic regulation are:

$$\begin{cases} x - y = c_1 \\ x + y = c_2 \end{cases}$$

Knowing that: (x, y) represent a couple of ago-antagonistic features, c_1 is a constant (generally:$c_1 = 0$) characterizing the antagonistic equilibrium, and c_2 is a constant (or a time relative variable) characterizing agonistic equilibrium. We have:

$$\dot{x} = \sum_i k_i (u + r)^i + \sum_i c_i (v + s)^i,$$
$$\dot{y} = \sum_i k'_i (u + r)^i + \sum_i c'_i (v + s)^i,$$
$$\dot{X} = \sum_i k_{i+4} (u + r)^i + \sum_i c_{i+4} (v + s)^i + \Lambda_1,$$
$$\dot{Y} = \sum_i k'_{i+4} (u + r)^i + \sum_i c'_{i+4} (v + s)^i + \Lambda_2,$$

Wherein

- $\Lambda_1 = \sum_i \lambda_j (X - \bar{X})^j$, $\Lambda_2 = \sum_i \lambda'_j (Y - \bar{Y})^j$; $i = 1,2,3$, $j = 1,2,3$.
  Λ_1, Λ_2: penalty function that permit to keep away from the drift of the limit-cycle of dimension 4 (x, y, X, Y)
- $x(t)$, $y(t)$: state variables ; $X(t)$, $Y(t)$: control variables ; k_i, c_i, m, n: constant parameters or variable in relation to time ; $g(t)$: a synchronizer ; $p(t)$, $q(t)$: respectively antagonistic and agonistic forces.
- $\boldsymbol{u(t)} = x(t) - y(t) + n + p(t)$; $\boldsymbol{r(t)} = X(t) - Y(t)$; $\boldsymbol{v(t)} = x(t) + y(t) - m + g(t) + q(t)$; $\boldsymbol{s(t)} = X(t) + Y(t)$.

SUPPLY CHAINS THROUGH AGO-ANTAGONISTIC SYSTEM THEORY LENS

When overlaying features seen above on a supply chain outlook, we find that most of them fit this organizational configuration. The first one deals about the definition of ago-antagonistic couples. The analysis of supply chain as hybrid governance structure permit to identify some ago-antagonistic strategies, like for example lean versus agile strategy; integration versus outsourcing or hierarchy versus market governance; reactive versus proactive strategy and cooperative versus competitive strategy. To illustrate this point we can present some ago-antagonistic couples in the supply chain. Leanness and agility can be a good example. These two strategic positions are opposite, but their combination has constructive effects. Assimilating leanness and agility gives us what is called leagility which is a bipolar strategy. This one join the fact of having a schedule level by eliminating non-value added time and at the same time, best cope with changing demand by extra reduction of value-added time through production technology breakthroughs (Naylor et al, 1996; Mason-Jones et al., 1999). Another example concerns integration as opposed to outsourcing. Once articulated, these two contrasted strategies produce positive effect. Actually, the search of light integration by matching vertical integration and strategic outsourcing extends a company's product portfolio and success, which in turn allows the development of a competitive advantage and thus contribute to performance (Rothaermel et al., 2006). Another case can be highlighted. Reactive strategies contrasted with proactive ones are differentiated in the literature, but their combination produce a positive and constructive effect. In this way, Lambrechts et al. (2008) stipulate that proactive-reactive scheduling entail an assortment of a proactive strategy that insures a protected baseline schedule with a reactive strategy that allow to cope with this schedule's infeasibilities caused by the distortions when performed. Another frequent example is the couple cooperative and competitive strategy. These two strategies are visibly unrelated. However, they constitute a bipolar strategy that has beneficial and positive effects. Dagnino and Padula (2002) tell us that the co-opetitive perspective come from the fact that value creation and value sharing processes occur together, allowing the development of quite convergent interest structure where both competitive and cooperative strategies are performed at the same time.

The second feature relative to the dissipative structure of the ago-antagonistic model is verified in supply chains. Actually, supply chains evolve in uncertain environment giving rise to flow non-linearity. This makes it striving to attain an asymptotic equilibrium (Giacomo and Patrizi, 2006) or chaotic one (Winding, 1996). Furthermore, there is a set of plausible equilibria (Cachon and Netessine, 2006), oscillating around a mean. The third feature, dealing with ago-antagonistic network, is also verified by the fact that the supply chain is composed of ago-antagonistic couples that constitute an ago-antagonistic network. Furthermore, regulating action on one couple may rebalance the overall network. The fourth characteristic relative to the concept constituent division can be perceived in the hybrid configuration of the supply chain structure. In fact, entities in supply chains are heterogeneous and have different interests, objectives and constraints, but when it comes to common value creation, they integrate their processes to achieve cost, quality or delay objectives or others Swaminathan et al. (1998).

The fifth feature deals about dichotomies. Lots of strategies adopted in the supply chain are dichotomous, like for example cooperation and competition that have incompatible basic properties. In more concise terms, everyone seeks the benefit until it is moderated by system regulations. The sixth feature which treats about pathological autonomy or homeostasis is noticeable in a supply chain. Supply chain represents a non-linear system that changes to maintain certain stability or equilibrium (homeostasis), or oscillate between plausible equilibria, as mentioned by (Cachon and Netessine, 2006) (pathological equilibrium). The seventh characteristic deals about wrong or false ago-antagonistic couples. In a supply chain approach, we, generally, do not combine wrong ago-antagonistic couples to generate a bipolar strategy. We perform contrasted strategies that generate positive and non-destructive effects. The last characteristic is about the meta-model of the supply chain approach. We consider that the meta-model of the supply chain is the network model. As long as we consider that the supply chain is a specific type of network, network theory remains the meta-model of the supply chain approach.

To conclude, when examining these features, we recognize that the supply chain remains ago-antagonistic behavioral system. Additionally, we can add the fact that the supply chain

system dominance comes from the fact that it allows the implementation of contrasted or even opposing strategies. In such organizational configuration partners try to design best strategies to insure both global and individual performance. This pushes partners to adopt a special game which starts with a win-win objective and ends with a zero sum intention.

EXAMPLES FROM SUPPLY CHAIN MANAGEMENT EMPIRICAL STUDIES

A lot of works have been done to materialize bipolar strategies adopted by organizations in different logistics and supply chain management fields. Concerning sourcing strategies, some companies adopt hybrid sourcing strategies, known as parallel sourcing strategies [49]. This kind of bilateral strategy integrates cooperation and competition in the same rational. It permits a company to establish cooperative relationships with each supplier, while maintaining competition between them [50]. In this way, Richardson [49] demonstrates, in a study of Japanese automobile industry using game theory, that parallel sourcing is better than sole sourcing depends on the sum of the setup costs for parallel source opposed to the lower trading and competitiveness costs resulting from higher supplier performance.

Likewise, as we saw above, leagile manufacturing strategies, integrating a lean and an agile vision are more and more adopted by companies, by shifting the decoupling point according to their objectives, capabilities and constraints. Naylor et al. [20] demonstrates that, in a PC manufacturing, companies definitely combine the two paradigms, using the decoupling point as a buffer between the variable demand for the paramount part of products and the level production schedule for some of the components. Qi et al. [51] support this argument by confirming that in some situations, these approaches can be combined together to enable a total supply chain strategy, which includes the best of both of them. However, we think that in this case, bipolar strategies can refer to leagile ones. As Naylor et al. [20] state, leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule. This requires close cooperation between the different members of the supply chain to ensure such a paradigm. On the other hand, agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace [20]. This is a strategy which is based more on a competition spirit and value-capturing within the chain. But we do believe that bipolar strategies fits more cases where, for example, there is a supplier which manufactures the same component for two competitors. Here, companies cooperate on some of their manufacturing activities, while competing in others, such as marketing, sales, etc.

IT strategies can also be good examples. Chin [52] studied the chemical process industries in American companies. Bipolar strategies were principally characterized by the establishment of a kind of e-marketplaces, namely e-hub, to connect multiple buyers to multiple suppliers by linking their ERP (Enterprise Resource Planning) systems. This e-hub is an inter-organizational system that permits competing companies to cooperate within their supply chain. This ago-antagonistic strategy enhanced performance of a big number of supply chain members.

Concerning inventory, Cachon and Zipskin [53] studied competitive and cooperative inventory policies in a two-stage supply chain using game theory. They demonstrate that games have generally a unique Nash equilibrium that differs from the optimal solution. They conclude from this point that competition reduces efficiency. Moreover, they show that value of cooperation is context specific. They stipulate that in some settings competition increases total cost by only a fraction of a percent, whereas in other settings the cost increase is enormous. So companies have to find a consensus on how the total cost will be allocated, and this suggests coopetitive solution in which companies act both in cooperative and competitive way [54].

CONCLUSION

The principal aim of this article is a theoretical approximation in order to better apprehend the supply chain dynamics. The ago-antagonistic approach belongs to the systemic nebula, but is a bit original. It allows us to see that systems are subject to paradoxical forces, but that their combination produces a positive and non-destructive effect.

This approach is perfectly suited to the paradigmatic context of the supply chain. So, developing a common analytical framework seems quite fecund for further research. This will allow understanding a lot of supply chain phenomena, like those evoked above, by conceptualizing bipolar strategies as an ago-antagonistic solution for supply chain requirements and its member's behavior. The second one is the need of the development of a mathematical model of members' differentiated behavior based on MMRAAC. This non-linear differential equation model will permit approximately to predict members' behavior and strategy. Also, the integration of the concept of pathological equilibrium in a game theoretical framework opens a door to future conceptual exploration. This can be applied to the supply chain framework, after having distinguished its characteristics within an organized complexity or within a chaotic (or desorganized) one.

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Bridge-Curriculum System for Multidisciplinary Courses: Application to Biomedical Engineering

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ABSTRACT

A bridge-curriculum system has been proposed for a sustained improvement of a curriculum in a multidisciplinary area. The system has been applied to the courses of "Biomedical Engineering". In the system, each course is taken by multiple teachers of variety of disciplines. A minor part, which bridges to another course, is taken by a teacher of the bridged course. Frequent communication between courses is guaranteed in the curriculum. The contents of each course are continuously reviewed by another teacher of the different discipline in the curriculum. The system is effective not only for an improvement of a curriculum but also for creation of a new discipline. The bridge-curriculum system works well to improve the courses of "Biomedical Engineering".

Keywords: Multidisciplinary Courses, Biomedical Engineering, Bridge-Curriculum and Communication between Courses

1. SEGMENTATION OF LEARNING

The academic field is divided into each field according to the subject and methodology (Fig. 1). Although reproducibility and logicality are common in every field, each field develops its own discipline. "Law" in a field cannot always be applied to study in another field.

Each field develops each discipline. Each field defines technical terms to describe research achievements. Sometimes the technical term makes communication mismatch (Fig. 2).

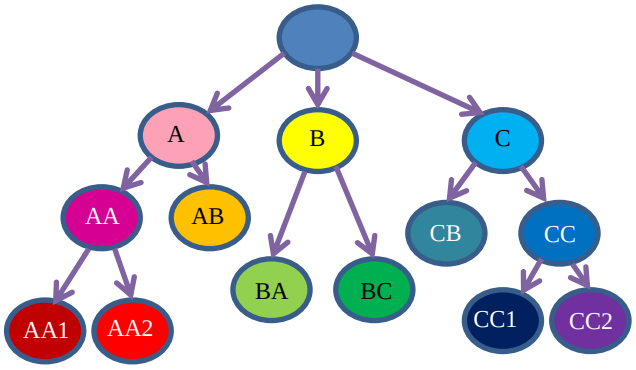


Fig. 1: Segmentation of learning.

Both "Medicine" and "Engineering" have their own technical terms. For example, "control" means comparison in medicine and regulation in engineering, respectively. "Plasma" is used for blood in medicine and for ionization in engineering.

The subject of medicine is diagnosis and treatment for disorders, where the subject of engineering is manufacturing and control of artificial materials. Although application is important both in medicine and in engineering, each field develops its own methodology.

Statistics plays an important role in medicine, because every biological specimen has individuality and changes every time. The protocol should not be changed for the statistical processing in medicine. Standardization plays an important role, on the other hand, in engineering, so that methodology and materials should be modified to minimize scattering in data (Fig. 3).

Achievement is applied in a hospital for medicine and in a factory for engineering. Clinical training in the hospital spend more than two years in a medical school, but engineering design training in the factory is not compulsory in an engineering school sometimes.

2. CURRICULUM

In a university curriculum with a credit system, each course is

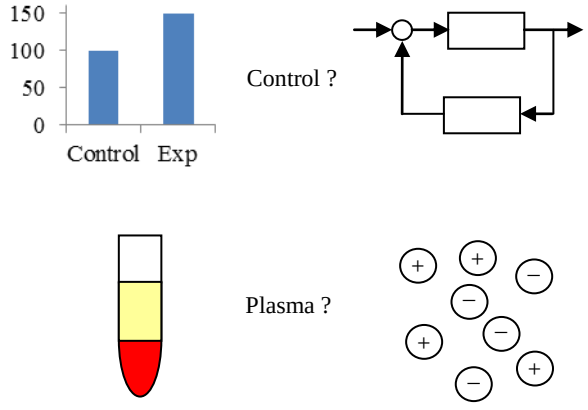


Fig. 2: Technical term makes communication mismatch.

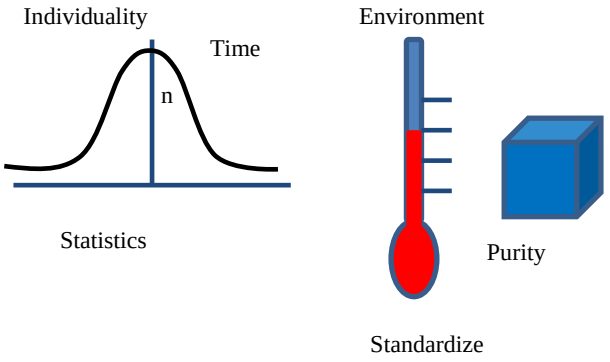


Fig. 3: Protocol should not be changed or should be modified..

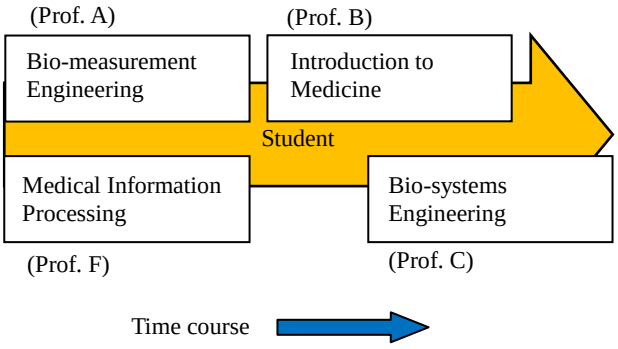


Fig. 4: Conventional curriculum.

usually handled by individual teacher alone. It is a student who should make bridges between courses (Fig. 4). Although the university teachers have their own original specialty, most of them have not trained how to make lessons. The licensed degree like a high school teacher is not necessary to be a professor in a university in Japan. In Japan, most of textbooks taken in the courses of universities have no official approval like those of high schools, either. This is convenient to offer "Place of a free doctrine". The cooperation between subjects is not enough, on the other hand, when each teacher discretely takes each class by his judgment. In a traditional field of study, every course is arranged systematically. In a new field of study, on the other hand, it is difficult for a student to understand the relation between subjects. This kind of system cannot guarantee the sustained improvement of the entire curriculum.

Recently, every university program requires a guaranteed system to improve curriculum sustainably without relying on "Student's initiative" in "Optional courses". The education program should be flexibly improved in the viewpoint not only from the program offer side but also from the student side, to extend the goals of the program.

3. MULTIDICIPLINARY COURSES

A curriculum of multidisciplinary area has a lot of chances to compare different disciplines. Contradistinction is effective not only for comprehension of a discipline, but also for creation of a new discipline.

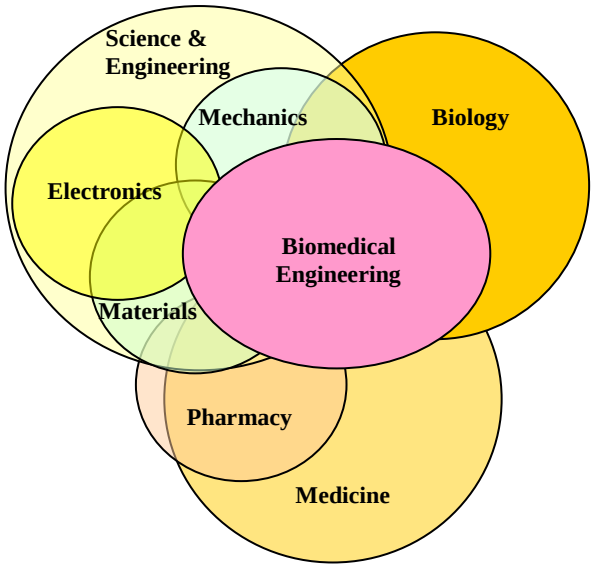


Fig. 5: Biomedical engineering field.

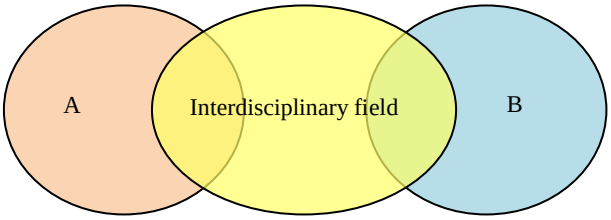


Fig. 6: Interdisciplinary field.

Because “Biomedical Engineering” is a multidisciplinary area [1], it has variations not only in teachers’ special fields but also in study backgrounds of students. The relation among courses might be hard to understand in the curriculum, when it consists of disorderly aggregated subjects taken by each teacher from variety of the study field. A fusion of various systems and backgrounds of study, on the other hand, creates a new field of study in a multidisciplinary area such as “Biomedical Engineering” (Fig. 5).

An interdisciplinary field is not a mere mixture of specialized fields. When several fields that extend to another area are connected to each other, they represent the academic value as an interdisciplinary field (Fig. 6). Aggregation of professors from various special fields cannot make a multidisciplinary education program. Every professor should experience multidiscipline, and should have ability to fuse special fields. In the present study, a challenging bridge-curriculum has been applied for a sustained improvement of a curriculum in a multidisciplinary area of “Biomedical Engineering”.

4. BRIDGE BETWEEN COURSES

The design of courses in the bridge curriculum (Fig. 7) is as follows:

1) Two or more professors take charge in every course at an omnibus style. A student meets two or more teachers in any class.
2) A key professor is in charge to arrange the entire syllabus and to decide the evaluation method to give a student a credit for the subject, collecting the contents from the related professors.
3) Through the communication between courses by class inspection and by discussion between professors, each professor proposes the content of the contribution part to the key professor.
4) A professor takes charge of the part, which should be bridged to another subject (Fig. 8). For example, the professor "B" of "Introduction to Medicine" takes charge of a statistics part of "Medical Information Processing" and the electrocardiogram part of "Bio-measurement Engineering".
5) Each lecturer takes charge of an experimental project. The contents of the experimental project relates to that of the lecture (Fig. 9).
6) Each experimental project includes many elements of learning: planning, designing, instrumentation, teamwork, analyzing, modeling, explanation, and presentation.
7) The experimental project provides a good opportunity to touch materials and to meet with application of fundamental subjects, which have been learned in the lecture.

5. DISCUSSION

Interviews to students, to their parents and to industry show the following advantages and disadvantages of the bridge-curriculum system.

Advantages:

1) The system gives a chance to refresh and inspire students from one object to another. Compatibility between a student and the content of the subject can be distinguished from that between a student and the professor individuality. Students can select professor, when they complain to the contents of the subject. Professor can collect opinion from students about the contents charged by another professor.
2) The bridging-charge system guarantees the daily discussion among subjects.
3) A constant exchange between subjects is guaranteed. Cooperation with other subjects can be considered at any time. Scheduled lecture is requested.
4) A discussion on the level of student's achievement among related subjects is guaranteed. A self-righteous evaluation to students can be prevented with the check by another professor.
5) The bias, which depends on professor individuality, can be compensated by another professor. The improvement of the content of the subject can be distinguished from that of the professor ability.
6) Because every professor takes part in the class of multi semesters, he can always check students' achievement according to their learning history.
7) Because two or more professors recognize the outline of the class, a lecturer at any class can be easily replaced by another professor in a case of an accident. The lesson schedule becomes flexible independent of teacher's convenience.

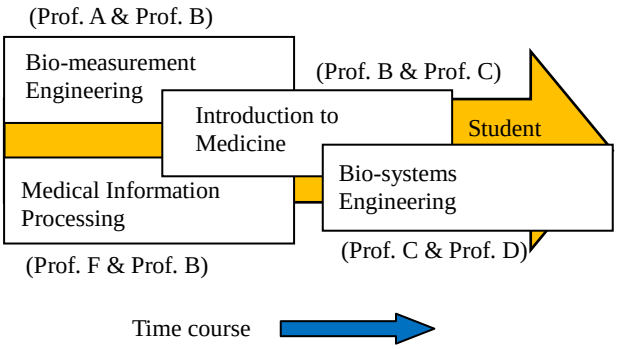


Fig. 7: Bridge curriculum.

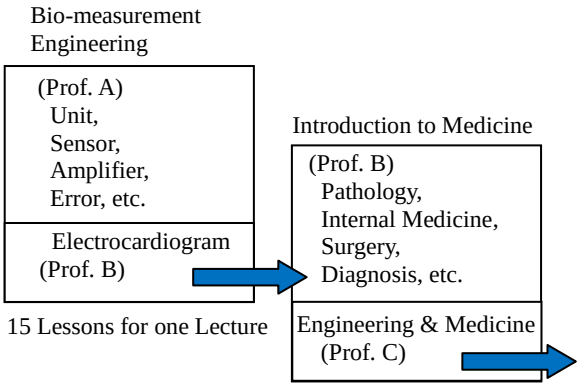


Fig. 8: Bridge (arrow) content between courses.

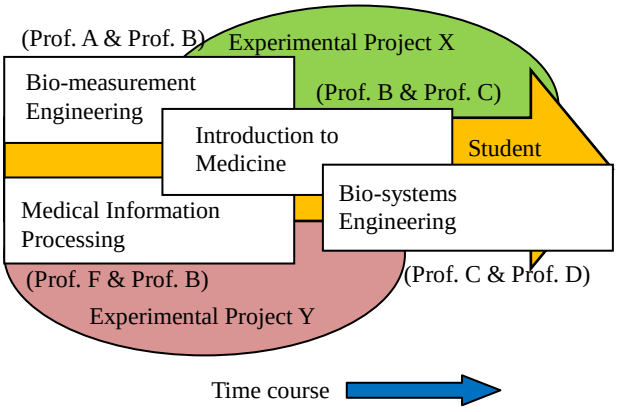


Fig. 9: Bridge curriculum with experimental projects.

8) The system breaks the wall between subjects, and enhances the exchange of the contents between them.
9) The system reforms the traditional style of "one teacher on one subject".
10) The system creates a new curriculum system, as well as a new academic system.

Disadvantages:

1) Interrupt the story of each course.
2) Students have to follow the change of the lecture style during one course.

3) Scheduled lecture is requested.
4) The management of the class schedule becomes complicated for faculties.
5) The class schedule becomes complicated for professors.
6) Alternation of professors might make it difficult for student to understand the continuousness of the content in a course.

The "Plan, Do, Check, Action (PDCA)" cycle to improve a curriculum works with the inspection of the class and with the meeting on the content of the course among faculties. The regular meeting, however, is not enough to support the cycle. The daily discussion among faculties is preferred to support the cycle. Before introduction of the system, the inspection of the class and the meeting on the content tended to be skipped.

Although it is the best way for students to select one from two or more classes prepared for each subject, a department does not have allowance to prepare such a huge amount of classes: neither enough space, nor enough professors. Students tend to select not the contents but professor's individuality. The subject does not depend too much on individuality of one professor in the bridging-charge system. Before introduction of the system, the improvement of the content of the subject could hardly be distinguished from that of the professor's ability. Monotonous contents of the basic subject can be changed to exciting contents by variation of professors' specialty. It is easy for a professor to take cooperation with another university under flexible class schedule in the system. Cooperation between universities is important especially in a multidisciplinary field.

The contents have been continuously reviewed with the designed system. Following the students' opinion about the weakness of the area in biology and in life science, fields on the cell technology and on the gene technology have been added to the curriculum [2-5]. The curriculum has serial subjects of small group activity in "Seminars" and in "Rotational Experimental Projects" from first semester to last semester. They enable polishing the ability of design, communication, presentation, and teamwork, as well as supplying the advisory system for students' learning. The bridging-charge system works well to improve the curriculum of "Biomedical Engineering".

6. CONCLUSION

A bridge-curriculum has been proposed for a sustained improvement of a curriculum in a multidisciplinary area. The curriculum has been applied to "Biomedical Engineering" courses. The curriculum works well to improve the curriculum of a multidisciplinary area.

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Effect of Vortex Flow on Cultured Cells in Vitro

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ABSTRACT

An effect of flow on cell culture has been studied *in vitro*. A silicone disk was placed on the bottom of a culture dish to make a doughnut-shaped canal. The dish was placed on a tilted plate, which rotates to make a vortex flow around the silicone disk with swing motion. Variations were made on the dimension of the canal of the silicone disk. Three kinds of cells were cultured in the vortex flow of Dulbecco's Modified Eagle's Medium for five days: C2C12 (mouse myoblast), L6 (rat skeletal muscle cell), and normal chondrocyte (Takara-bio). The experimental results show that the cells adhere in the low shear area in the first stage, and that cells line to the perpendicular direction to the flow in the second stage. C2C12 is more adhesive than chondrocyte on the culture dish with collagen coating in the flow.

Keywords: Biomedical Engineering, Muscle Cell, Cartilage Cell, Cell Culture, Flow and Orientation

1. INTRODUCTION

Cell culture technique has been progressed and several methods have been studied to arrange cell orientation to make engineered tissue [1]. Myocytes can be cultured and can be differentiated to myotubes *in vitro*. The repetitive contractive movement can be controlled with electric pulses [2]. The efficiency of contraction depends on the orientation of myotubes.

A cartilage layer is hard to be reconstructed [3]. Chondrocytes in a joint are exposed to shear stress according to the movement of the joint. The lubrication property might depend on the orientation of chondrocytes.

Acceleration technique for orientation of cells has been studied to make tissue *in vivo* and *in vitro* [1, 4]. Control methodology for orientation of cells would be applied to the regenerative tissue technology. For example, myoblasts have been clinically applied to ischaemic cardiomyopathy in the field of regenerative medicine [5].

The behavior of biological cells depends on various environmental factors, such as electric [6], magnetic [7] and mechanical fields [1, 4, 8]. The cells might tilt to the direction of these fields. Erythrocytes, for example, orient under the blood flow [9-11].

Several systems for circulation of the medium have been designed to apply the flow stimulation on the cell culture [9]. Most of them use pumps and tubes, which might cause an extra effect of materials of the flow path.

In the present study, a novel simple culture methodology with a vortex flow of the medium has been developed to make orientation of cells *in vitro*.

2. METHODS

Culture system with vortex flow

A system for the cell culture has been designed to apply a vortex flow on cells *in vitro*. A polystyrene culture dish with collagen coating was used. A silicone rubber disk of 3 mm thick (K-125, Togawa Rubber Co., Ltd., Osaka) is attached on the inner bottom of the culture dish to restrict the space for the flow of the medium (Fig. 1). Two kinds of dishes were used to make two types of canals: a canal around the silicone disk and a canal between the silicone disks. To make the former type of canal, the silicone rubber disk is attached at the center of the culture dish of 52 mm internal diameter (Fig. 1(a), (b)). Variation was made on the diameter: 30 mm and 40 mm. To make the latter type of canal, the silicone disk of 30 mm diameter and the silicone ring are attached at the center of the culture dish of 100 mm internal diameter (Fig. (c)). The silicone ring has the inner hole of 40 mm diameter. The centers of the disks are adjusted to the center of the dish. In the latter system, cells are cultured in the donut shape interspace between silicone disks of 5 mm width. The silicone rubber disk is stuck on the bottom of the dish with affinity between their surfaces without adhesive.

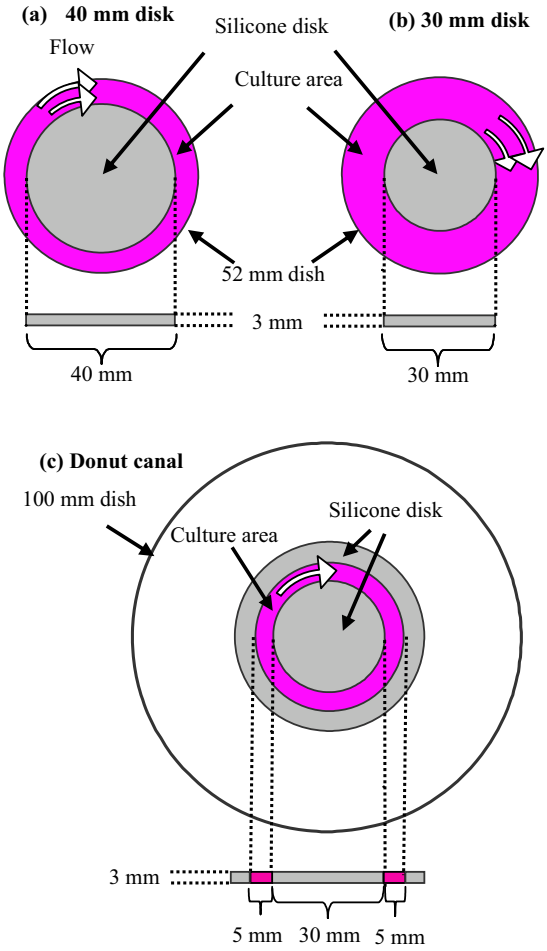


Fig. 1: Culture dish with silicone disk. Three types of donut-shaped area are filled with medium.

The culture dish is placed on a plate, which inclines at 0.1 rad of the horizontal plane (Fig. 2). The plate rotates to generate a swing motion (WAVE-SI, Taitec, Co., Ltd., Koshigaya). The rotating speed of the plate is 20 revolutions per minute (rpm) (2.1 rad/sec). The motion produces a one-way clockwise vortex flow in the medium around the silicone rubber disk in the dish. Fifteen dishes can be simultaneously placed on the plate, which generates the same vortex flow in the medium in each dish.

The continuously swinging plate is placed in an incubator, where both temperature of 37 degrees Celsius and carbon dioxide partial pressure of 5 percent are maintained.

Cell Culture

Variations were made on cells: C2C12 (Mouse myoblast cell line originated with cross-striated muscle of C3H mouse), L6 (rat skeletal muscle cell), and the normal cartilage cell (Takara-bio). Each kind of cells was alternatively suspended in the Dulbecco's Modified Eagle's Medium (D-MEM) with density of 1.0×10^6 cells per mL. Fetal bovine serum (FBS)



Fig. 2: Culture dishes on swinging plate in incubator.

was added to the medium with the volume rate in 10 percent of FBS and in 90 percent of D-MEM. The suspension was poured into the dish and cultured in the incubator for three hours without flow stimulation. After the cultivation for three hours, the cells were cultured with flow stimulation for five days. The continuous rotation of the plate makes a steady flow in the medium through canal.

The volume of the suspension is 3 mL for the dish of 52 mm diameter, and 1 mL for the donut shaped canal, respectively. The volume of the medium is adjusted to cover whole surface of the bottom of the canal in the culture dish, and not to flow over the superior surface of the silicone disk during the swing motion of the plate. The cells were cultured in the vortex flow of the medium, while the plate was continuously rotating at 37 degrees Celsius in the incubator. The medium was refreshed every two days.

The directions of cells were observed with an inverted phase-contrast microscope. The number of cells adhered on the bottom of the culture dish was counted after cultivation with the flow for 3 days or for 5 days. The cells were exfoliated with enzymatic treatment, and the suspension was introduced into the interstitial space between the slide glasses to be counted under the microscope. The results were compared to those of cultivation without the flow.

3. RESULTS

The flow around the silicone disk synchronously with the movement of the swinging plate was observed with the movement of a tracer particle.

C2C12

The experimental results with C2C12 of 40 mm disk show that cells adhere to the bottom of the culture dish adjacent to the silicone disk in three hours (Fig. 3A). Few adhered cells were observed in the circumferential area in the dish. The cells proliferate in the vortex flow of the medium. The array of myotubes grows around the silicone disk day by day, and the alignment curves to the radial direction (Figs. 3CR & 3DR). The longitudinal axes of cells orient to the direction perpendicular to the flow on the third day of culture (Fig. 3CR). This tendency is same as that of 30 mm disk. The results of

donut shaped canal show that cells adhere adjacent to the inner circle in the donut shape of the canal between the silicone disks. The orientation develops from the inner circle to the outer circle (Fig. 4). The experimental results show that cells extend to the area, where cells have not adhered yet.

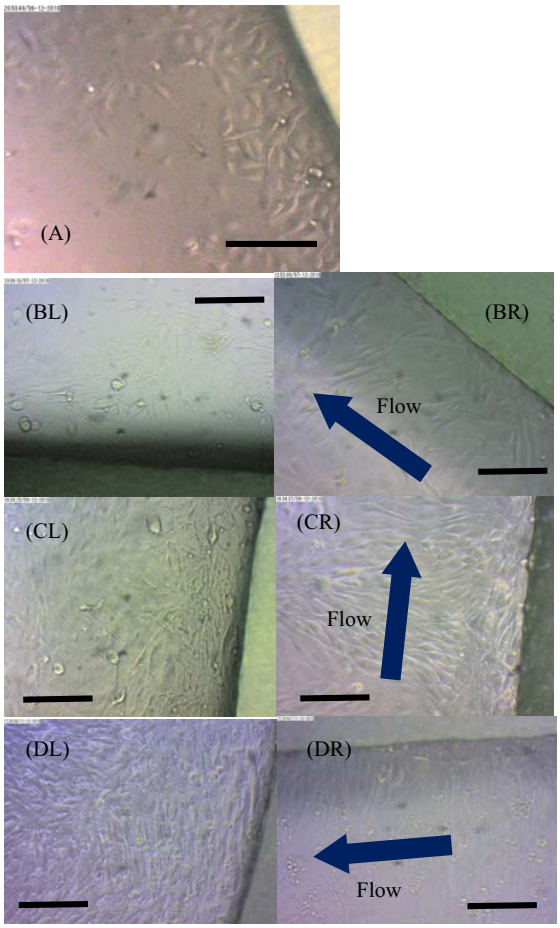
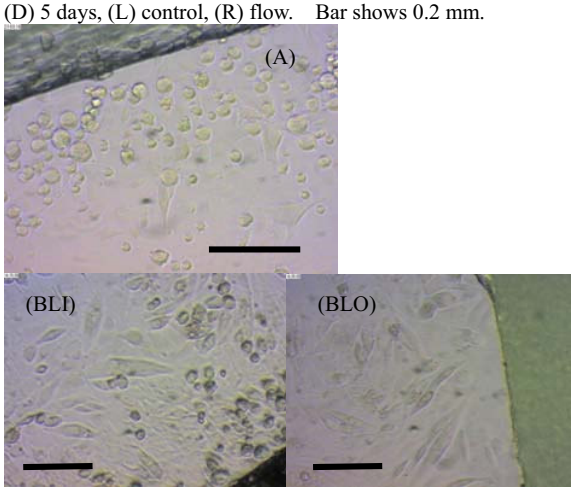


Fig. 3: C2C12, 40 mm disk, (A) 3 hours, (B) 1 day, (C) 3 days, (D) 5 days, (L) control, (R) flow. Bar shows 0.2 mm.



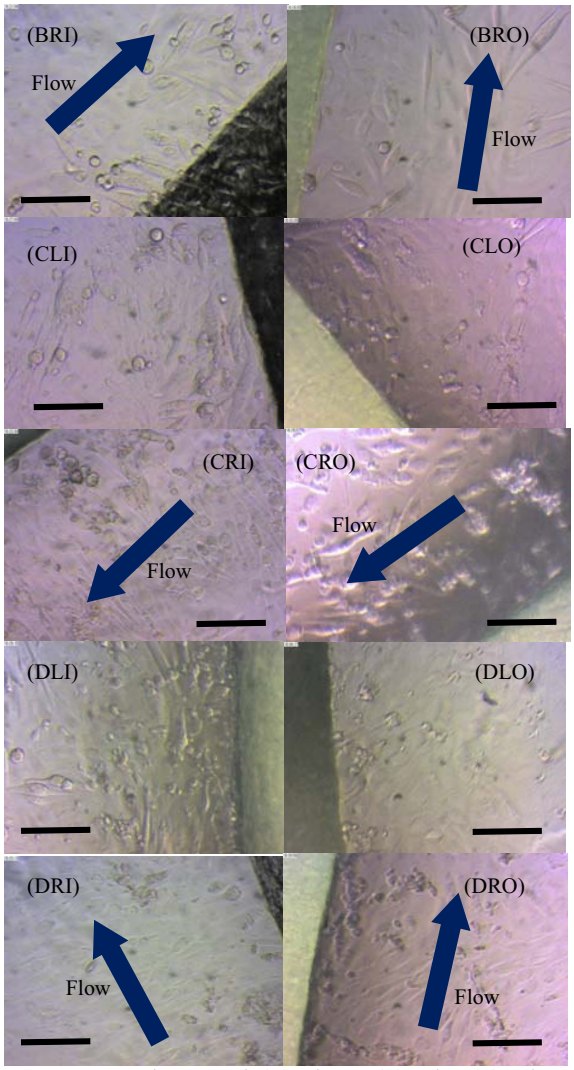


Fig. 4: C2C12, donut canal, (A) 3 hours, (B) 1 day, (C) 3 days, (D) 5 days, (L) control, (R) flow, (I) inner circle, (O) outer circle. Bar shows 0.2 mm.

L6

The experimental results with L6 of 30 mm disk show that cells adhere to the bottom of the culture dish adjacent to the silicone disk in three hours (Fig. 5A). The results show that cells orient to the direction perpendicular to the flow on the third day of culture (Fig. 5CR). This tendency is same as that of 40 mm disk. L6 adheres adjacent to the inner circle in the donut shape of the canal between the silicone disks. The orientation of L6 develops from the inner circle to the outer circle (Fig.6).

Chondrocyte

Chondrocytes adhere to the bottom of the culture dish in three days. Chondrocytes adhere more at the inner circle than at the outer circle (Fig.7).

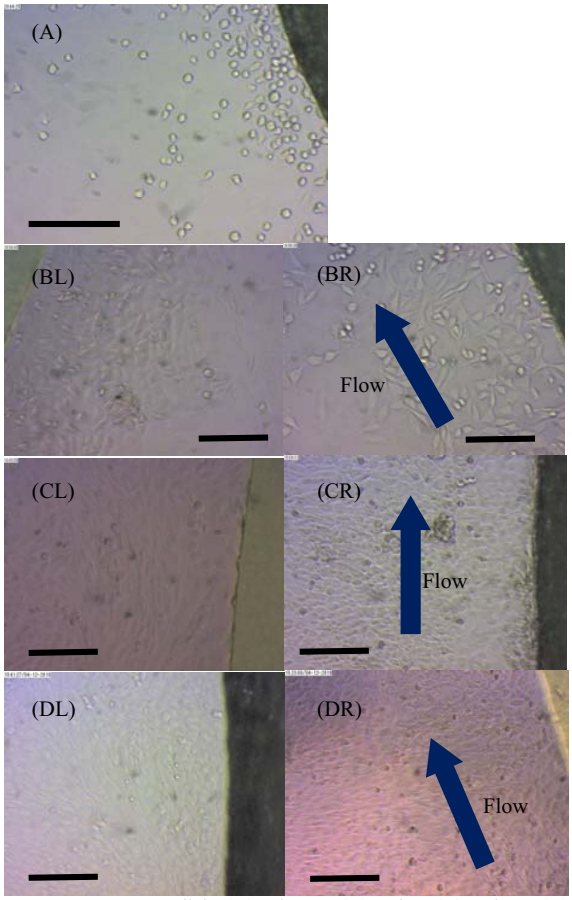
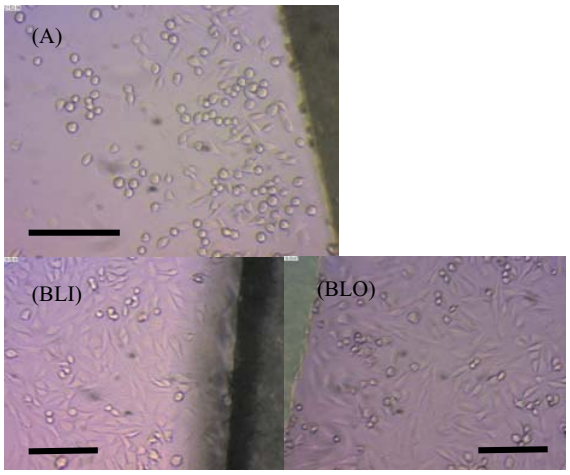


Fig. 5: L6, 30 mm disk, (A) 3 hours, (B) 1 day, (C) 3 days, (D) 5 days, (L) control, (R) flow. Bar shows 0.2 mm.



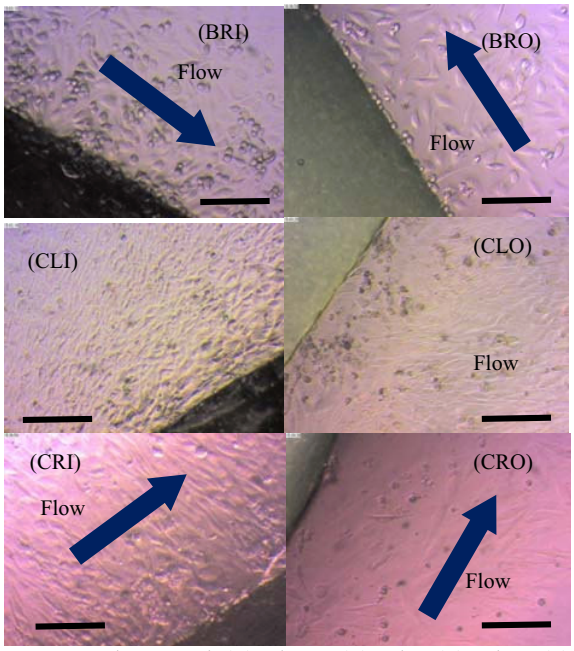


Fig. 6: L6, donut canal, (A) 3 hours, (B) 1 day, (C) 5 days, (L) control, (R) flow, (I) inner circle, (O) outer circle. Bar shows 0.2 mm.

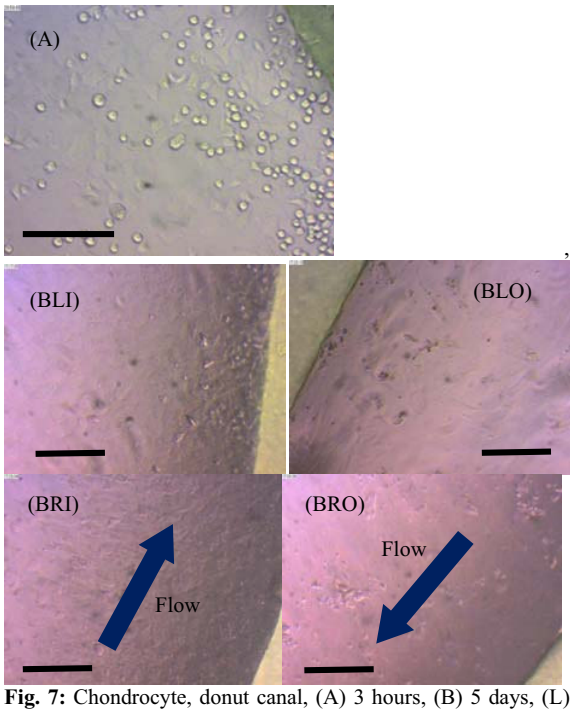
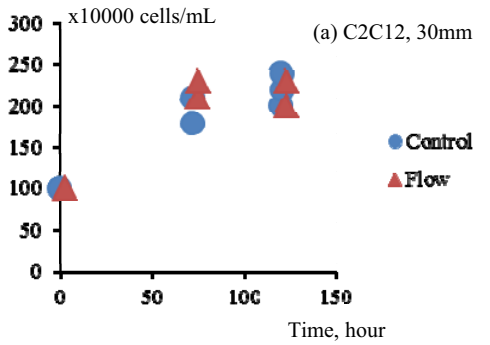
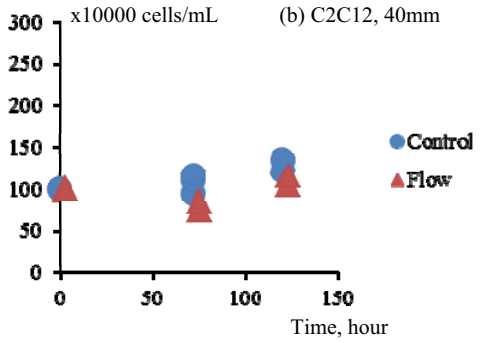
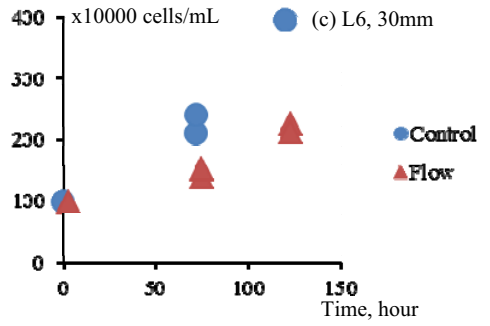
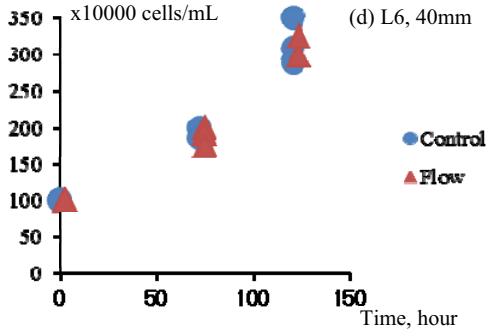


Fig. 7: Chondrocyte, donut canal, (A) 3 hours, (B) 5 days, (L) control, (R) flow, (I) inner circle, (O) outer circle. Bar shows 0.2 mm.



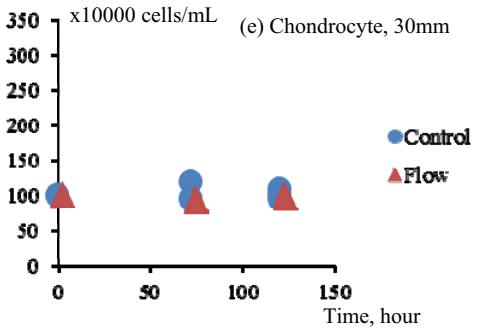






Number of cells

The number of cells adhered on the bottom of the culture dish is smaller with the flow than without the flow (Fig. 8). The proliferation of L6 is rapid. The number of L6 adhered on the bottom of the culture dish increases triples in five days (Fig. 9). The number of C2C12 adhered on the bottom of the culture dish doubles in three days and saturates in five days. The



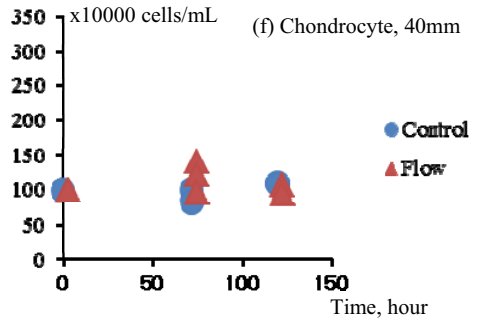


Fig. 8: Number of cells.

proliferation of cartilage cells is slow. The adhered cartilage cells do not increase for five days both with and without flow stimulation. Several chondrocytes exfoliate in the flow around the disk of 30 mm.

4. DISCUSSION

In the previous study, micro patterning technique has been applied to the experiment to investigate relation between morphology of the surface and orientation of cells [12-14]. Oriented fibers have been applied to the scaffold of cells [14]. The mechanical property of the scaffold should be adjusted that of myotubes, when the combined unit works as an actuator. Orientation of myotubes without scaffold might have an advantage for a simple design of a tissue-engineered actuator [15].

The orientation of cells in the present system depends on several factors: (1) shear stress under flow, (2) gravitational force with slope, (3) centrifugal force with rotation, (4) interactive force between cell and scaffolds (silicone disk, adhered chemicals or wall of dish), (5) interactive force between cells (repulsion or fusion) [8]. The orientation of cells tend to develop in the inner circle area, when the materials of the rims of the canal are same; silicone. The experimental results of the double ring disk of silicone show that the flow stimulation governs the orientation of cells in the present study.

The cells might be stabilized in the direction, where the stress on cells is minimized. The previous study shows that smooth muscle cells orient to minimize internal mechanical stress [16].

The cells might receive stress being stretched to the flow direction. The effect of the steady flow might be different from that of the pulsatile flow [9]. It is not easy to estimate wall shear stress value on the bottom surface of the dish in the flow of the medium, because of the free counter surface of the medium. A test with a flow between parallel plates has advantage to estimate wall shear stress [17]. Because the endothelial cells orient in the same condition of flow [8], the shear stress might be in the range of several Pa, which is estimated in the previous studies [10]. A swing motion makes a vortex flow in a culture dish. The vortex flow makes wall shear rate distribution on the bottom of the culture dish. The shear rate increases from the inner circle to the outer circle.

The present study shows the following speculation. Both muscle cell (C2C12, L6) and cartilage cell orient along the stream line at lower steady shear rate in the flow. Cells proliferate in the lower steady shear field. The flow at higher shear rate constricts proliferation and orientation of cells. The muscle cells are more adhesive than the cartilage cell, so that the muscle cells can orient and proliferate in the flow at the higher shear rate. The orientation of cells develops from the area of the lower shear rate to that of the higher shear rate. The development makes a chance to orient cells in the direction perpendicular to the stream line of the flow. The orientation of cells depends not only on the flow rate, but also on affinity between the cell and the wall. The ability of proliferation of cells affects the orientation, too. Both the shear rate and affinity of the cell to the wall govern development of the orientation. The muscle cells might have a higher affinity than the chondrocytes to stick to the bottom of the culture dish. The muscle cells also have the high rate of proliferation so that they can make the orientation faster.

5. CONCLUSION

An effect of the vortex flow on cell culture has been studied *in vitro*. The experimental results show that the cells adhere along the direction of the flow in the low shear area in the first stage, and tilt to the perpendicular direction to the flow in the second stage. C2C12 is more adhesive than chondrocyte on the culture dish with collagen coating in the flow.

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Effect of Excess Gravitational Force on Cultured Myotubes in Vitro

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ABSTRACT

An effect of an excess gravitational force on cultured myoblasts has been studied in an experimental system with centrifugal force *in vitro*. Mouse myoblasts (C2C12) were seeded on a culture dish of 35 mm diameter, and cultured in the Dulbecco's Modified Eagle's Medium until the sub-confluent condition. To apply the excess gravitational force on the cultured cells, the dish was set in a conventional centrifugal machine. Constant gravitational force was applied to the cultured cells for three hours. Variations were made on the gravitational force (6 G, 10 G, 100 G, 500 G, and 800 G) with control of the rotational speed of the rotator in the centrifugal machine. Morphology of the cells was observed with a phase-contrast microscope for eight days. The experimental results show that the myotube thickens day by day after the exposure to the excess gravitational force field. The results also show that the higher excess gravitational force thickens myotubes. The microscopic study shows that myotubes thicken with fusion each other.

Keywords: Biomedical Engineering, Myotube, Gravitational Force, Cell Culture, Fusion and Differentiation

1. INTRODUCTION

Several effects of a gravity free condition on a biological system have been studied with various experimental systems [1-3]. Keeping a muscle condition is important for an astronaut in a micro gravity condition. The gravitational force might affect on differentiation or on multiplication of muscle cells. A cell culture technique enables observation of cell behavior in a designed condition about gravitation.

Control methodology for cell culture would be applied to regenerative tissue technology. For example, myoblasts have been clinically applied to ischemic cardiomyopathy in the field of regenerative medicine. Behavior of biological cells depends on various environmental factors, such as electric, magnetic and mechanical fields [4-6].

A sophisticated experimental instrumentation is necessary to realize zero gravity condition on the earth [7, 8]. In the present study, a conventional centrifugal machine has been applied to the control method of the gravity condition, and the effect of an excess gravitational force on cultured muscle cells has been studied in an experimental system with centrifugal force *in vitro*.

2. METHODS

Cell Culture

Mouse myoblasts (C2C12) were suspended in the High-Glucose-Dulbecco's Modified Eagle's Medium (DMEM) with fetal bovine serum (FBS) at the density of one million cells per milliliter. Two milliliter of the suspension was poured into a culture dish of 35 mm diameter, and cultured for 24 hours in the incubator (MCO-18AIC, Sanyo, Osaka, Japan) on the first day. In the incubator, the temperature of 37 degrees Celsius and carbon dioxide partial pressure of 5 percent are maintained.

Application of Excess Gravitational Force

The excess gravitational force was applied to cultured cells with a centrifugal force. The culture dish of 35 mm diameter was set on the top of a centrifugal tube of 50 mL. The tube was put on a swing rotor in the centrifugal machine (2800, Kubota, Tokyo, Japan) (Fig. 1). The rotor was rotated with the speed of <3000 rpm, which makes an excess gravitational force of <800 G at the bottom of the culture dish. Variation was made about the excess gravitational force: 6 G, 10 G, 100 G, 500 G, and 800 G. To keep balance of a rotator in the centrifugal machine, two culture dishes were placed in the counter position each other.

The constant excess gravitational force was applied on cells for three hours at 25 degrees Celsius on the early part of the second day. For the concurrent control study, a culture dish was kept at 25 degrees Celsius for three hours without centrifugal forces. After morphological observation, the cells were cultured in the incubator again for 21 hours on the rest part of the second day.



Fig. 1: Four dishes on the rotor in the centrifugal machine.

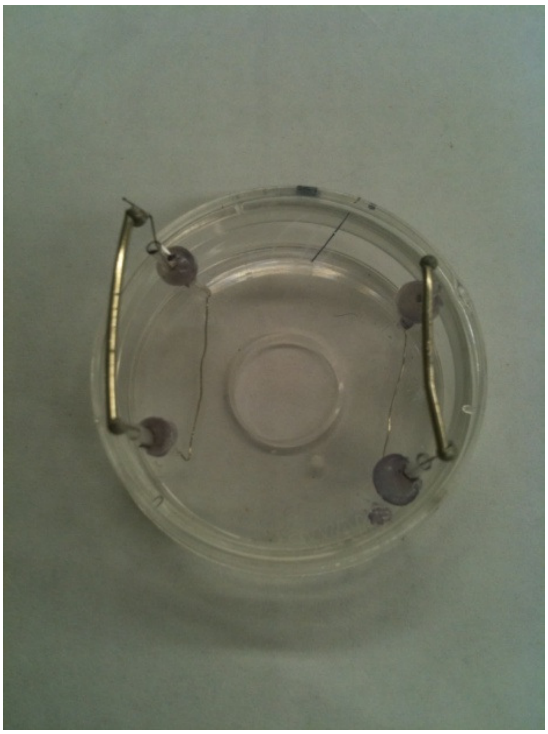


Fig. 2: A pair of electrodes attached on the cover of the culture dish.

The second term stimulation with excess gravitational forces for another three hours was performed on the early part of the third day. The rest of the cultivation term, cells were cultured in the incubator. Cells are proliferated to sub-confluent condition in 72 hours.

At the end of the third culture day, FBS was replaced with horse serum (HS) for differentiation. The ratio of serum in the medium is ten percent in FBS, and seven percent in HS. The medium was refreshed every two days.

A polystyrene culture dish with type I collagen coating (Iwaki, 3010-060, Asahi Glass, Tokyo, Japan) was used.

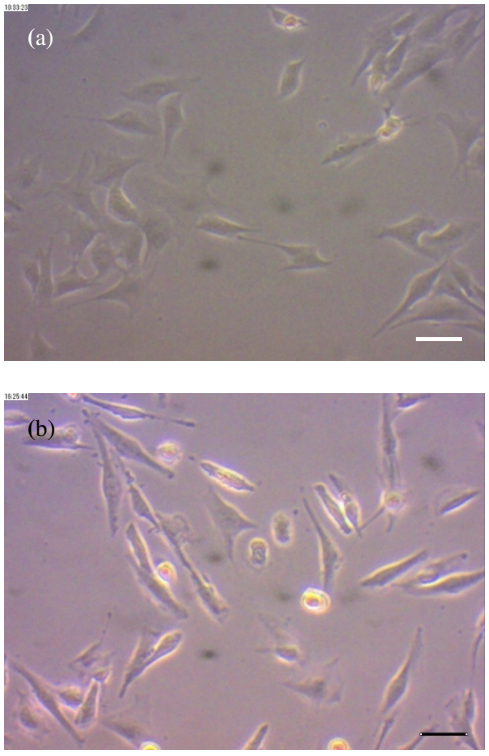
Morphological Study

Morphology of cells was observed with an inverted phase-contrast microscope (IX71, Olympus, Tokyo, Japan) every 24 hours for eight days. The same area was traced in the serial cultivation, and the maximum width of every myotube was measured after the sixth day of culture.

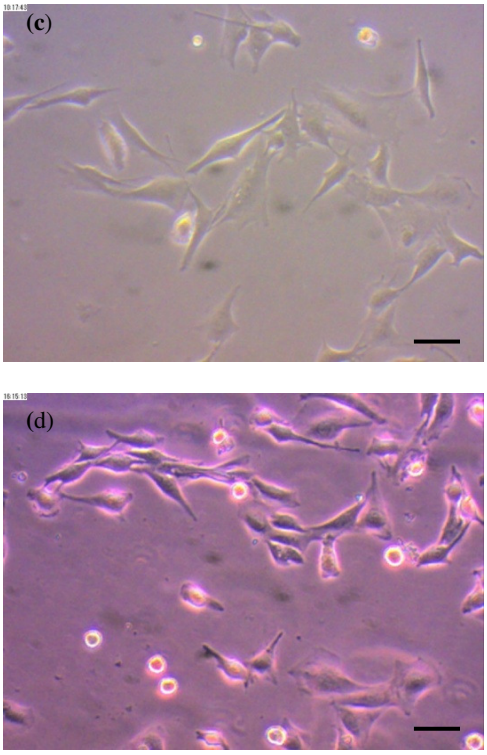
To confirm differentiation of muscle cells, the electric stimulation was applied to the culture medium after the fourth day, and the contractive movement was observed under the microscope. The electric pulses (the pulse width of one millisecond, the period of one second, and the amplitude of 30 V) were applied through a pair of electrodes of platinum wire (diameter of 0.2 mm), which are attached on the cover of the culture dish (Fig. 2).

3. RESULTS

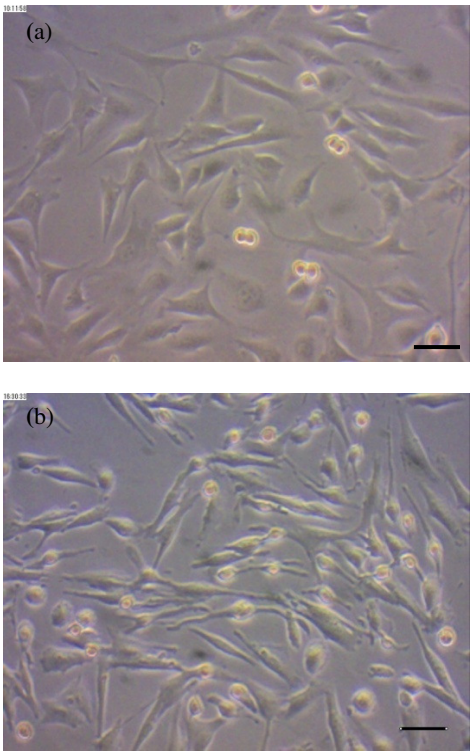
Figs. 3a-8b exemplify typical microscopic appearance of cells. The bars in those figures indicate 0.050 mm. Fig. 3a shows cells before stimulation of the excess gravitational force for three hours on the second day. Myocytes adhere to the bottom of the culture dish in 24 hours (Fig. 3). Fig. 3b shows cells after stimulation of the gravitational force of 800 G for three hours on the second day. The figure shows that most of cells extend and some cells exfoliate after the excess gravitational stimulation. Figs. 3c & 3d show cells of the simultaneous control study on the second day. Any remarkable morphologic change has not been observed for three hours. Some cells also exfoliate in three hours of the control study.



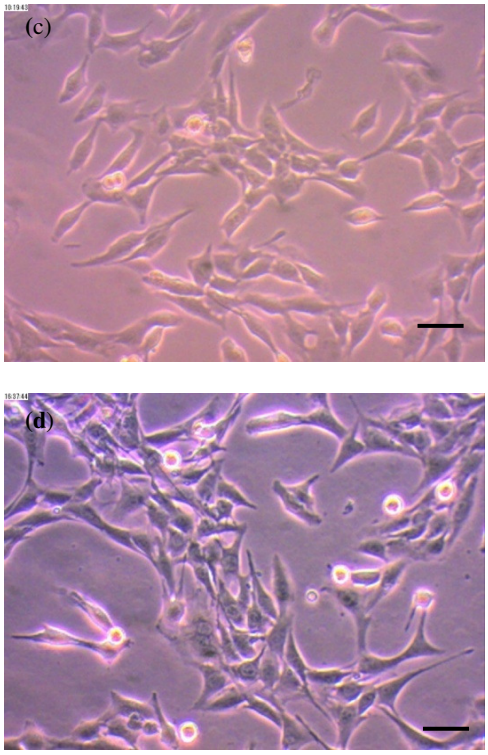
Figs. 3a & 3b: Cells before (a, upper) and after (b, lower) gravitational stimulation of 800 G for three hours on the second day. The bar indicates 0.05 mm.



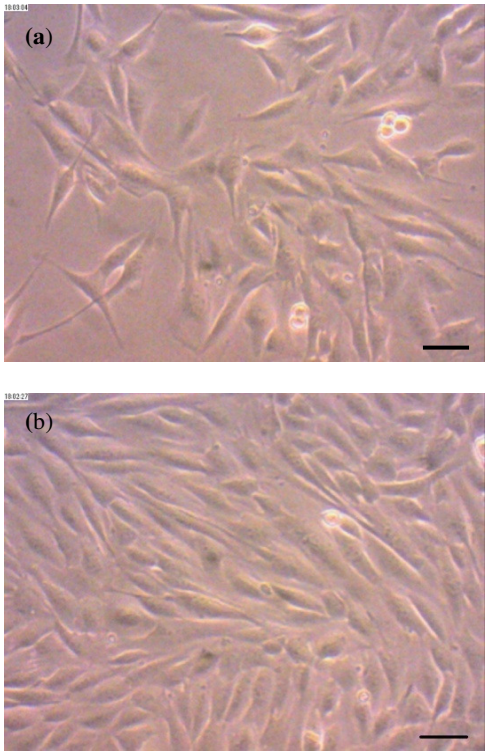
Figs. 3c & 3d: Cells before (c, upper) and after (d, lower) control three hours on the second day. The bar indicates 0.05 mm.



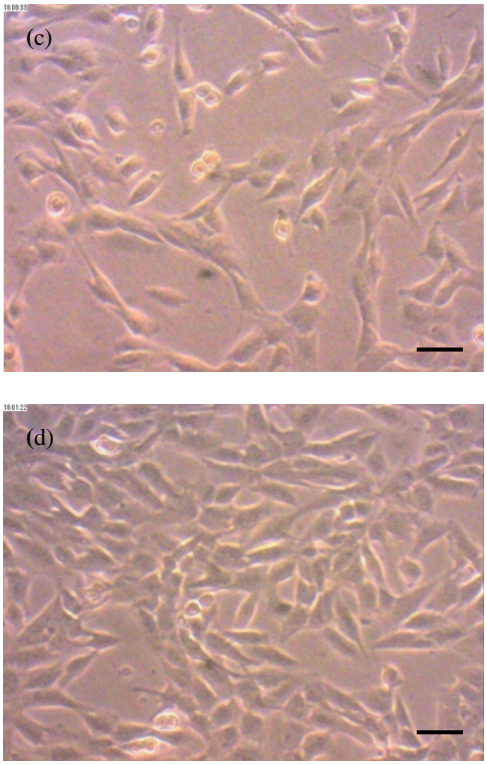
Figs. 4a & 4b: Cells before (a, upper) and after (b, lower) gravitational stimulation of 800 G for three hours on the third day. The bar indicates 0.05 mm.



Figs. 4c & 4d: Cells before (c, upper) and after (d, lower) control three hours on the third day. The bar indicates 0.05 mm.



Figs. 5a & 5b: Cells in the circumferential area (a, upper) and middle area (b, lower) of gravitational stimulation of 800 G on the fourth day. The bar indicates 0.05 mm.

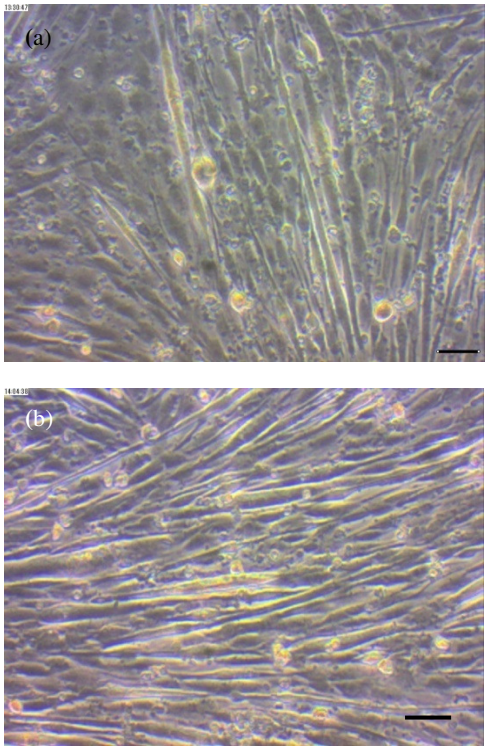


Figs. 5c & 5d: Cells in the circumferential area (c, upper) and middle area (d, lower) of control study on the fourth day. The bar indicates 0.05 mm.

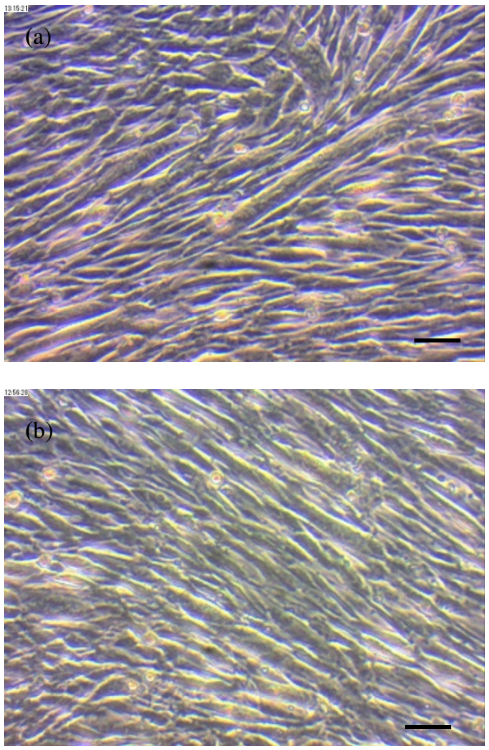
Fig. 4a shows cells before stimulation of the excess gravitational force for three hours on the third day. Fig. 4b shows cells after stimulation of the gravitational force of 800 G for three hours on the third day. The results show that cells become slim after stimulation of 800 G. Figs. 4c & 4d show cells of the simultaneous control study on the third day. Any remarkable morphologic change has not been observed for three hours. Some cells also exfoliate in three hours of the control study.

Fig. 5a shows cells in the circumferential area of the stimulation (800 G) study on the fourth day (72 hours). Fig. 5b shows cells in the middle area of the stimulation (800 G) study on the fourth day. Fig. 5c shows cells in the circumferential area of the control study on the fourth day. Fig. 5d shows cells in the middle area of the control study on the fourth day. The results show that cells are proliferated to sub-confluent condition in the middle area.

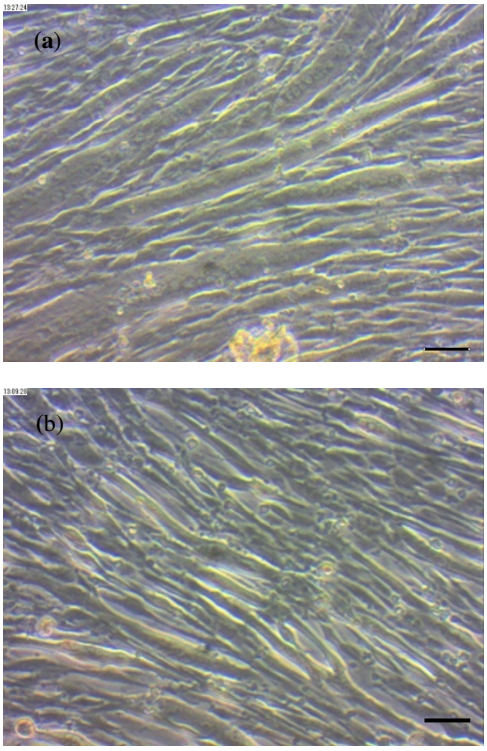
Fig. 6a shows cells of the stimulation group of 6 G on the eighth day. Fig. 6b shows cells of the simultaneous control study on the eighth day. Fig. 7a shows cells of the stimulation group of 800 G on the sixth day. Fig. 7b shows cells of the simultaneous control study on the sixth day. Fig. 8a shows cells of the stimulation group of 800 G on the eighth day. Fig. 8b shows cells of the simultaneous control study on the eighth day. The results show that cells start to fuse each other, and to form myotubes. Fig. 8b shows three lines of nuclei in a myotube.



Figs. 6a & 6b: Cells of stimulation group of 6 G (a, upper) and of control group (b, lower) on the eighth day. The bar indicates 0.05 mm.



Figs. 7a & 7b: Cells of stimulation group of 800 G (a, upper) and of control group (b, lower) on the sixth day. The bar indicates 0.05 mm.



Figs. 8a & 8b: Cells of stimulation group of 800 G (a, upper) and of control group (b, lower) on the eighth day. The bar indicates 0.05 mm.

The results at higher gravitational force show that cells aggregation decreases at the first stage. Several cells are floating in Fig. 3b. Cells are scattered and elongated in Fig. 3b.

The relation between the maximum width of myotube (X) and days of culture is displayed in Figs. 9-10. Measured value of X scatters, so that both the mean value and maximum value are displayed in Figs. 9 & 10. The Data point shows mean value and the top of the bar shows maximum value. The width of myotube becomes larger at the higher gravitational forces (500 G, 800 G).

When periodical pulses were introduced in the culture medium through electrodes, repetitive contractions were observed at the myotubes both in the control study and in the excess gravitational force stimulation study. The contraction of the myotube was synchronized with the electric pulses.

4. DISCUSSION

The effect of gravitational forces on biological system has been discussed in several previous studies. Some of these studies have been extended to a biological reflection under condition with micro gravitational forces. The gravitational force at a space station, for instance, is smaller than a millionth part of that at the surface of the earth.

An effect of the higher gravitational field on a mutation of a cell has been studied in the previous experiment *in vitro* [3]. At the higher gravitational force in the present study, several

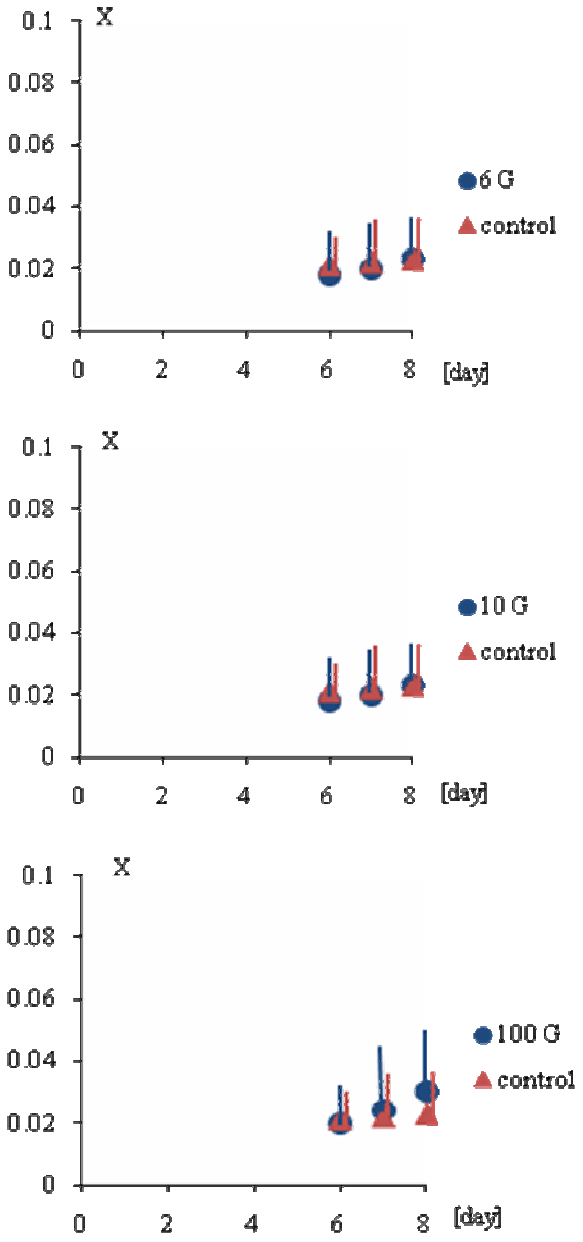


Fig. 9: The relation between the maximum width of myotube (X) and days of culture: 6 G (upper), 10 G (middle), 100 G (lower).

myocytes are exfoliated. That may controls aggregation of cells and the cells acquire space for elongation around themselves. These effects might accelerate differentiation to form myotubes.

The functional property of myotubes was confirmed by their repetitive contractions with electric pulses, which were introduced through the electrodes dipped in the medium.

In the gravitational field, several mechanical stresses might be generated around the cells: the compressive stress between the cell and the bottom of the dish, the compressive stress between cells, the tensile stress in the perpendicular direction to the

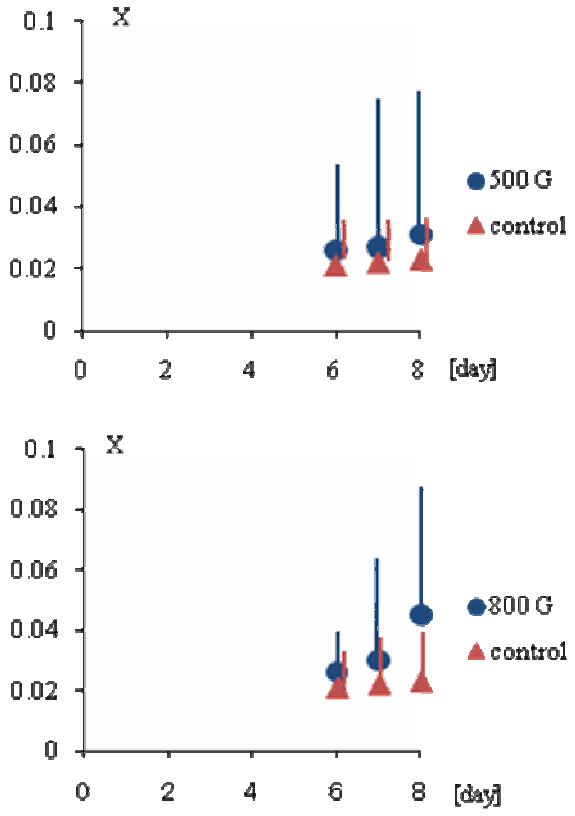


Fig. 10: The relation between the maximum width of myotube (X) and days of culture: 500 G (upper), 800 G (lower).

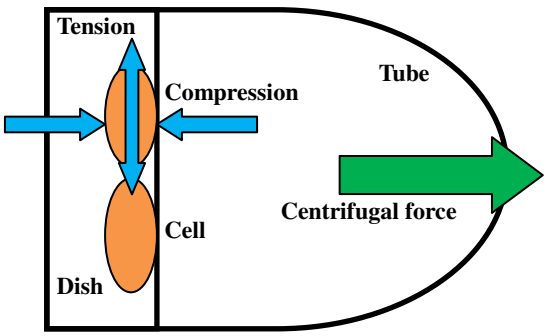


Fig. 11: Forces around a cell, during centrifugation.

gravitational field.

Some studies show that the electric stimulation enhances differentiation of muscle cells [9, 10]. Another study shows that the mechanical stimulation improves the tissue-engineered human skeletal muscles [5].

5. CONCLUSION

The experimental results show that the myotube thickens day by day after the intermittent constant excess-gravitational-force stimulation for three hours. The results also show that thickness of myotube increases with the excess gravitational force (<800 G). The microscopic study shows that myotubes thicken with fusion each other.

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Effect of Shear Flow on Cultured Cartilage Cells

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ABSTRACT

An effect of the flow on migration and on deformation of a cultured cartilage cell has been studied *in vitro*. A flow chamber was designed to observe behavior of adhered cells on a plate in a culture medium flow under a microscope. A thin sheet of silicone rubber was sandwiched by two plates of transparent glass to form a rectangular flow channel of 2 mm width × 52 mm length × 0.1 mm depth. After several cells adhered to the glass plate, the medium steady flow between 4 mL/hour and 30 mL/hour was applied on the cells with a syringe pump, and behavior of adhered cells in the flow was observed at 30 degrees centigrade. The flow generates wall shear stress between 0.3 Pa and 3 Pa. The experimental results show that cells tend to deform and migrate downstream before exfoliation.

Keywords: Biomedical Engineering, Cartilage Cell, Cell Culture, Flow, Migration and Orientation

1. INTRODUCTION

Behavior of biological cells depends on various environmental factors, such as electric [1-4], magnetic [5-7] and mechanical [8-17] fields.

Cell culture technique has been developed and myoblasts have been clinically applied to ischaemic cardiomyopathy in the field of regenerative medicine. Acceleration technique for orientation and proliferation of cells has been studied to make muscle tissue *in vivo* and *in vitro* [2, 6, 7, 10, 15-17]. Control methodology for orientation and proliferation of cells would be applied to regenerative tissue technology. The cartilage cells are thought to have poor regenerative ability *in vivo*. Regenerative technique on cartilage cells has been investigated for reconstruction of the function of a joint.

The mechanical stress is one of the interested points in the environment of the cartilage cells, because they receive mechanical forces in the joint. Several methods have been designed to apply mechanical stress to cells [8-10, 12]. A transmission point of stress to a specimen is important. In many studies, stress is applied to a scaffold. When fixation between the cell and the scaffold is not enough, stress is not transmitted to the cell. A flow can be used, on the other hand, to apply a stress field to a specimen [11, 13, 15-17]. The specimen directly receives shear stress in the shear flow.

In the present study, the effect of the flow on orientation of cultured cartilage cells has been studied *in vitro*.

2. METHODS

Culture Medium Flow System

A one-way flow system was designed to observe an effect of the flow on cells adhered to a plate. The system consists of a flow chamber, a syringe pump, tubes and a microscope (Fig. 1). TE-331S (Terumo Co., Ltd. Tokyo) was used for the syringe pump. A plastic tube of 2 mm internal diameter and of 3 mm external diameter was used for the connector to a flow chamber.

The flow chamber consists of two transparent glass plates and a thin silicone rubber sheet (Fig. 2a). The dimension of two glass plates is 76 mm length, 26 mm width and 1.5 mm thick, each. A rectangular open space of 2 mm × 52 mm is cut off in a thin sheet of silicone rubber being 0.1 mm thick, and sandwiched between the glass plates (Fig. 2a). The sheet is sandwiched between two plates of glass to form a rectangular channel of 2 mm width × 52 mm length × 0.1 mm depth. The three plates stick together with their surface affinity without an adhesive. At the upper glass plate, two holes of 2.5 mm diameter are machined by a grinder, where the plastic tube is stuck by an adhesive of polyurethane resin (Figs. 2a, 2b).

One of the tubes is connected to the plastic syringe pump (Fig. 2b). The room temperature was maintained at 25 degrees Celsius. The chamber is placed on the inverted phase-contrast microscope (IX71, Olympus Co., Ltd., Tokyo).

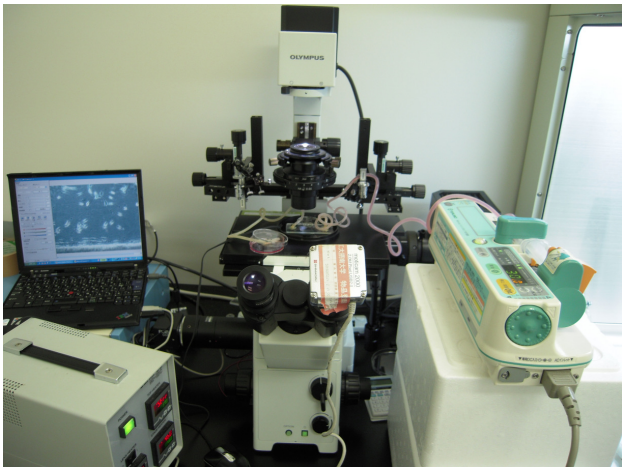


Fig. 1: Flow test system: flow chamber and microscope (middle), syringe pump (right).

Cell Culture

Normal cartilage cells (collected from costal cartilage of Sprague Dawley rat, Takara-bio) were used in the experiment. The cells were cultured on a dish with the Dulbecco's Modified Eagle's Medium (D-MEM) in an incubator for one week. Then, Cells were exfoliated from the plate of the culture dish with trypsin, and suspended in the D-MEM. The suspension was introduced to the chamber and cultured in the incubator for 24 hours to make cells adhere to the glass plate of the chamber before the flow test.

Flow Test

After the chamber was set on the microscope out of the incubator, the constant flow of the medium was applied to adhered cells with the syringe pump (Fig. 1). The flow path was carefully examined to avoid mixing of air bubbles, which might stir the medium in the flow chamber and induce exfoliation of cells. The behavior of cells on the plate of the chamber was observed with the microscope. The photos of cells were taken during the flow test for one hour. Variation was made in flow rate between 4 ml/hour and 30 ml/hour. The flow rate started with 4 mL/hour and was escalated to 30 ml/hour: 4, 5, 8, 20, 30 ml/hour.

Shear Rate on Wall

The shear rate [G, s^{-1}] on the wall of the glass plate is calculated by Eq. 1, which is assuming a parabolic velocity profile between parallel plates (Fig. 2c).

$$G = 6\,q\,/\,(b\,D^2) \qquad (1)$$

In Eq. 1, q is the flow rate [$m^3\ s^{-1}$], b is width of the canal [m] and D is distance [m] between two parallel walls. In the present study, b is 2 mm (Fig. 2a), and D is 0.1 mm.

The shear stress T [Pa] is the product of viscosity N [Pa s] of the fluid and the shear rate G [s^{-1}] of the flow (Eq. 2).

$$T = N\,G \qquad (2)$$

The viscosity of the medium was measured with the cone and plate type of a viscometer (TVE-22L, Toki-Sangyo Co., Ltd. Tokyo).

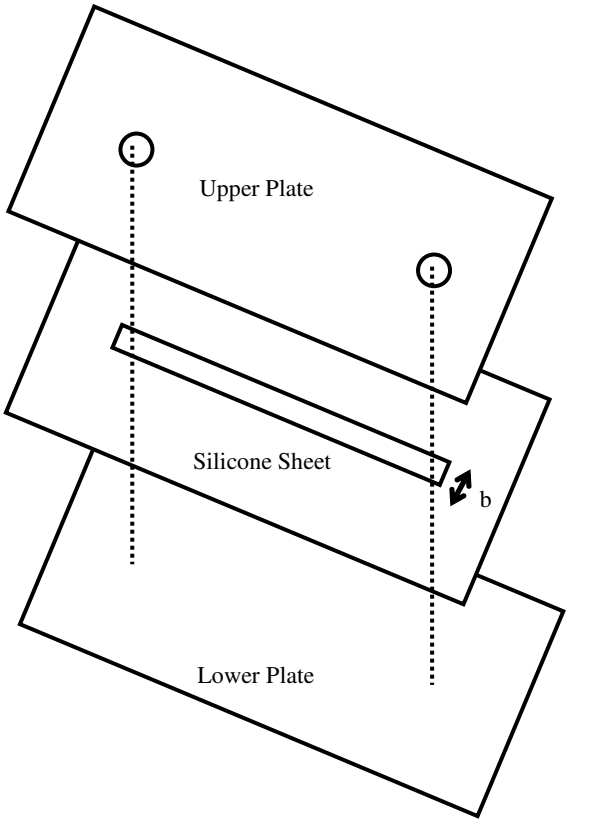


Fig. 2a: Flow chamber of three plates; upper plates of glass, silicone sheet, lower plates of glass.

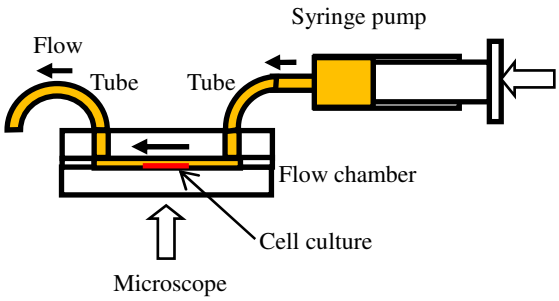


Fig. 2b: Flow from syringe pump through flow chamber.

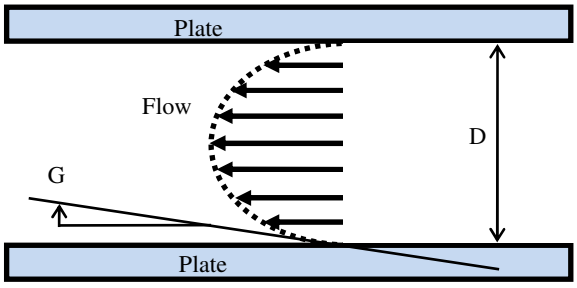


Fig. 2c: Shear rate (G) on wall. D is distance between two parallel walls.

3. RESULTS

The result of measurement with the viscometer shows that the viscosity of the medium is 0.0010 Pa s at 25 degrees Celsius at the shear rate of 600 s^{-1}. The calculated shear rate on the glass wall of the flow chamber by Eq. 1 varies between 330 and 2500 s^{-1}, when the flow rate varies between 4 and 30 mL/hour. The calculated shear stress, thus, varies between 0.3 and 3 Pa for viscosity of 0.001 Pa s, when the shear rate varies between 330 and 2500 s^{-1}.

Fig. 3 exemplifies cartilage cells suspended in the medium in the flow chamber before incubation. Several cells adhere to the glass plate of the camber in 24 hours before flow stimulation.

Fig. 4 shows cells under the flow of 5 mL/hour, which generate a wall shear stress of 0.4 Pa estimated by Eqs. 1 & 2. The medium flows from right to left in Figs. 4 & 5 (the arrow). A Cartilage cell elongates to the downstream along the streamline of the flow (A in Fig. 4). Another cartilage cell migrates to the downstream, and re-adheres to the glass plate (B in Fig. 4).

Fig. 5 shows cells under the steady flow of 30 mL/hour, which generate a wall shear stress of 3 Pa estimated by Eqs. 1 & 2. The cell (C in Fig. 5) elongates to the downstream (Fig. 5b) and exfoliates in three minutes (Fig. 5c).

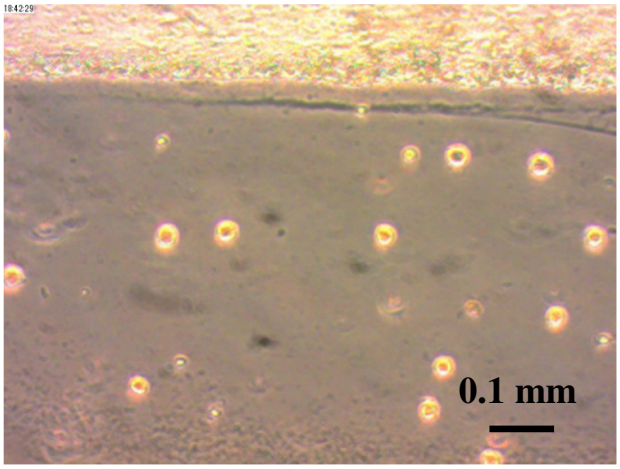


Fig. 3: Cartilage cells suspended in the medium in the flow chamber before incubation. The bar shows 0.1 mm.

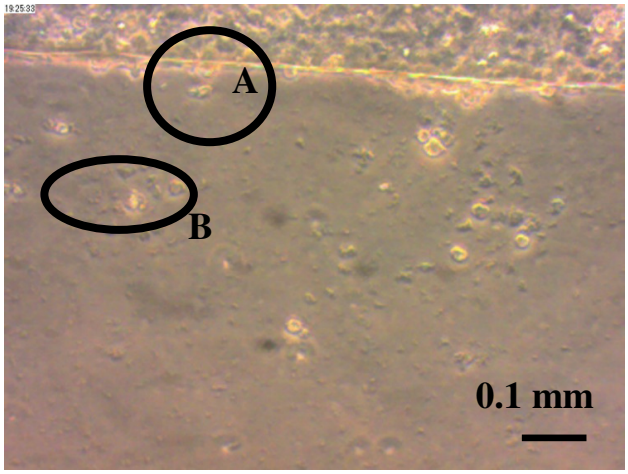


Fig. 4a: Cells just before flow stimulation. The bar shows 0.1 mm.

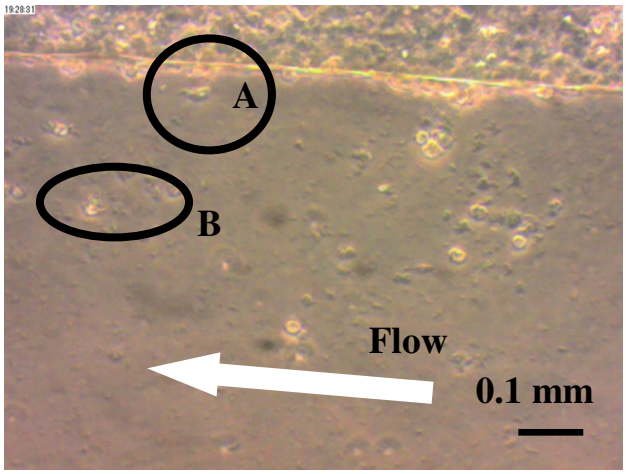


Fig. 4b: Cells after flow stimulation of 5 mL for three minutes. The bar shows 0.1 mm.

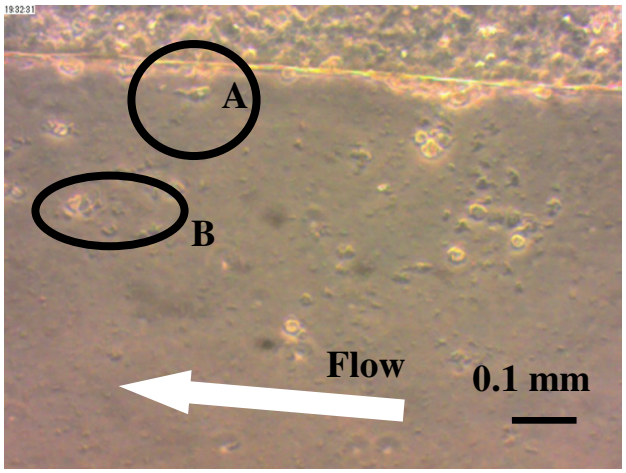


Fig. 4c: Cells after flow stimulation of 5 mL for 23 min. The bar shows 0.1 mm.

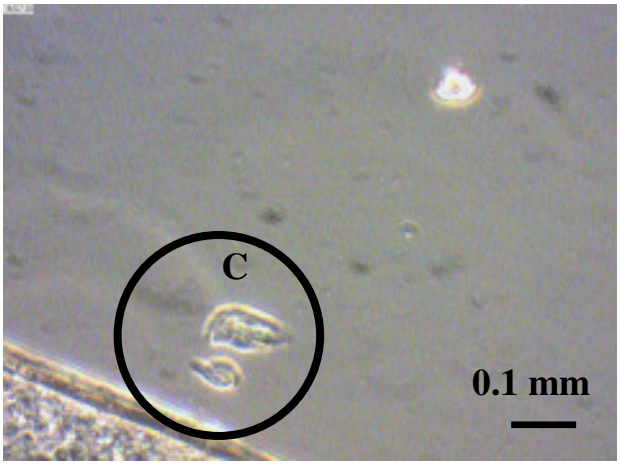


Fig. 5a: Cells just before flow stimulation.

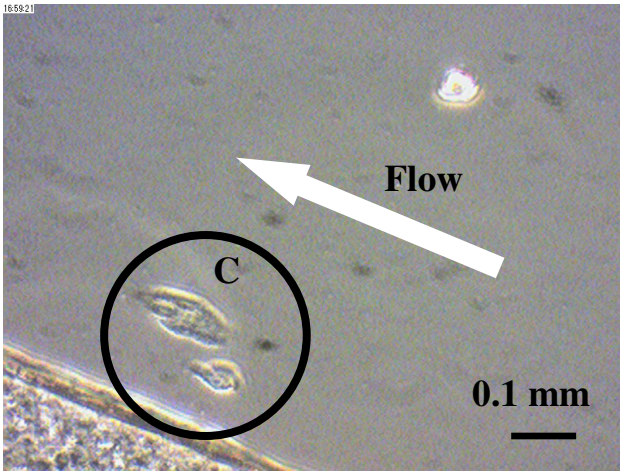


Fig. 5b: Cells after flow stimulation of 30 mL for two minutes.

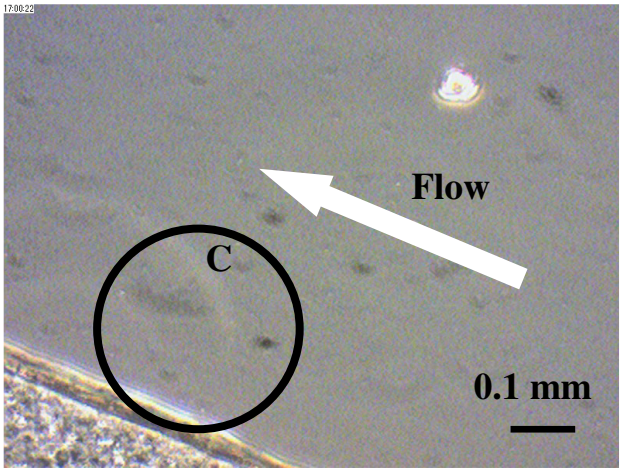


Fig. 5c: Cells after flow stimulation of 30 mL for three minutes.

4. DISCUSSION

Several movements occur on adhered cells in the flow: deformation, tilting to downstream, elongation along the streamline, deformation to be rounded, exfoliation, rolling to downstream (Fig. 6). The deformation and the migration of cells in the flow depend on the adhering point of the cell to the wall. The free part of the cell might rotate around the adhering point.

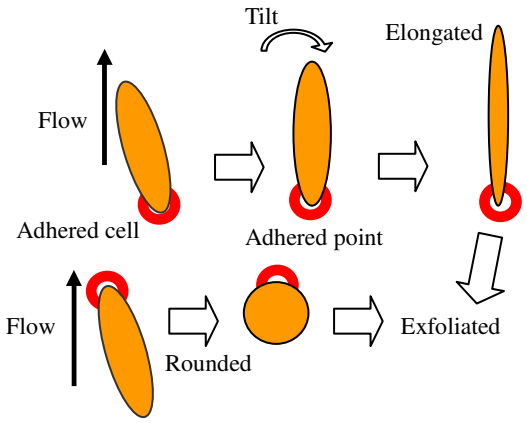


Fig. 6: Cells deformation and migration under flow.

Both acceleration of proliferation and orientation of cells are important targets in the research field of regenerative medicine on cultured biological tissue. The previous study shows that electric stimulation enhances differentiation of muscle cells [1]. Another study shows mechanical stimulation improves a tissue-engineered human skeletal muscle [8]. Another previous study shows that muscle cells can adhere and proliferate under electric stimulation with periodical pulses, and that adhesion of muscle cells can be controlled with the amplitude of the pulse [3].

Bioreactors have been developed to control the environment around the cultured cell [18].

The previous studies show that a mechanical field, on the other hand, affects on cells' behavior. Erythrocytes are very flexible, and are rolled and deformed in the shear flow [11]. The shear flow also affects on the orientation of endothelial cells [12, 17]. The shear stress affects on the orientation of the smooth muscle cells in the biological tissue [9]. The direction of the mechanical field affect fibroblasts [10]. The previous study shows that the micro-grooves govern the orientation of cells [19, 20].

Too strong mechanical stimulation damages cells. The moderate mechanical stimulation, on the other hand, might accelerate differentiation of cells [17]. The mechanical stimulation decreases proliferation of cells [21]. The mechanical stress also exfoliates several cells, which makes vacancy around the adhesive cell. The differentiation might be optimization of cells to changing environment.

The chamber which has been used in the present study is very useful, because it can be rinsed and re-constructed without the chemical adhesive. The chemical bond might affect to cells behavior through chemical reactions.

5. CONCLUSION

The effect of shear flow on cultured cartilage cells has been studied *in vitro*. The experimental results show that cells tend to elongate along the streamline and tilt to the direction of downstream.

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Effect of Pulsatile Electric Field on Cultured Muscle Cells in Vitro

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ABSTRACT

An effect of an electric field on proliferation and on differentiation of cultured muscle cells has been studied *in vitro*. C2C12 (Mouse myoblast cell line originated with cross-striated muscle of C3H mouse) was exposed to electric stimuli. In the first experiment, the adhered cells were exposed to the electric field between two electrodes made of a platinum wire of 0.2 mm diameter dipped in the medium at 37 degrees Celsius for 72 hours. The electric pulses at a period of one second with a pulse width of 0.1 second were generated with a function generator. Variation was made on the pulse amplitude lower than 12 V. The number of adhered cells was counted after exposure to the electric stimulation. In the second experiment, the cells were cultivated for 96 hours without electric stimulation in an incubator, after electric stimulation of 0.1 V for 72 hours. After incubation, the movement of myotubes was observed with an electric stimulation at a period of one second with a pulse width of one millisecond of 30 V. The experimental results show that cells adhere and proliferate under electric pulses lower than 8 V, and that differentiation accelerates with the amplitude of electric pulses of 0.1 V.

Keywords: Biomedical Engineering, Muscle Cells, Cell Culture, Electric Field, Differentiation and Proliferation

1. INTRODUCTION

The muscle tissue is exposed to the electric pulses in the biological body. The movement is also controlled with the electric pulses. The biological systems have ability to optimize themselves to their environment. The optimum electric stimulation has a potential to control growth of the muscle tissue, which might be interested in regenerative medicine. In the present study, the effect of electric pulses on differentiation of muscle cells has been studied *in vitro*.

Behavior of biological cells depends on various environmental factors, such as electric [1-5], magnetic [6] and mechanical [7, 8] fields. Electric pulses are generated with ion movement through membrane *in vivo*. The muscle tissue is controlled with electric stimulation under the nerve system *in vivo*. The electric stimulation has also been applied to a body in some medical treatments for rehabilitation.

Cell culture technique has been progressed and myoblasts have been clinically applied to ischaemic cardiomyopathy in the field of regenerative medicine. Acceleration technique for proliferation of cells has been studied to make muscle tissue *in vivo* and *in vitro* [4]. Control methodology for proliferation and differentiation of cells would be applied to regenerative- tissue technology.

In the present study, the effect of an electric field on proliferation and on differentiation of cultured muscle cells has been studied *in vitro*.

2. METHODS

Electric Field
The cells were cultured in a culture plate, which has six wells of a flat bottom without coating of collagen. The internal diameter of each well is 35 mm.

The electrodes are made of platinum wire of 0.2 mm diameter, and attached on a plate of polypropylene. When the plate covers the wells, a couple of electrodes in the rim position of each well generate an electric field in the medium. The wire has a square form in order to avoid concentration of the electric current, which might induce electrolysis. The cover plate has six square holes, through which the medium is observed during electric stimulation (Fig. 1).

Electric pulses of a period of one second with a pulse width of 0.1 second were generated with a function generator (DF1906, NF Co. Ltd., Yokohama, Japan) (Fig. 2). Variation was made on amplitude of pulse between 0.1 V and 12 V.

Cell Culture
C2C12 (Mouse myoblast cell line originated with cross-striated

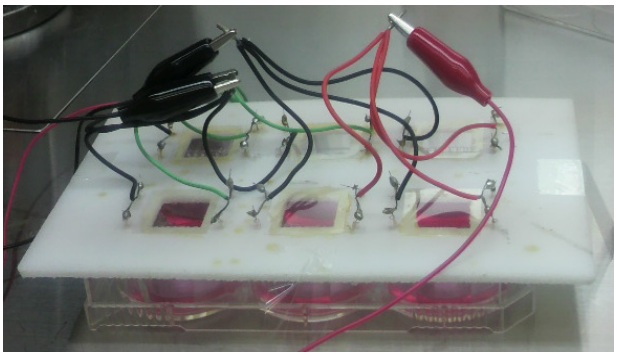


Fig. 1: Six pairs of electrodes and wells for cell culture.

muscle of C3H mouse) was used in the experiment. The muscle cells were suspended in Dulbecco's Modified Eagle's Medium (D-MEM). Fetal bovine serum (FBS) was added to the medium with the volume rate in 10 percent of FBS and 90 percent of D-MEM. The four milliliter of suspension including eight hundred thousand of cells was poured into each well.

To keep the temperature of 37 degrees Celsius and to keep the carbon dioxide content of five percent, an incubator was used for cultivation of cells. In the electric stimulation test, the electrodes were introduced into the incubator, and electric signals were introduced from the function generator outside.

Tolerance Test to Electric Pulses

After the cells were cultured in an incubator for 24 hours, electric pulses with constant amplitude were applied continuously in an incubator for 72 hours (Fig. 2a). Variation was made in the amplitude of the electric pulse: 2, 4, 6, 7, 8, 9, 10 and 12 Volts. In the control test, the cells were cultured without electric stimulation.

After the electric stimulation, the medium was discarded and the number of cells adhered on the bottom of the dish was counted with the trypsin technique. The adhered cells were exfoliated with medium including trypsin, and the suspension was introduced into a cytometry micro chamber to be counted under a microscope.

Myotubes after Electric Stimulation

After the cells were cultured in an incubator for 24 hours, electric pulses with constant amplitude of 0.1 V were applied in the incubator for 72 hours. In the control test, the cells were cultured without electric stimulation. After the continuous electric stimulation, the medium was changed to that with horse serum (HS) for differentiation (Fig. 2b). The volume ratio of HS in the medium is seven percent. The cells were cultured for successive 96 hours without electric stimulation, which means cells were cultured for eight days in total.

The movement of myotubes with the response to electric stimulation was observed under an inverted phase-contrast microscope once a day to examine their functional differentiation. The period, the width, and the amplitude of the electric pulse were one second, one millisecond, and 30 V, respectively. The electric stimulation was made only for a short term for observation. The cells were not stimulated with the electric pulses in the rest of the cultivation term. Fig. 2b shows the protocol of the experiment.

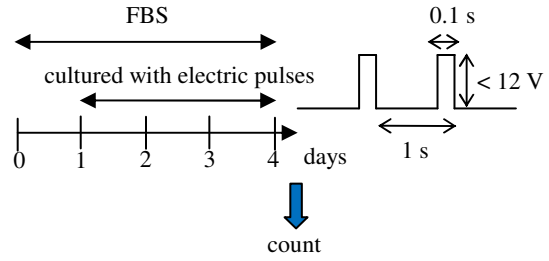


Fig. 2a: Protocol of tolerance test to electric pulses.

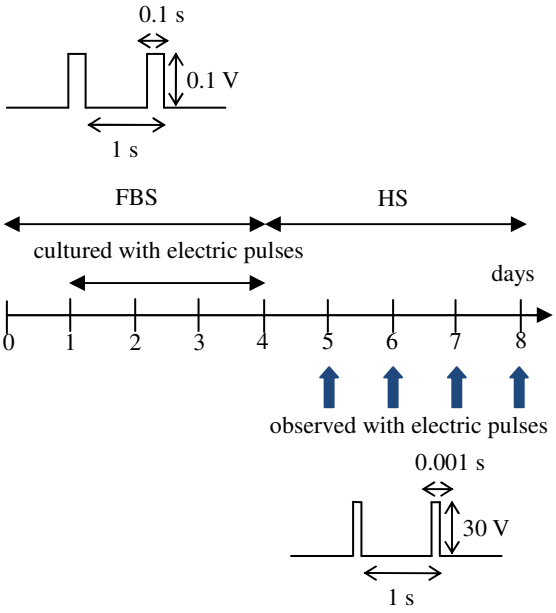


Fig. 2b: Protocol of the experiment of myotubes after electric stimulation.

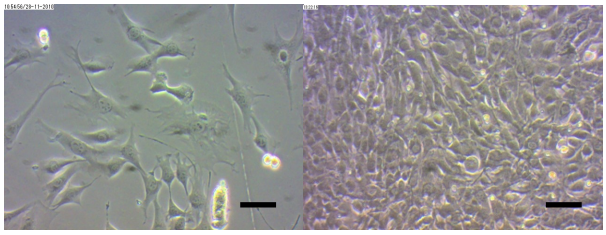


Fig. 3: Cells cultured without electric pulses. The bar indicates 0.1 mm. Left, 24 hours; Right, 96 hours.

3. RESULTS

Fig. 3 exemplifies cells in the control test without electric stimulation. The results show that cells proliferate to a confluent condition in four days.

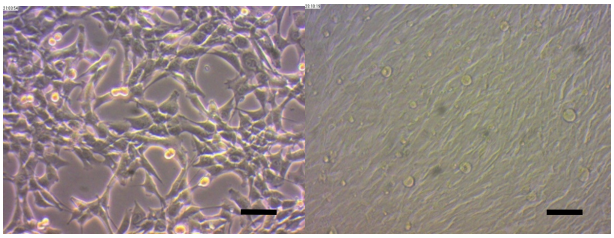


Fig. 4: Right, cells cultured with electric pulses of 2 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

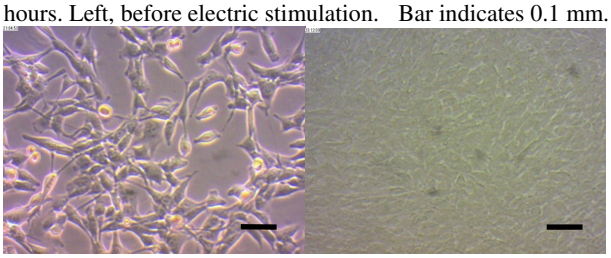


Fig. 5: Right, cells cultured with electric pulses of 4 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

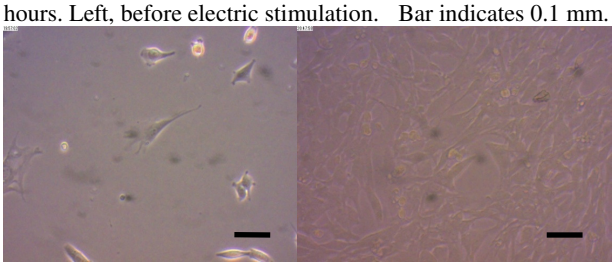


Fig. 6: Right, cells cultured with electric pulses of 6 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

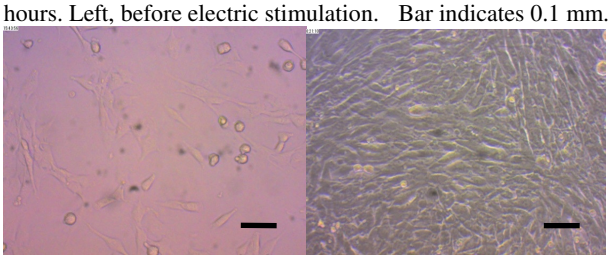


Fig. 7: Right, cells cultured with electric pulses of 8 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

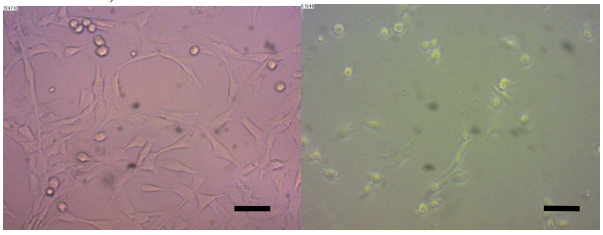


Fig. 8: Right, cells cultured with electric pulses of 10 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

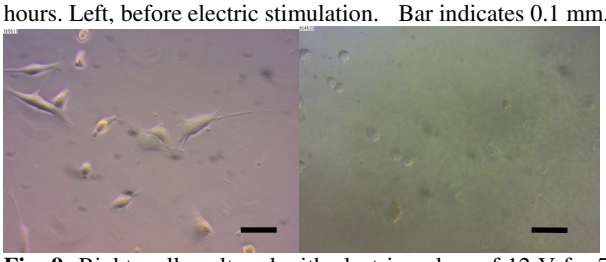


Fig. 9: Right, cells cultured with electric pulses of 12 V for 72 hours. Left, before electric stimulation. Bar indicates 0.1 mm.

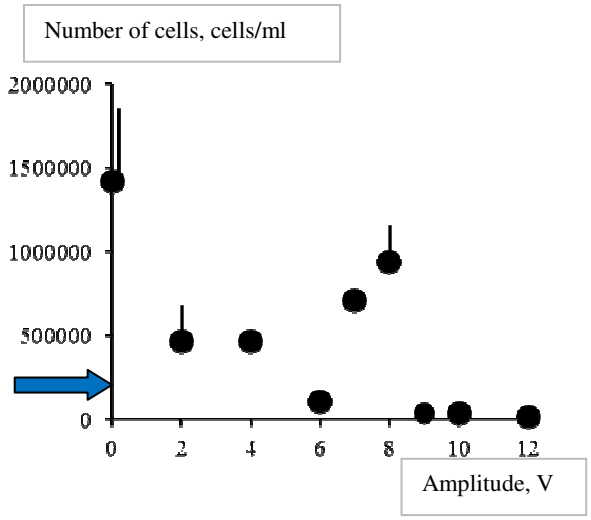


Fig. 10: Number of C2C12 after cultivation for 72 hours with electric stimulation. Arrow shows initial number.

Figs. 4-9 exemplify cells in the electric stimulation tests with the variation of the amplitude: 2 V, 4 V, 6 V, 8 V, 10 V and 12 V. The left and the right photos show cells before electric stimulation and those after electric stimulation, respectively. The figures show following results. Cells proliferate to confluent condition in four days, when the amplitude is smaller than 8 V. The number of cells does not increase in four days with the electric stimulation of the larger amplitude of 10 V and of 12 V, while several cells are adhering.

The numbers of cells after incubation for 72 hours with the electric stimulation are collected in relation to amplitude of the pulse in Fig. 10. The datum point shows the mean value of the three trials, and the top of the bar shows the maximum value in the Fig. 10. The data scatter, but the number of cells is very small after the electric stimulation with pulses higher than 9 V.

Figs. 11-14 show myotubes formed after one, two, three and four days of incubation with horse serum, respectively. The myotubes in control test and those in electric stimulation test are displayed in A and in B of the figures, respectively. In every test, cells were morphologically differentiated to myotubes on the fifth day of culture. Several highly fused myotubes are shown in the stimulated cells (arrow in Fig. 14B). The repetitive contraction was observed with the electric pulses on the eighth day of culture. The numbers of myotubes which shows repetitive contraction with the electric pulses in stimulated cells and in control cells are 106 and 20, respectively. The repetitive contraction of myotubes was more frequently observed in electrically stimulated cells than in control cells.

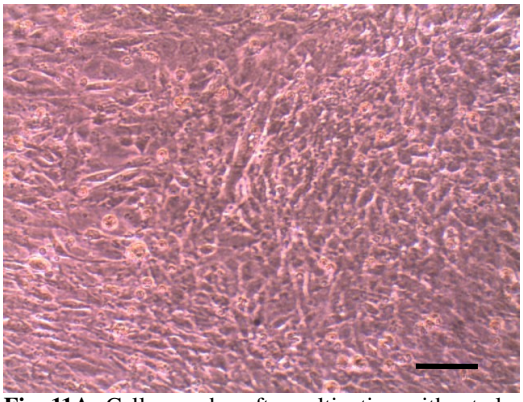


Fig. 11A: Cells one day after cultivation without electric pulses four 4 days. The bar indicates 0.1 mm.

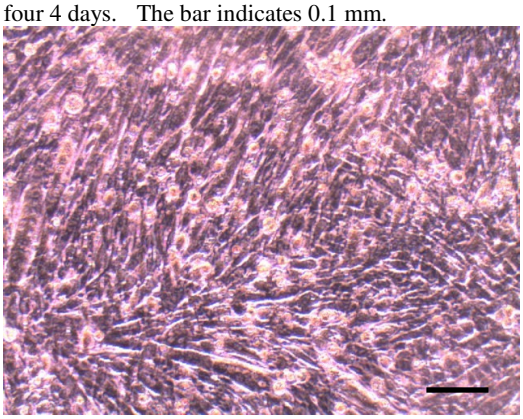


Fig. 11B: Cells one day after cultivation with electric pulses for 4 days. The bar indicates 0.1 mm.

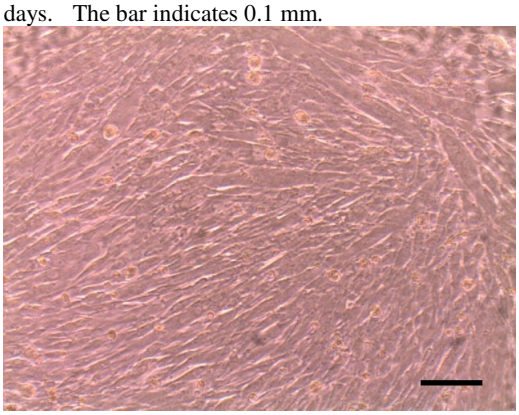


Fig. 12A: Cells two days after cultivation without electric pulses. The bar indicates 0.1 mm.

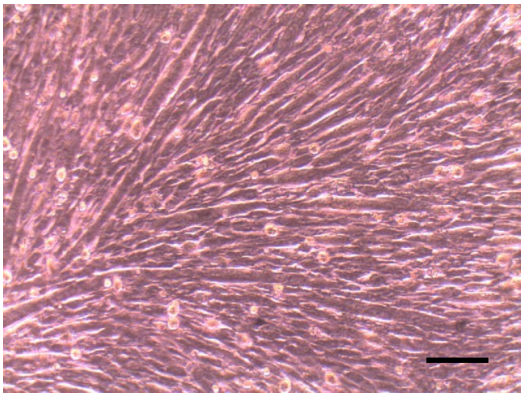


Fig. 12B: Cells two days after cultivation with electric pulses for 4 days. The bar indicates 0.1 mm.

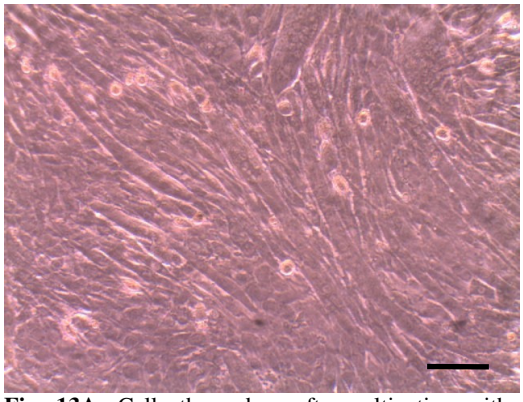


Fig. 13A: Cells three days after cultivation without electric pulses for 4 days. The bar indicates 0.1 mm.

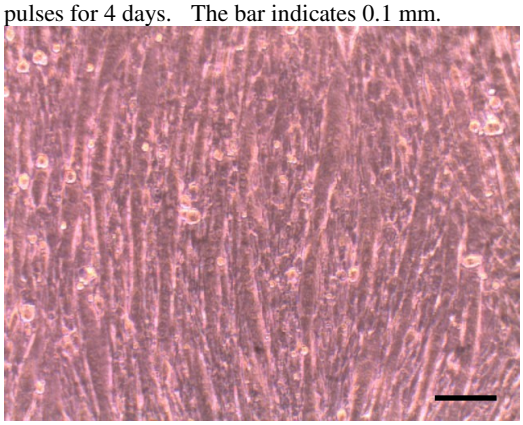


Fig. 13B: Cells three days after cultivation with electric pulses for 4 days. The bar indicates 0.1 mm.



Fig. 14A: Cells four days after cultivation without electric pulses for 4 days. The bar indicates 0.1 mm.

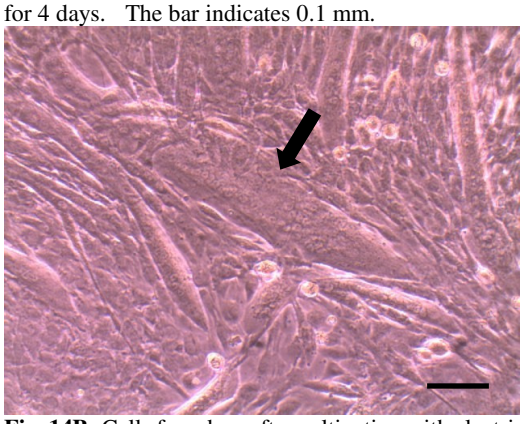


Fig. 14B: Cells four days after cultivation with electric pulses for 4 days. The bar indicates 0.1 mm.

4. DISCUSSION

The previous study shows that electric stimulation enhances differentiation of muscle cells [1]. Another previous experimental result shows that proliferation decelerates with the amplitude of electric pulses [5]. Another study shows that mechanical stimulation improves the tissue-engineered human skeletal muscle [7].

Several factors might govern adhesion of biological cells. The previous study shows that electric stimulation can restrict adhesion of muscle cells [5]. Another study shows an electromagnetic field affects on the cell [6]. An alternating magnetic field might affect on adhesive molecules on the cell membrane.

The muscle tissue is daily exposed to the field of electric pulses, which are signals for the control of contraction. It serves a double purpose when the electric fields control regeneration of the tissue.

Several stresses might stimulate differentiation of cells. The electric stimulation might also affect myocytes to differentiate into myotubes. The change of environment stimulates the change of behavior of myocytes, so that myocytes differentiate into myotubes. The experimental results show that differentiation accelerates with the electric pulses.

An Electrolytic process occurs around the electrode with the higher amplitude of pulses, which makes change of local pH in the medium. The environmental change restricts cell proliferation. The number of cells does not increase in four days with electric stimulation of the amplitude larger than 9 V in the present study. Too strong electric stimulation damages myocytes. The moderate electric stimulation, on the other hand, might accelerate differentiation of myocytes (Fig. 15). The electric stimulation decreases proliferation of cells. The electric stimulation also exfoliates several cells, which makes vacancy around the adhesive cell. The modification helps thickening of cells, and stimulates differentiation of cells. The differentiation might be optimization of cells to the changing environment.

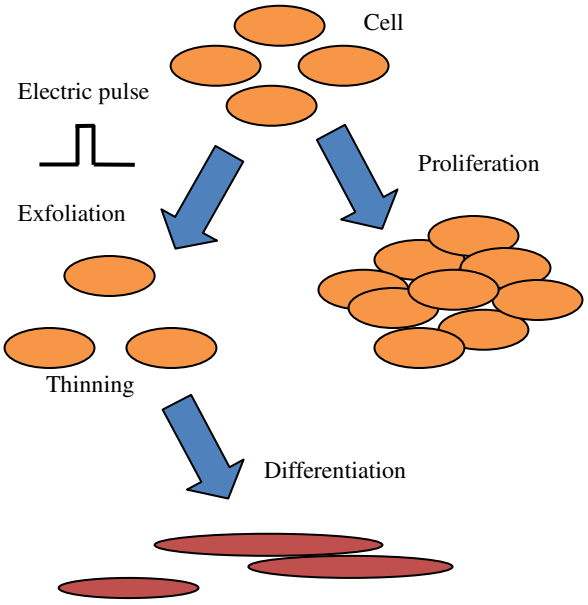


Fig. 15: Moderate electric stimulation might accelerate differentiation of myocytes.

The repetitive contraction proves functional differentiation of muscle cells. The present study shows the effect of electric stimulation on differentiation of muscle cells.

5. CONCLUSION

The effect of an electric field on differentiation of cultured myocytes has been studied *in vitro*. The experimental results show that cells adhere and proliferate under continuous electric pulses lower than 8 V, and that differentiation accelerates with the amplitude of electric pulses of 0.1 V.

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Diagnostic Expert System with Application in Maritime Affairs

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ABSTRACT

Expert systems have a wide range of applications in everyday life and because of their modular nature and simple integration in various programming languages, could be used to solve even the most difficult problems. Therefore the proposed system describes only one aspect of the application, the one in the area where a chronic lack of a human expert is obvious. Those are the cases where the expert system can be used as an adequate substitution for a human specialist. Application of the proposed system is not limited only to the situations happening at sea, but at all other sites where no medical aid is available and where correct diagnosing can be of crucial importance. Data sampling and analysis of seamen diseases were carried out in cooperation with the commercial maritime company, and outcomes were taken as the basis for inference rules design processes. The prerequisite of the system design is to have the basic programming knowledge to allow easy upgrade to the next application level where a wider range of possible diseases may be analyzed

Keywords: expert system, medical application, maritime, diagnostics, simulation, modelling, information technology, data processing

1. INTRODUCTION

The initial assumption is the fact that the commercial fleet and numerous yachts face serious issues related to the fast, reliable and efficient diagnosis of both benign and serious health problems [1].

On many occasions the captain and crew members can consider the symptoms of one of their colleagues to be benign and not to require docking, however on the other hand the captain still wishes to be able to protect himself and the company from any potential mistakes. Since the economic aspect of the entire case is very important, the costs of changing the ship's route in case of medical emergency can not be ignored. There is a chance of somebody getting sick while the ship is on the ocean with the first port more than twenty days away.

Thirty years ago, usually every ship had its own doctor and an infirmary. However as the time passed, the number of crew members reduced, telecommunication services enhanced and budget reduced, hence the infirmaries were removed from today's ships infrastructures.

Nowadays, an emergency medical treatment is carried out by the captain or the first officer who have a basic medical training. In cases of severe problems and needs for more complex diagnosis, the diagnostic documentation is sent by e-mail or by telephone to the doctors on land.

These doctors usually have signed agreements with the naval companies, and send their response by same communication links.

Abovementioned reasons enforce a real need for an expert system for diagnostics and treatment procedures [2]. In the cases of non presence of doctor aboard, the implementation of diagnostic system should be a must.

This idea of developing an expert system which should simulate a real doctor is not new in the field of information technologies. One of the first expert systems (MYCIN) [3], developed in the seventies of the last century at Stanford University, aimed at creation of the medical diagnostic tool. One of the basic reasons of its rare use was the presence of underdeveloped information technology (IT) infrastructure, i.e. the hardware could not enable fast data processing processes. The other reason was the fact that the system was designed in the pre-Internet age so its usage was limited to the test laboratories within Stanford University where it was developed and implemented. Since the hardware problems have been surpassed and improvements in telecommunication technologies have brought Internet to every corner of the world we may say that reviving this type of system in the form of Internet service would be commonsensical.

2. BASIC FUNCTIONALITY AND SYSTEM MODELS

Basic functionalities [4][5] of the proposed system that could be implemented on the commercial - ship should include the following:

- Use of the smart cards [6]: the user logs in while in offline mode with his smart card (using a reader that is included with the software package). The card can be considered to be user's health insurance card containing all of his data and medical history like illnesses, blood type, allergies to certain drugs, etc... This data may be processed to make further diagnosing easier.
- Offline mode: an Internet connection aboard a ship can only be established via a satellite, often taking just a couple of hours a day, while in offline mode the software has built-in a pre-defined set of questions and diagnoses in accordance with such type of environment.
- Online mode: if the sickness and the therapy are not determined in the offline mode, then all of the

collected and prepared data is sent via a satellite link (when the connection is available and established) to the central location where the data is processed.

- Subscription: this system is a commercial one. Besides the limited time of subscription that can be extended easily, the user is allowed to make ad hoc inquiries through the web interface. The payment transactions may be initiated by banking cards or by any of Internet based wallet systems i.e. Pay Pal [7][8].

As follows, there are several models representing the components and functionalities of the proposed system.

Component model (Fig. 1) is shown by two diagrams that represent the client (Fig. 2) and central (Fig. 3) system installation while the use case model (Fig. 4) depicts diagnose determination process.

Component and use case models represent an excellent base for initial system architecture modelling because they enable us to design software components and their interfaces.

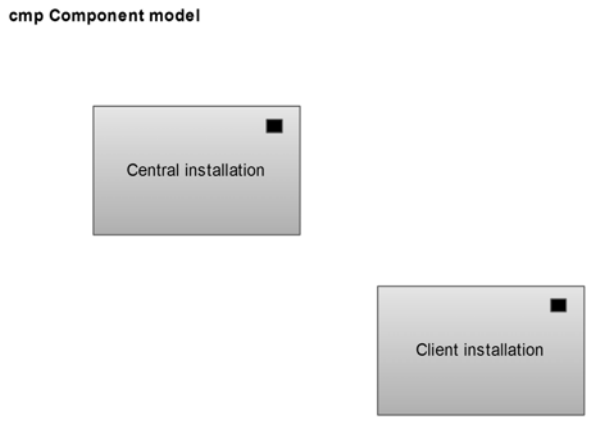


Figure 1. Component model of the proposed system

3. THE INITIAL DEFINITION OF THE SYSTEM

Backward chaining was chosen for the basic inference-making model. Inference process begins with a final conclusion that needs to be reached and works backwards through an inference engine which means that for example data needed to reach the desired goal is discovered from right to left.

System's objective is to reach the desired goal (also called the assumed solution or the 'then' part of the clause) using a set of defined rules that exist within the acknowledgement base.

In this type of system we analyse all rules that lead to the desired goal simply shifting the procedure from the goal towards the initial premise, then we treat the individual results or inferences as hypotheses or outcomes of the rules that pass through analysis process. By these actions, we should be aware that the inference process needs to happen bottom-up, from the desired goal upwards.

4. CREATING THE INITIAL SET OF RULES

Observing the way a doctor performs his work, conclude that he/she asks a lot of questions related to the patient's current condition and medical history.

To simplify the entire diagnostic process, the following issues need to be considered as prerequisites:

- Presence of any chronic disease,
- Existing symptoms,
- Factors that cause the symptoms behaving worse,
- Definition set of drugs used by patient
- Inherited diseases.

The initial set of rules that will be embedded in the system is built by clear definition of the rules set that lead us directly to the expected goal.

If we observe the symptoms of a heart attack we may conclude that this condition could be caused by stress, presence of the disease in the family, using certain drugs (like Yasmin) and by similar causes.

The system that has only one level consists of rules directly leading as to the given goal. Such system consists of the following procedures:

a) it asks the patients for symptoms and then
b) it activates the rule that is in accordance with the symptoms and reach the target..

Obviously, there is a need to have as many defined rules (of this type) as there are possible diagnoses.

The system often does not have the sufficient amount of data or knowledge to be able to solve the problem. That's why the expert systems often introduce a certain level of abstraction among the rules which help the users and the systems to reach the desired goal proposing the proper solution.

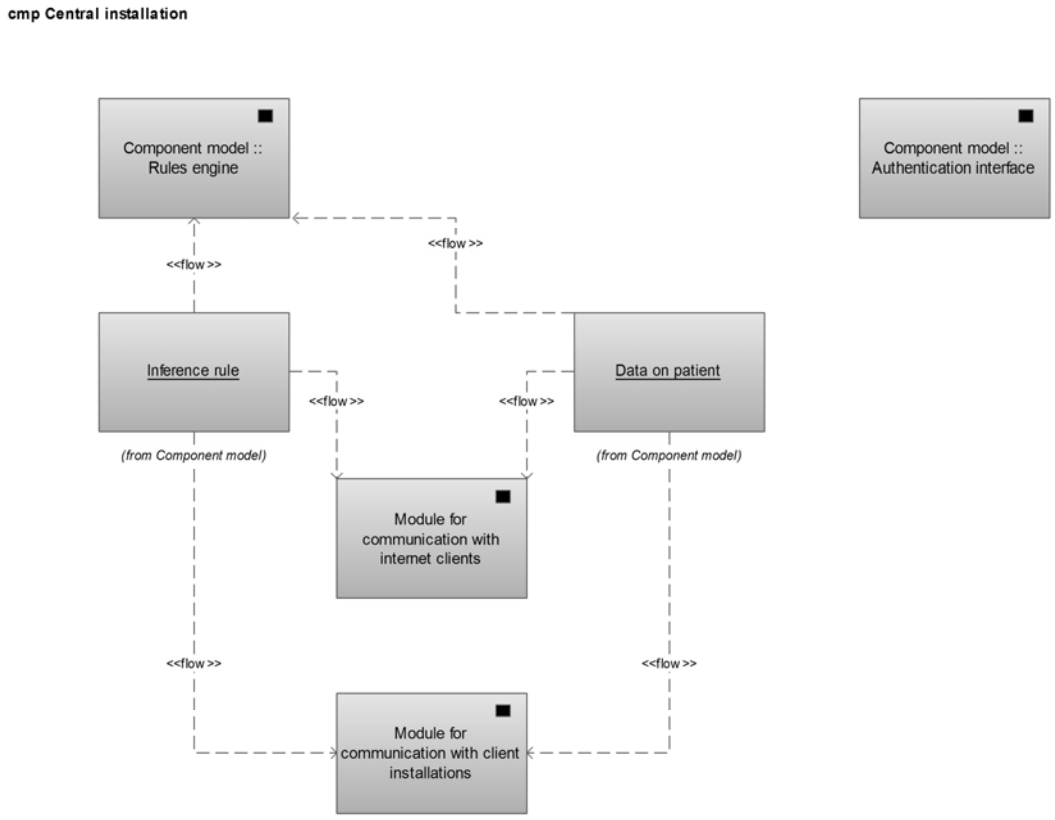


Figure 2. Component model of central installation

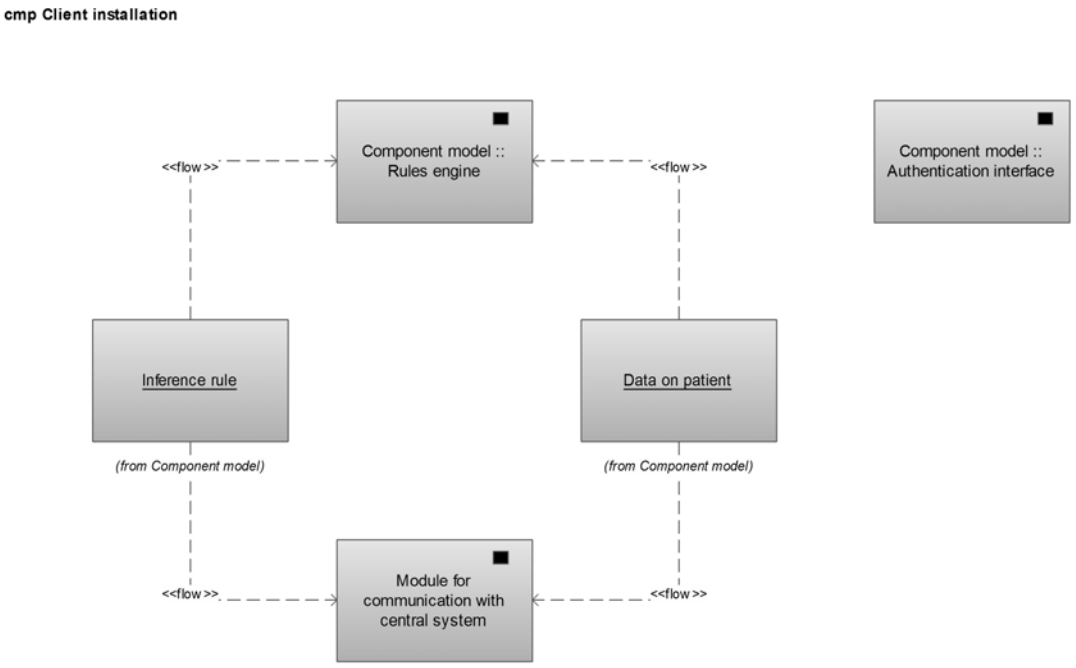


Figure 3. Component model of client installation

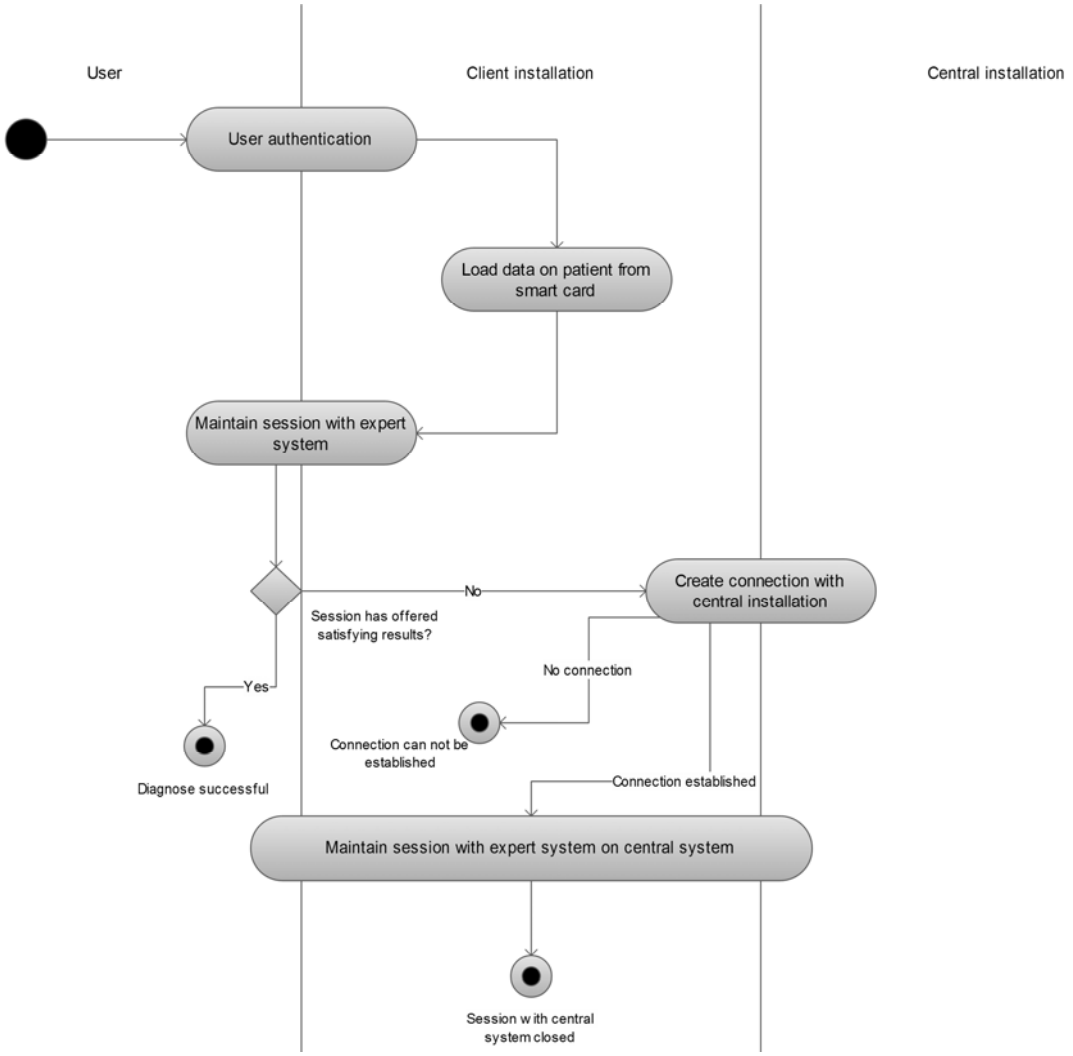


Figure 4. Use case diagram depicting the detection of diagnosis

Basic assumptions that one should be aware of while creating the initial set of rules are:

- To be ascertained if the system contains the rules that will lead the process to the defined goal
- To prepare built-in articulated messages and distinct questions, to simplify the communication and interaction between the human being and the machine. If possible, the speech recognition system should be implemented imitating the human expert
- To provide continuous improvement of the rules of the core of the decision-making mechanism
- To allow users to use the system unlimited number of times
- To design system in such a way that within the same given conditions it always produces the same results.

5. ADAPTATION OF DEDUCTION PRINCIPLES AND THE SYSTEM CONTROL

Inference techniques and tools that are already integrated within the designing and programming tools of the expert systems are in most cases sufficient for design and construction of simple systems. Although, at times there is a demand for changes that surpass the boundaries of the given tool techniques.

Since the most of the tools do not allow these changes to be processed, the most frequent way of achieving this goal can be determination of the triggering order of certain rules.

If we design an expert system containing a large number of rules, and in particular developing stage we wish to rearrange them, the target will be achieved simply by changing the priority of the rules. In this case we will get a system that does not operate at a hierarchical principle, these rules will not be triggered the way we need to reach deeper levels of the system, but they will rather be triggered depending on their already assigned level of priority.

6. SEAMEN'S MEDICAL RECORDS

To design a reliable system expressing the real conditions, we analysed data [9] about the most frequent diseases appeared aboard the ships of the commercial maritime company.

During each of the seaman's disembarkations the reason of his leaving the ship is also recorded. This data provides the information about the most frequent diseases and the age groups that are usually afflicted by them.

The sampling data was entered in the database during one year period, more precisely from October 1st 2009 to October 1st 2010.

Fig. 5 represents the frequency of certain diseases found with seamen and these have been grouped in several basic categories for easier understanding.

Obviously, the most frequent problems are injuries and fractures, coming out of the nature of the work on ships. These are followed by heart condition issues, kidney and urinary tract problems and lung diseases. Mental problems like anxiety or depression were also recorded, as a result of life and work within a small area surrounded by a large number of people.

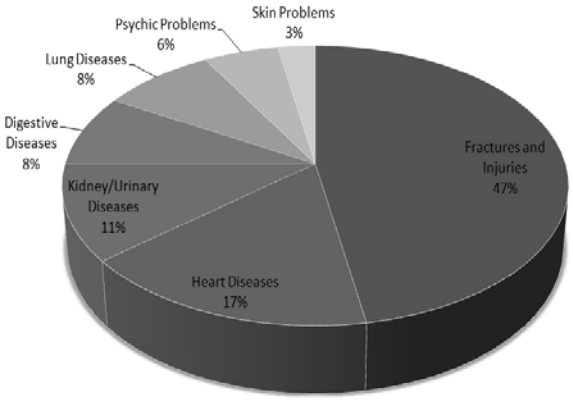


Figure 5. Frequency of certain categories of seamen's diseases

Fig. 6 clearly shows that older population of seamen is the most susceptible to different diseases. Relation between age and certain disease categorise is shown in Fig. 7.

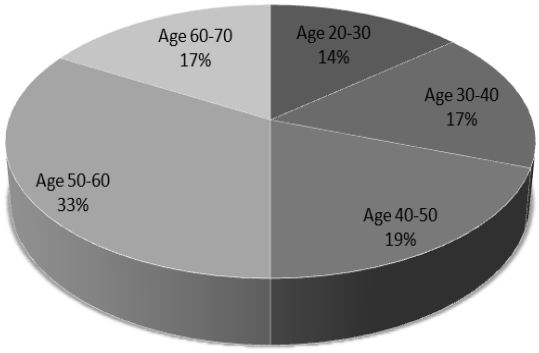


Figure 6. Frequency of certain categories of seamen's diseases related to their age

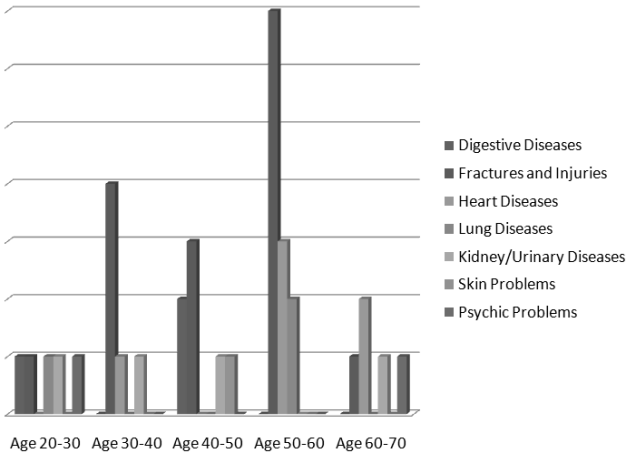


Figure 7. Relation between age groups of sailors and certain disease categories

These diagrams were created to simplify the creation of deduction rules of the proposed system.

7. CONCLUSION

Artificial intelligence [10][11] and expert systems have been merged as a scientific discipline with overlapping fields of interest, thanks to the combination of computing techniques and scientists' efforts to imitate human intelligence by emulating and formalising it.

Expert systems enable us to present knowledge in a modular and highly structured shape. Modularity is one of more important characteristics of the expert systems. It allows easy transformation and implementation of new sets of rules. Although this article brings a proposal of a specialised expert system, the abovementioned modularity allows us its easy upgrade and transformation that can be implemented into other areas of human activities where a human expert is not always available. The use of expert systems becomes crucial factor not only in the cases shown in this paper, but within broad range of real time and real life cases.

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Effect of Hurricane Katrina on Low Birth Weight and Preterm Deliveries in African American Women in Louisiana, Mississippi, and Alabama

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ABSTRACT

Using three statistical models (GLR, GEP, and GM), the effect of Hurricane Katrina on low birth weight and preterm delivery babies for African American women is examined in Louisiana, Mississippi and Alabama. The study results indicate that risk factors associated with low birth weight and preterm delivery for American African women include unemployment and percent of mothers between the ages of 15-19. Among White women, ages 15-19, risk factors included poverty rate, median household income, and total birth rate. The GMs performed accurate predictions with increasing low birth weight and preterm delivery trends for African American women in the Gulf Coast states and other U.S. states, and decreasing low birth weight and preterm delivery trends for their White counterparts in the same state locations. Data presented between 2007-2010 show low birth weight and preterm delivery for White women as a decreasing tendency while birth outcomes for African American women exhibited a monotonically increasing trend. The empirical findings suggest that health disparities will continue to exist in the foreseeable future, if no effective intervention is taken. The models identify risk factors that contribute to adverse birth outcomes and offer some insight into strategies and programs to address and ameliorate these effects.

Keywords: Health Disparity, Low Birth Weight, Preterm Delivery, GLR, GEP, and GM.

INTRODUCTION

Adverse birth outcomes for African American women in Louisiana, Mississippi, and Alabama reflect a major health disparity before and after Hurricane Katrina. Using three statistical models (generalized linear regression model (GLR); gene expression programming (GEP); and grey model (GM)), the effect of Hurricane Katrina on low birth weight and preterm delivery babies for African American women are examined before and after Hurricane Katrina. The study population includes a comparison of African American and White women between the ages of 15-19 living in Louisiana, Mississippi, and Alabama and their counterparts across the United States before and after Hurricane Katrina.

Recent studies show that disasters such as Hurricane Katrina and their aftermath may lead to factors that disrupt healthy pregnancies. These disruptions can be characterized as limited or no access to prenatal care, lack of social support, and the inaccessibility to physical resources such as food, pharmacy, housing, etc. (Xiong, Mattison, Elkind-Hirsch, Pridjuan, & Buekens, 2009). Historically, natural disasters lead to adverse pregnancy outcomes; the frequency of low birth weight infants increases immediately following a disaster (Xiong, Mattison, Elkind-Hirsch, Pridjuan, & Buekens, 2009). Despite large declines in the U. S. infant mortality in recent years, low birth weight infants born to African American women continue to increase. However, the improvement in birth outcomes is faster among White women, resulting in a wider gap between the two racial groups.

Hurricane Katrina, a deadly storm that struck the Gulf Coast in August of 2005, continues to have a major health effects on the Gulf Coast Region in the United States. Many of the effects have been studied by other researchers including economic devastation, displaced populations, and increased levels of health problems in survivors, ranging from mental health issues to child health issues. In 2009, the National Vital Statistics Report indicated that there were fewer births in the Gulf Coast region following Hurricane Katrina when compared to births outcomes prior to the Hurricane, 27 and 33, respectively (Hamilton, Matthews, Martin, & Ventura, 2009).

This retrospective study offers some insight and is critically important as potential risk factors may contribute to infant mortality, which is one of the measures that predict nation's health. This article examines the effect of Hurricane Katrina on low birth weight and pre-term delivery of infants born to African American women living in the geographical target states of Louisiana, Mississippi, and Alabama. Examining the root cause of adverse birth outcomes for African American women before and after the

Hurricane Katrina may help explain the dramatic increase of these cases in these target states. By identifying the risk factors that may contribute to adverse birth outcomes, appropriate health care strategies and programs can be put into place to address and ameliorate these effects.

LITERATURE REVIEW

Data shows that among all factors that could lead to infant mortality, low birth weight and preterm delivery are most prevalent in the African American community (Chang, O'Bren, Nathanson, Mancini, & Witter, 2003). Despite indications that more African American women are receiving prenatal care, African American infants die more often of low birth weight than any other leading causes. Many studies have concluded that socioeconomic status leads to this alarming trend. However, it alone cannot describe or explain the health disparity gap. Research has actually proven that race and socioeconomic status have separate, independent effects on low birth weight (Colen, Gernoimus, Bound, & James, 2006). Given that teenage mothers have a high prevalence of giving birth to a low birth weight infant; the race-specific relative risk for babies born to mothers less than 16 years of age were at an 11% to 40% increase compared to babies born to mothers 25-29 years of age (Friede, et al, 1987). It has been indicated that while the risk for poor pregnancy outcomes is high among young adolescents, young African American mothers appear to be particularly vulnerable. African American women are two times more likely to give birth to an infant with a weight of less than 2500 grams than their White counterparts. They are also more likely to have a preterm delivery, which is defined as the birth of a baby before 37 weeks of pregnancy

The adverse effects of childbearing by African American teenagers on the outcome of pregnancy among African American women appear to have been overemphasized. African American infants in the U. S. are more than twice as likely as White infants to die in the first year of life. African Americans aged 10-14 have a birth rate of 4.29 per 1,000 live births, which is seven times more than their counterparts (0.59 per 1,000 live births). African American mothers also had higher proportions of very low (3.7 grams) and low birth weight (2.6 grams) infants than non-Hispanic Whites, 15.0 and 10.5 respectively (Leland, Petersen, Braddock, & Alexander, 1995).

Rates of infant mortality are substantially higher for less than 15 year olds (8.1 per 1,000 live births) than 16-17 year olds (6.3 per 1,000 live births) and 18-19 year olds (5.4 per 1,000 live births). In a study on the effect of gross domestic product (GDP) and infant mortality, the distribution of income suggests that in rich countries, reduction of income inequality was likely to be more effective in lowering infant mortality rates. Health system variables, particularly the method of healthcare financing and the supply of physicians significantly attenuated the effect of wage inequality on infant mortality. Disruption of health care provisions due to the hurricane is likely to have an impact on the overall quality of healthcare, and ultimately, increase health disparities among African American women.

The study objectives are (a) to identify risk factors associated with the adverse birth outcomes before and after Hurricane Katrina, (b) to compare mean difference of the adverse birth outcomes before and after Hurricane Katrina, (c) to compare mean difference of the adverse birth outcomes before and after Hurricane Katrina within the Gulf Coast states and other U.S. states, respectively, and (d) to perform statistical analysis to determine future predictions for the adverse birth outcomes of African American women in this target geographical area.

STUDY METHOD

To explore the study objectives as proposed, secondary data from Center for Disease Control and Prevention (CDC) Wonder, and the U.S. Census Bureau are used retrospectively to show important risk factors leading to an increase in low birth weight and preterm deliveries in this comparison study. The outcome variables are (1) the number of low birth weight babies per 10,000 live births (defined as the weight of infants less than 2,500 grams) and (2) the number of preterm delivery babies (defined as the birth of an infant before 37 weeks of pregnancy) for each county/perish from years 2003-2004 (before Katrina) to 2006 (after Katrina). The ten (10) explanatory variables used in this study include the number of total primary care physicians, unemployment rate, poverty rate for all ages, median household income, total birth rate, percent of African American mothers aged 15-19, and percent of White mothers aged 15-19, state group (Gulf Coast states vs. other U.S. states), timeline (2003-2004 before Katrina vs. 2006 after Katrina), and interaction of state group by timeline for the same county/parish in the study period.

To identify a subset of significant risk factors associated with low birth weight and preterm delivery and compare marginal mean difference of low birth weight and preterm delivery before and after Katrina for the study group, the generalized linear regression (GLR) model in the SPSS package is used for the data analysis. In the GLR model, multiple linear regression analysis and 2 x 2 factorial designs with a two-way analysis of variance (ANOVA) are combined. In this study, the numbers of low birth weight and preterm delivery babies are postulated to be larger after the timeline of Katrina than before the timeline of Hurricane Katrina, regardless of the state group.

To rank risk factors affect low birth weight and preterm delivery in African American and White mother aged 15-19, the gene expression programming (GEP) approach is performed. The GEP model offers new possibilities for solving complex scientific problems. As the world constantly changes, the population within it is suspected to change accordingly, so that it has a chance of surviving. The GEP algorithm simulates this occurrence by creating models that consist of populations that are derived from previous generations that were best fit to survive the model under previous conditions (Ferreira, 2006). In the GEP model, the outcome variables of interest are low birth weight and preterm delivery at the county/parish, respectively, and the genotypes (chromosomes) placed into

the system that are executed include all independent variables. These chromosomes are placed into the system and each chromosome is expressed through a mathematical equation, phenotype (expression tree).

To predict a mid-range of 4-year low birth weight and preterm delivery for African American and White groups, grey models (GMs) are constructed. The main strength of the GM is to use a short-term time series (a minimum of four data points) to perform reliable and accurate predictions (Deng, 1982). The GM model can be used to determine health disparity in terms of low birth weight and preterm deliveries between African American and White women and to predict the 2007 – 2010 low birth weight and preterm delivery babies for African American and White women who reside in Gulf Coast states vs. other U.S. states, respectively. The traditional time series methods (simple, Holt's, and Brown's exponential smoothing models) are used to compare the prediction accuracy of the GMs based on the small value of mean absolute percentage error (MAPE).

STUDY RESULTS

Low birth weight and preterm deliveries were analyzed using the GLR and GEP models at the county/parish level. The sample size (1,467 counties/parishes) with low birth weight infants and preterm deliveries in the Gulf Coast states were 81 counties/parishes and 1,386 other counties/parishes in the U.S. This number was equal to the total number of counties with preterm deliveries and low infant birth weight before Hurricane Katrina (978) in Years 2003-2004 and after Hurricane Katrina (489) in year 2006.

The GLR model was also used to determine trends for risk factors affecting low birth weight and preterm deliveries over the three year study period. Risk factors were further examined for low birth weight and preterm deliveries separately. The separate analysis of low birth weight, the significant variables found by the GLR model (R squared value of 0.884), and the important variables ranked in GEP order for African Americans were the percentage of African American mother's ages 15-19 ($b1=0.692$, $p<0.001$, GEP rank no. 1), percentage of White mothers ages 15-19 ($b2=-.068$, $p<0.001$, GEP rank no. 2), state group ($b3=87.096$, $p< 0.001$, GEP rank no. 3), and timeline concerning Katrina ($b4=59.178$, $p<0.001$, GEP rank no. 4), unemployment rate ($b5=-2.959$, $p<0.01$, no GEP rank), and state group by timeline interaction ($b6=60.328$, $p <0.001$, no GEP rank). For Whites model (R squared value of 0.709), the most important risk factors were the percentage of White mothers ages 15-19 ($b1=4.40$, $p <0.001$, GEP rank no. 1), poverty rate ($b2=-8.843$, $p <0.001$, GEP rank no. 2), and the total number of primary care physicians ($b3=.141$, $p<0.001$ GEP rank no. 3), median household income ($b4=.002$, $p <0.001$, no GEP rank), total birth rate ($b5=-.088$, $p <0.001$, no GEP rank), and state group ($b6=59.747$, $p <0.001$, no GEP rank).

The mean difference in low birth weight babies was significantly higher in the Gulf Coast states than in other U.S. states. For African American women the marginal mean difference of low birth weight babies in target geographical area and other U.S. states was 56.932 with $p<0.001$. The marginal mean difference for White women was 48.195 with $p<0.001$. White women had increased the marginal means for low birth weight babies in the Gulf Coast states in comparison to other U.S. states; however, African American women had a larger marginal mean difference of low birth weight babies between Gulf Coast states and other U.S. states. The marginal mean of low birth weight babies was higher after Hurricane Katrina for both African American and White women. However the marginal mean difference (29.014) in pre and post Hurricane Katrina was only significant ($p <0.001$) for African American women.

When comparing marginal means by timeline within state groups, Gulf Coast states had a higher number of low birth weight babies for African American women and Whites before and after Katrina. There was a larger marginal mean difference in low birth weight babies before and after Katrina in the Gulf Coast states. The marginal mean of African American low birth weight babies decreased in other U.S. states while this number increased for that in the Gulf Coast states after Katrina. For Whites, this number increased in both Gulf Coast states and other U.S. states after Katrina.

The individual analysis of preterm deliveries, the significant variables found by the GLR model (R squared value of 0.889) and the most important variables ranked in GEP order for African American were percentage of African American mothers aged 15-19 ($b1=.95$, $p<0.001$, GEP rank no. 1), percentage of White mothers aged 15-19 ($b2=-.088$, $p<0.001$, GEP rank no. 2), state group ($b3=57.746$, $p<0.001$, GEP rank no. 3), unemployment rate ($b4=-7.554$, $p<0.001$, GEP rank no. 4), timeline ($b5=32.746$, $p<0.05$, GEP rank no. 5), and state group by timeline interaction ($b6=34.371$, $p<0.05$, no GEP rank). For White Americans, the significant variables found by the GLR model (R squared value of 0.712) and the important variables ranked in GEP order were percentage of White mothers ages 15-19 ($b1=.729$, $p<0.001$, GEP rank no. 1), poverty rate ($b2=-14.892$, $p<0.001$, GEP rank no. 2), median household income ($b3=.003$, $p<0.001$, GEP rank no. 3), unemployment rate ($b4=-5.584$, $p<0.05$, GEP rank no. 4), state group ($b5=128.470$, $p<0.001$, GEP rank no. 5), number of total primary care physicians ($b6=.184$, $p<0.001$, no GEP rank), and total birth rate ($b7=-.103$, $p<0.001$, no GEP rank). Preterm delivery was significantly higher in the Gulf Coast states than other U.S. states for both Whites and African Americans. For African American women, there was a marginal mean difference of 40.083 with the .01 significance level and for White women the marginal mean difference of 36.946 was significant at the .01 significance level.

Overall preterm deliveries were higher for African American and White women in the Gulf Coast. African American women living in the Gulf Coast had a higher increase in preterm deliveries than did their White counterparts in the Gulf Coast before and after Katrina. After analyzing low birth weight and preterm delivery data

both separately and collectively, there seems to be an emerging trend for African American women and adverse birth outcomes. Low birth weight babies and preterm deliveries disproportionately affect African American women more than White women. African American women had consistently greater mean differences in low birth weight and preterm deliveries before and after Katrina as well as when comparing state location. Another overall trend observed was the consistently higher levels of low birth weight and preterm deliveries in the Gulf Coast states when compared to other U.S. states. These marginal means also increased after Hurricane Katrina, while these numbers for other U.S. states increased minimally or decreased. These trends in results suggest that African American women and their infants in the Gulf Coast states were more affected by Hurricane Katrina than their counterparts in the geographical area and their counterparts in other U. S. states.

The grey prediction models outperformed all exponential smoothing models. The GMs for African American women and their White groups had the smallest MAPEs compared to the most accurate simple, Holt's, and Brown's exponential smoothing models in the areas of low birth weight and preterm delivery for both Gulf Coast states and other U.S. states.

The minimal value for MAPE of the GMs for low birth weight rates in the Gulf Coast states among African American groups was 34%, compared to the most accurate and simple, Holt's, and Brown's exponential smoothing models (2.87%, 0.65%, and 1.26%, respectively). Among the non-Hispanic White groups, the minimal value was 0.27%, compared to the most accurate and simple, Holt's, and Browns exponential smoothing models (1.35%, 1.14%, and 1.80%, respectively).

When viewing the MAPE value among the other U.S. states by race, the results differed. The minimal value for MAPE of the GMs for low birth weight among African American groups was 0.97%, compared to the most accurate and simple, Holt's, and Brown's exponential smoothing models (2.15%, 2.15%, and 2.68%, respectively). Among the non-Hispanic White groups, the minimal value for MAPE was 0.21%, compared to the most accurate and smallest, Holt's, and Browns exponential smoothing models (0.66%, 0.57%, and 0.55%, respectively).

A similar test was run to determine the smallest MAPE of the GMs for preterm delivery among the Gulf Coast States compared to other U.S. states. Among African Americans residing in the Gulf Coast, the minimal MAPE was 0.64%, compared to the most accurate and simple, Holt's, and Brown's exponential smoothing models (2.58%, 1.42%, and 2.48%, respectively). Among the non-Hispanic White Gulf Coast residents, the smallest MAPE was 0.89%, compared to the most accurate and simple, Holt's, and Brown's exponential smoothing models (1.98%, 2.01%, and 2.55%, respectively).

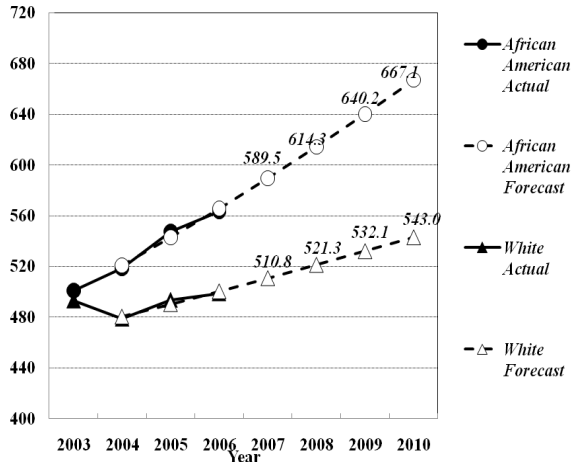
In regards to other U.S. states, the smallest MAPE of the GMs for preterm delivery among African American women was 0.07% in comparison to the most accurate and simple, Holt's, and Brown's exponential smoothing models (1.41%, 0.44%, and 0.51%, respectively). Among the non-Hispanic Whites, the smallest MAPE was 0.24%, compared to the most accurate and simple, Holt's, and Browns exponential smoothing models (0.73%, 0.52%, and 0.52%, respectively).

LOW BIRTH WEIGHT AND PRETERM DELIVERY PREDICTIONS IN 2007-2010

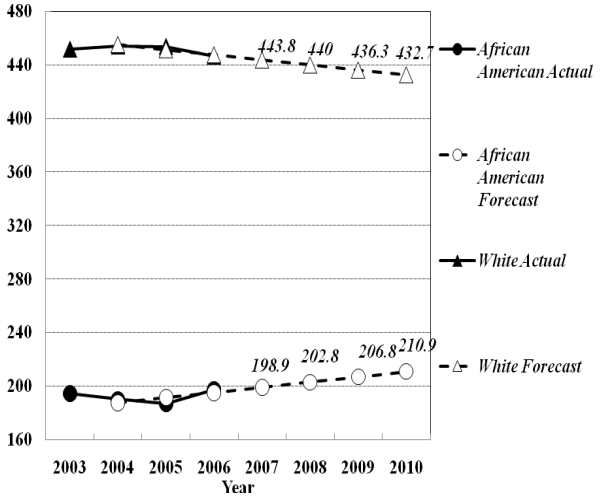
The magnitude of change in low birth weight or preterm deliveries between two consecutive years is called the average annual rate of change which equals to $(e^{-a} - 1)$ 100% for time period (t) being greater than or equal to two.

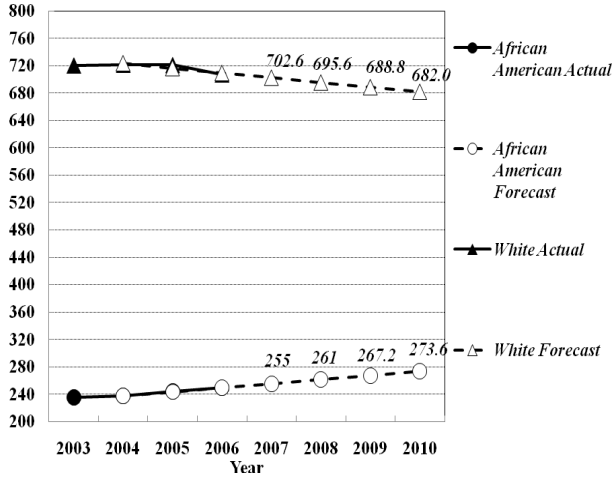
Graph #1 indicates that the African American women have the sharpest increase prediction for low birth weight, with an average annual rate of 41.8%, compared to 2.02% among non-Hispanic Whites in the Gulf Coast. Among the other states in the U.S (Graph #2), African Americans have an average annual rate increase of 1.92% while non-Hispanic Whites experience an average annual rate decrease of 0.85%.

Graph #1:
Low Birth Weight Prediction Results for Gulf Coast States, 2003 - 2010



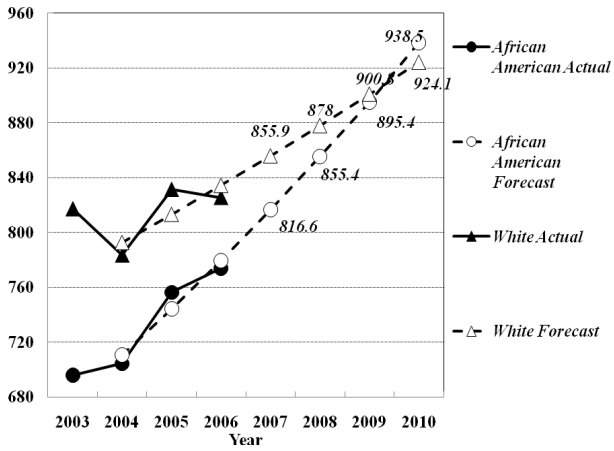
Graph# 2:
Low Birth Weight Prediction Results for Other U.S. States, 2003 - 2010





Graph #3 indicates that African American women had the sharpest prediction of an increase in preterm delivery, with an annual average rate increase of 4.71%, compared to a rate increase of 2.63% for non-Hispanic Whites in the Gulf Coast Region. Among the other U.S. states (Graph #4), African American women had an annual average rate increase of 2.43% while non-Hispanic Whites experienced an annual average rate decrease of 0.99%.

Graph #3:
Preterm Delivery Prediction Results for Gulf Coast States, 2003 - 2010



Graph #4:
Preterm Delivery Prediction Results for Other U.S. States, 2003 - 2010

CONCLUSIONS

This study indicates that when compared the Gulf Coast Religion to other U.S. states, African American women had more adverse birth outcomes. The outcome included more infants that were born preterm and low birth weight within the first year of life. Risk factors associated with low birth weight and preterm delivery among this target group included unemployment, and the percent of African American mothers aged 15-19. Among White women, factors included the poverty rate, median household income, total birth rate, and the percent of White mothers aged 15-19.

The GMs were viable tools used to predict the 2007-2010 low birth weight and preterm delivery of African American and White women who reside in the Gulf Coast and other U.S. states. Not surprisingly, the GMs performed accurate predictions with increasing low birth weight and preterm delivery trends for African American women in both the Gulf Coast and other U.S. states, and decreasing low birth weight and preterm delivery trends for their White counterparts in the same state locations. In years 2007-2010, low birth weight and preterm delivery for White women presented a decreasing tendency while the same birth outcomes for African American women exhibited a monotonically increasing trend. The empirical findings suggested that the health disparities will continue to exist in the foreseeable future, if no effective intervention is taken.

Although there were different factors that contributed to the race-specific low birth weight and preterm deliveries, birth outcome by both races were affected by the presence of Hurricane Katrina. Due to this increase in the Gulf Coast states, existing prevention programs should seek to incorporate an educational strategy into community-based program, focusing on those teens that are not pregnant, finding ways to avoid teen pregnancy, and reduce the percentage of low birth weight and preterm delivery infants in the Gulf Coast Region. Intervention programs may focus on teenage pregnancy to increase educational attainment, career options, and the probability of better health outcomes for both mother and child.

This study illustrates the effect that Hurricane Katrina has on the Gulf Coast Region with regard to low birth weight and preterm delivery and the necessity for policy implementation and program development in Louisiana, Mississippi, and Alabama. The field of public health and its practitioners should be enlisted to assist in bringing action to eliminate low birth weight and preterm deliveries among African American women living in Louisiana, Mississippi, and Alabama.

DISCLAIMER

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Using a Combination of Artificial Neural Networks for the Diagnosis of Multiple Sclerosis

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ABSTRACT

Very often the number of data available in the average clinical study of a disease is small. This is one of the main obstacles in the application of neural networks to the classification of biological signals used for diagnosing diseases. A rule of thumb states that the number of parameters (weights) that can be used for training a neural network should be around 15% of the available data, to avoid overlearning. This condition puts a limit on the dimension of the input space

In this paper we work with the Radial Basis Function and Functional Link artificial neural networks. To have enough data to train both neural networks, we increment the number of training elements, using randomly expanded training sets. This way the number of original signals does not constraint the dimension of the input sets.

Once the radial basis function has been trained, we train four functional link neural networks using samples of positives, false positives, negatives and false negatives results of the previous one. We then test the Radial Basis Function neural network by itself, and the chain of networks. A comparison with results obtained using other methods is presented.

Keywords: Neural Networks, Radial Basis Functions, Functional Link Architecture, Signal Processing, Wavelets, Health Sciences, Multiple Sclerosis.

1. INTRODUCTION

Doctors utilized Brain Stem Auditory Evoked Potentials (BSAEP) to diagnose patients with multiple sclerosis. MS can reveal, among other symptoms, a decrease of the wave V amplitude, an increase on absolute latencies and interpeak intervals latencies I-III, I-V, III-V. But the border between pathological and normal values sometimes is not well defined [1].

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Figures 1 and 2 show the BSAEP of one of the healthy people, that it is called healthy # 1, and one of the sick people, called sick # 12. As can be seen, the discrimination between one case and the other is not very simple. Therefore when doctors diagnose this disease they often find difficult to state the rules they use to reach their conclusions and their percentage of success in the diagnosis is around 80%, with recognition for healthy people in the order of 95.7%, and recognition for sick people around 73.9%.

This diagnosis involves the estimation of the effects of the disease on the form of the waveform components. These components, which are localized in time and frequency, are given a physiological interpretation

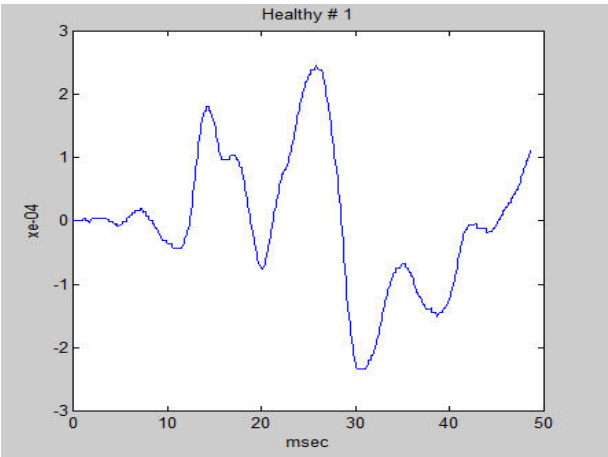


Figure 1: Healthy # 1

A Fourier expansion of the signals would allow us to classify the potentials according to their frequency, but would lose the phase information. Therefore we have used the wavelet transform that can be easily implemented and it is time localized as well as frequency localized.

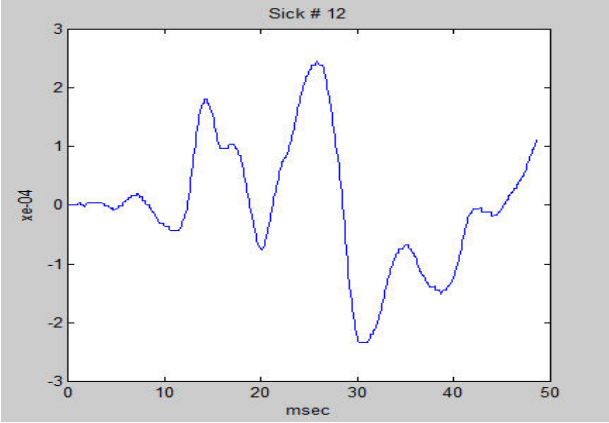


Figure 2: Sick # 12

Note that even cases corresponding to sick people may look completely different (See Figure2 and Figure 3).

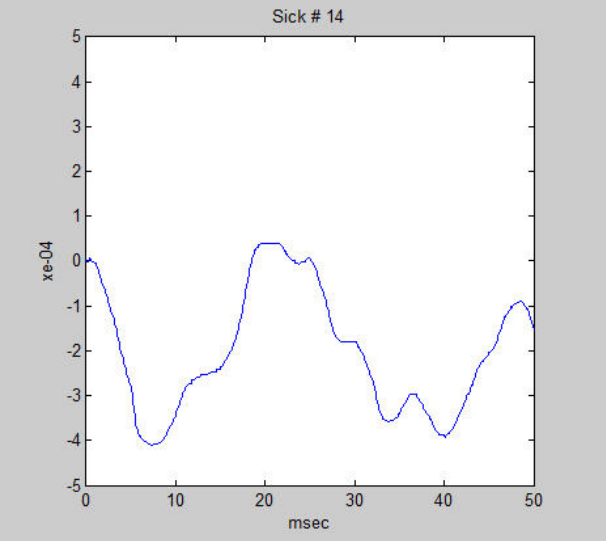


Figure 3: Sick # 14

Although the biological signals studied in this paper are BSAEPs, the techniques that we applied to them could be easily applied to study any time series related to the evolution of biological parameters. For instance, they could easily be applied to VEP, ECG's , EEG or EMG 's potentials, [2], [3], [4], [5].

The main obstacle in the application of this approach is the limited number of available signals. We have a set of 193 BSAEP signals, obtained from the Hospital Ramon y Cajal, Madrid (Spain), where 70 are normal signals, i.e., corresponding to healthy people, and 123 belong to patients diagnosed with multiple sclerosis. Small samples impose a limit on the number of parameters that can be learned by neural networks.

The signals are therefore first preprocessed and then compressed. The preprocessing begins by using the same time interval for all signals. Then the signals are digitized and incremented to 256 points using cubic splines, and finally we normalize them [6]. For the compression we use wavelet transforms that, as we mentioned, allow us to capture the decrease of the wave V amplitude, and an increase of interpeak intervals latencies. This reduces the loss of significant information contained in the signals.

Once they have been compressed, the authors, in collaboration with other colleagues, [7], selected a small number of the most significative features, according to different statistical criteria, like Kolmogorov-Smirnov, largest coefficients, Shannon's Entropy. These selected coefficients were then used as inputs. It is clear that the classification. would be better the more features we could feed into the network.

In this paper we first increment the number of training elements, using randomly expanded training sets [8] and we use them to train radial functions networks, following the ideas on [9], [10]. Clustering algorithms were used previously to find centers and radii for the radial basis functions [11]. The availability to generate an arbitrary number of samples removes not only the need to find centers and radii, but also the constraint that the number of original signals places on the dimension of the input set of the network. For each neuron we can determine the coordinates of the center (the same number as the inputs), the radius and the output weight. Thus, an n input network, with m radial functions, would require the fitting of $m*(n + 2) + 1$ parameters. So we still, from the hundreds of wavelet coefficients, must select only a handful of them and they must be the coefficients that contain the most significant features [12]. We use these networks with different kinds of wavelets and different selection criteria.

Once the radial basis function has been trained, we test them and record our results. This will allow us to determine the strength of this approach [13]. Since we have at our disposal as many training and testing sets as we need, we can generate enough samples of positives, false positives, negatives and false negatives results to train the other kind of neural network, the functional link neural network. The purpose of this approach is to complement the learning of the radial basis functions network with this chain of networks, where the knowledge acquired by the first one is passed to the second one, to improve the training. We then test the original data using first the radial basis function neural network by itself, and the chain of networks.

The fact that we can generate as many training sets as needed is very important for the generation of new training elements for the functional link neural networks, since we need to generate enough elements to obtain four kinds of different sets to train the four functional link neural networks.

In the neural network architectures section of this paper we describe the type of radial basis neural network that was used, with its number of input and hidden nodes, and how the network is trained using 37 wavelet bases offered in MATLAB: all biorthogonal bases (bior11- bior68), all Coiflets bases (coif1-coif5), the first 10 Daubechies bases (db1-db10) and the 7 first Symlets bases (sym2- sym8). In the same section we describe the functional link neural network architecture that was used in the four different

trainings. One for each of the four kinds of input elements, sick people that were recognized as such by the previous network, sick people that were diagnosed as healthy, and the other two opposite cases. Some of the results obtained using the different trainings are exposed in the following section, and in the conclusion we comment on the results and suggest some ideas for future work.

2. NEURAL NETWORK ARCHITECTURES

The radial basis function network architecture used for this work can be seen in Fig. 1. There are *n* input nodes in the fanout layer, *m* nodes and a bias in the hidden layer, and one output node.

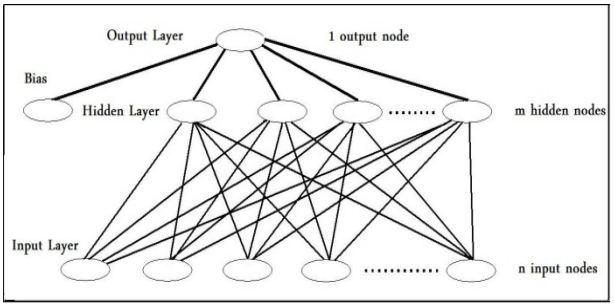


Figure 4: Radial basis function neural network

The value of *n* used was 10, and so was the number of hidden nodes. This will imply a set of 121 free parameters that needs to be fitted. This number of free parameters is consistent with the requirement that the number should be, at most175, and at best around 112. This will avoid the overlearning of the training set and allow the neural network to be able to generalize. This condition was imposed by the fact that the number of randomly generated input training vectors was 750. Of course if we increment this last number, the values of *m* and/or *n* could also be incremented correspondingly.

The functional link neural network architecture appears in Fig. 2, where only a few powers of the input data and a few connections among them have been shown.

In this case we use 10 nodes as the ones that will generate the polynomials, the same number that was used in the input layer of the radial basis function network. Instead of a bias, we use the output of the previous network as one extra input, but it will not be considered for the formation of higher order products between the original input nodes. In fact, for the rest of the input nodes, we compute the square of each value, the cubic value, and the forth power value, and we use them, together with the original values, as part of the new input set.

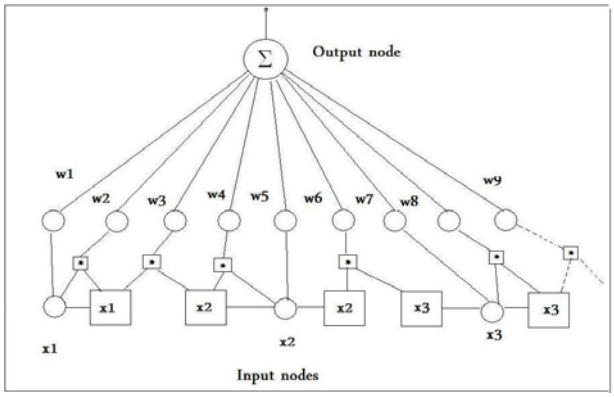


Figure 5: Functional Link Neural Network

Then we multiply the first value times each of the next 4 values. The second values times the next 3 values, until we compute the fourth value times the fifth value. All these values will also be part of the input nodes. The next set of input values will be generated taking the square of the first 5 values, and multiplying them for the other values in the set of the first 5 elements. This will end the generation of the input set, consisting of 71 values. Again, this number is consistent with the number of 500 input vectors that we used to train the functional link neural networks.

It should be noted that the values of the input vectors were obtained sorted by the power of discrimination of features, with the higher one placed in the first position. Therefore we try to maximize the benefit of the functional link neural network using the five elements with more discrimination power, when generating mixed higher order products.

For the generation of all the extra new input training vectors the ideas found in [8] were followed. For each of the two clusters corresponding to sick and healthy people, an estimation of the values for the elements in the probability density function, $f_{kME}(z)$, also denoted as $N_k(\mathbf{U}, R)$, k =1,2 Eq.(1), that maximized the differential entropy for that cluster, were computed.

$$\mathbf{N_k}(\mathbf{U}, \mathbf{R}) = \frac{1}{(\sqrt{2\pi})^{n+1}\,|R_k|^{\frac{1}{2}}}\, e^{-\frac{1}{2}(z-U_k)^T R_k^{-1}(z-U_k)} \qquad (1)$$

Here z denotes an input-output data vector, U_k is the mean vector of the cluster k, R_k is the covariance matrix of the same cluster, $|R_k|$ is its determinant, and T denotes the operation that performs the vector transpose operation. We denote the estimation of the mean vector as $\hat{U}_k$, and of the covariance matrix as $\hat{R}_k$, where here a diagonal load was added to insure its invertibility.
With this information, data were drawn for each cluster using the formula given in Eq. (2)

$$Z^i = \hat{U}_k + \hat{L}_k s^i \qquad (2)$$

where s^i is an independently identically distributed (i.i.d.) vector sequence drawn from N(0,1), and $\hat{L}_k$ is the

Cholesky lower triangular matrix from the decomposition of $\hat{R}_k$.

Using this technique we generated the 750 input vectors for the training of the radial basis function neural network, and thousands of input vectors to obtain the sets to train the four different functional link neural networks.

The first network was trained using the 37 different wavelet bases. For the input space we selected the coefficients of the wavelet transforms that discriminated more according to the Kolmogorov-Smirnov test.

The input-output space of our data requires that all the values of every coefficient, on our sample, are normalized, with mean zero, and standard deviation of one. This avoids the problem that the output values, being far greater than any of *n* inputs in the case of sick people, could dominate the making of the partitions and in doing so, defeat the purpose of the algorithm. The mean value for each coefficient and the corresponding standard deviation is kept, to be utilized for the normalization of any future input vector that needs to be tested.

Each training process consisted of 3,000 random presentations, beginning with different random values. The random number generator utilized was the one included in MATLAB.

The learning rates η(k) for the centers, the radii and the weights were given by the linear function

$$\eta(k) = \eta_0 + (\eta_1 - \eta_0) * \frac{k}{NPR} \qquad (3)$$

where *k* is the iteration step, NPR is the number of presentations, η_0 is the initial learning rate, set at 0.001, and η_1 is the final rate, set at 0.08. These values for the initial and final learning rate for both the hidden and input layers were known to be acceptable.

Once the radial basis function network was trained, we used the thousands of generated new input vectors, and test them using the trained network. This way four sets of training set for the functional link network were created. The first set contained the all the input vectors corresponding to sick people whose diagnosis by the radial basis function network was correct. The second set contained those whose result was incorrect. Similarly the third and four set contained the correct and incorrect results of the healthy people.

We trained the four functional link neural networks with these new sets. Here we also use the learning rate given by (3), but the initial and final learning rates were ten times smaller. When the functional link neural networks were trained, we took our original set of data and tested using the radial basis function neural network. We recorded the results, and according to them, we test again the same original set using the functional link neural networks. If the result of the previous neural network suggested that the input vector corresponded to a sick people, the input vector would be tested using the functional link neural network that gave correct results for the sick people and the functional link neural network that gave incorrect results for the healthy people. A similar approach was used when the radial basis function neural network associated an input vector with a healthy person.

This way we could determine the cases of the positive-positive, false-positive, false-negative and negative-negative cases on the testing of the radial basis function neural network. This in fact improves the accuracy of our results.

3. EMPIRICAL RESULTS

The empirical results had a wide range of discrepancy. We selected original results on the range of success rate in the neighborhood of 75%, and then we applied the second set of functional link neural networks.

In the case of db4 wavelet, this second set improved the accuracy rate about 5%, with all the improvement, except one, being for the sick people. On the other extreme, for the bior13, the improvement rate was 12%, but in this case, we had a higher number of healthy people whose diagnosis was improved. In fact this number was more than double the corresponding number for the sick people. Looking into the original results, there is an explanation for these differences. Since the db4 wavelet was very accurate diagnosing the healthy people, most of the improvement occurred in the sick people. On the hand, the bior13 wavelet was more accurate for the sick people, and the improvement went to the healthy people.

Wavelet	RBFANN			CHAINED		
	Sick	Healthy	Total	Sick	Healthy	Total
db4	74.0	77.1	75.1	79.7	78.6	79.3
bior1.3	83.7	61.4	75.6	88.6	85.7	87.5

Table 1: Percent of success rate for the different cases.

A view of these results can be found in Table 1. The first row indicates whose results are we considering: Using the single radial basis function neural network (RBFANN), or the chain of neural networks. Each other row corresponds to the success rates for a particular wavelet basis whose name appears in the first column. The columns reflect the general success rate for that wavelet basis and for the sick and healthy people. ,

There are other samples that were computed, but the results were similar to those shown, so we have omitted them.

4. CONCLUSIONS

Radial basis function networks had been used to diagnose Multiple Sclerosis. They provide an automatic, fast and reliable way to discriminate the signals from sick and healthy people, provided that we use a high number of hidden nodes. But we can improve their accuracy using a chained set of neural networks. Since the selection of the wavelet coefficients was done in order of their power of discrimination, it is more beneficial, for the same number of free parameters, to use more hidden nodes than to use more inputs beyond a certain number. Although we are making the selection from the several hundreds of wavelet

coefficients, an input dimension of ten is appropriate, and selecting a larger number does not enhance the learning of the networks.

One of the problems that we encounter with both networks is that the learning was bad when a local minimum for the error function was reached. Although we thought that we could avoid the clustering of the data to find centers and radii for the Gaussian functions, the need to avoid local minima suggests otherwise. In the future we should use a clustering algorithm to find the starting centers and radii of these functions. Besides we will have the advantage that in this case, before we start the clustering algorithm, we will know the number of clusters that we want, the number of hidden nodes in the network. This will avoid the problem of not knowing the number of clusters that should be created, a common problem in many of the clustering algorithms.

For the functional link neural network we could use another learning algorithm, to avoid the local minima.

In most of the previous approaches, the sick people had a higher success rate in their discrimination. But as we can see from the table, the success rate was higher for sick people in one case, and lower in the other.

For future research, we will try to use the random number generator described in [14]. Different discriminating criteria, like the largest coefficient in absolute value, Shannon entropy, or the Student t-test could be used. We could also consider a margin based feature selection criterion and apply it to measure the quality of sets of extracted features [13].

To work with other type of data, samples could be taken from the original data instead of using the wavelet transform coefficients, to generate the sets of extra new values. Another possibility is to select the even or odd values in the set of original data when they are expanded using cubic splines. This will generate twice as many numbers of starting data for the randomly generated expanded training set. Of course we could use a combination of all these approaches to compare the results with those obtained in this paper.

All these ideas for future research follow the line of using the expansion of training sets. We can apply different architectures and training algorithm to the functional link neural network. Instead of using regular polynomials involving all the data, we could use Chebyshev polynomials. Similarly instead of simple LMS learning, we could use swarm optimization to approach the global minimum [15] or prepare the functional link using the ideas of genetic algorithms [16]. Considering the approach to clustering we could obtain results using the ideas found in [17] and [18] to proceed as in [11] and [12], and compare all the results based in performance and cost.

In conclusion we can say that our findings are a good sign that chaining artificial neural networks with radial basis functions and functional link architectures could be used to help doctors when they are diagnosing cases of multiple sclerosis.

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Automatic Retrieving Data from Medical Equipment to Create Electronic Medical Records (EMRs) for an e-Hospital Model in Vietnam

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ABSTRACT

Applications of Information Technology (IT) in a healthcare management system, especially in Personal Health Records (PHRs) management has recently received a great attention in developing countries such as Vietnam [1,2]. The Vietnamese Government has implemented a special campaign to promote this process in hospitals. Several big hospitals have implemented electronic-based hospital systems, but have only concentrated on patient admission information, medical equipment management, and pharmaceutical and human resources. Besides, PHRs are rather simple, incomplete and involve much manual work [3]. Especially, many devices used in hospitals do not have digital outputs. Within our research, we have analyzed and built some methods that automatically retrieve data from medical devices and put them into EMRs. These data can be images, video, bio-parameters, waveforms, graphs, etc. This process is done by software that can be integrated into hospital information systems in Vietnam hospitals. Several modules have been tested in Khanh Luong hospital, Hanoi Vietnam.

Keywords: Electronic Medical Records (EMRs), e-Hospital, Computerized, Image, Video, Laboratory data, Waveform.

1. INTRODUCTION

Vietnam now has approximately 1000 hospitals that have over 500 beds. Most of them have computers and LAN connections. However, documentation systems and patient health records within hospitals are paper-based [4]. Besides, in recent years, many modern medical types of equipment have been acquired (imaging devices, laboratory equipment, multi-parameter patient monitors). That leads to the increase of patients as well as health records. The Ministry of Health has issued a policy that requires hospitals to implement electronic-based hospital models in Vietnam in the following years [5]. A few hospitals are using data management software but their databases are simple and incomplete. Complex data such as images, video, and waveforms are not automatically retrieved from medical devices to archiving devices. Numbers data are manually input to computers [3]. Therefore, an automatic retrieving process into patient health records will facilitate these problems, and meet requirements of electronic-based hospital models in Vietnam.

2. METHODS FOR AUTOMATICAL RETRIVING DATA

1) Images and video data retrieving

According to our survey, imaging and video devices mainly used in hospitals include ultrasound systems, CT Scanners, CRs, DRs, MRIs, video endoscopies, and microscopy systems. Images or videos that are produced by this equipment then are displayed on the screen accompanied with them. Results delivered to patient will be printed. Hence, in order to archive these data into computers, doctors have to scan all these images and save them into the computer database. If data are in video form, they have to save to disks, memory sticks and then to computers. That consumes quite a lot of time and increases errors due to manual work. To solve that problem, we need a process to retrieve data automatically from medical devices. Data will be stored in computers by software corresponding to patient health records. To store images or video from imaging devices, we follow the sequence shown in Figure 1:



Fig.1 - Acquisition data from imaging equipment

Solution: In fact, most imaging devices have video output that is an analog signal. So they require an A/D converter circuit before sending data to the computer. This process is implemented by using a Capture video card that is available in the Market. In Vietnam, there are many brand names of this card such as Aver, Gadmei, Pinnacle, Snazzi and Hauppauge with digital output support USB or PCI standard. Software installed in computers then receives and processes digital data. Depending on programming languages, we can choose data processing tools including Image and Video Processing ActiveX OCX of X360soft, Viscomsoft, and Brothersoft.

In our work, we used the Sanzzi Capture video I card and VideoCap SDK ActiveX 5.0 processing tool of Viscomsoft, the programming language is ASP.net, we

have been developing software to retrieve and process image data from imaging devices. This software can be integrated into the database management system in the electronic-based hospital model to retrieve and store image and video data into personal health records [6].

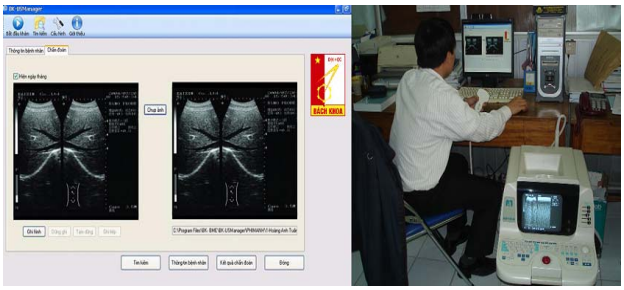


Fig.2 - Acquisition image data resulting from the software from the ultrasound machine, MEDELKOM *model SLE-101M*

2) Laboratory data retrieving

Laboratory data in most hospitals in Vietnam are mainly: hematology, biochemistry, microbiology, immunology, cell and urine analysis and electrolyte data. These devices are supplied by Sysmex, Siemens, Abbott, Nihon Kohden, Hitachi, Roche, Hemacell, Mindray and Boule [3]. As we researched, all these devices make use of RS-232 – compatible digital output. Laboratory equipment, hence, can easily connect to computers that support RS-232. After processing laboratory samples, results will be displayed on the monitor. These data are concurrently sent to the RS-232 port. Therefore, we need a software algorithm to automatically receive each message after being sent to the RS-232 port. The message is then interpreted to extract useful information to put into patient health records. This algorithm and analysis message is as in Figure 3 [7]:

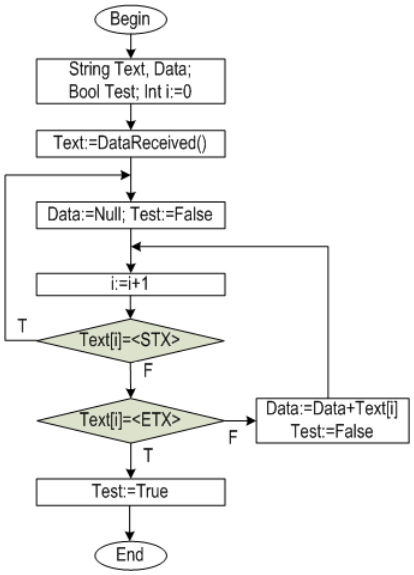


Fig.3 - Analysis message's structure algorithm from laboratory equipment

However, to identify fields in message we need to know the output format of each message from laboratory equipment. This is because different suppliers have different definitions for their output messages. Fortunately, we can find this information in Technical documents (normally in the Service manual) that comes with the equipment. The structure of the message that is sent to the RS-232 port of the Sysmex-KX21 hematology analyzer machine follows. This message includes 306 characters for each result. The initial character is STX, followed by data character DATA and ETX is the end character. Characters in DATA are divided into smaller fields that correspond with lab results. Each field has fixed length and is separated by character 0D. Field order in DATA is illustrated in table 1:

Table 1 - Definition fields' structure in the message of Sysmex-KX21

Field Name	Meaning	Filed Length (Character)
Field 1: STX($02)	Massage Start	1
Field 2: R($52)	R Character	1
Field 3: zz]	No of Test	3
Field 4:YYYYYYYYYYYYYYYY]	Code of Test	17
Field 5:YYYYYYYYYYYYYYYYYYYY]	Doer	31
Field 6:zz/zz/zz-zzhzzmzznzzs#]	Date	21
Field 7:zzzzz-RN]	WBC	9
Field 8:zzzzz-RN]	LYM#	9
Field 9:zzzzz-RN]	LYM%	9
Field 10:zzzzz-RN]	MON#	9
Field 11:zzzzz-RN]	MON%	9
Field 12:zzzzz-RN]	GRA#	9
Field 13:zzzzz-RN]	GRA%	9
Field 14:zzzzz-RN]	NEU#	9

Field 15:zzzzz-RN]	NEU%	9
Field 16:zzzzz-RN]	EOS#	9
Field 17:zzzzz-RN]	EOS%	9
Field 18:zzzzz-RN]	BAS#	9
Field 19:zzzzz-RN]	BAS%	9
Field 20:zzzzz-RN]	ALY#	9
Field 21:zzzzz-RN]	ALY%	9
Field 22:zzzzz-RN]	LIC#	9
Field 23:zzzzz-RN]	LIC%	9
Field 24:zzzzz-RN]	NULL	9
Field 25:zzzzz-RN]	NULL	9
Field 26:zzzzz-RN]	NULL	9
Field 27:zzzzz-RN]	NULL	9
Field 28:zzzzz-RN]	RBC	9
Field 29:zzzzz-RN]	HGB	9
Field 30:zzzzz-RN]	HCT	9
Field 31:zzzzz-RN]	MCV	9
Field 32:zzzzz-RN]	MCH	9
Field 33:zzzzz-RN]	MCHC	9
Field 34:zzzzz-RN]	RDW	9
Field 35: zzzzz-RN]	NULL	9
Field 36: zzzzz-RN]	PLT	9
Field 37: zzzzz-RN]	MPV	9
Field 38: zzzzz-RN]	PCT	9
Field 39: zzzzz-RN]	PDW	9
Field 40:ABCDEFGHIJKLMNOPQRSTU]	5 WBC Memory Flag	22
Field 41:LMMGGG]	LMG Memory Flag	7
Field 42:PSM]	PLT Memory Flag	4
Field 43:CRC	Check Code	1
Field 44: ETX ($03)	Massage End	1

Note: "-" is space, which is $20 in ACSII coding system. "]" indicates the carriage return that separates fields, which $0D; zzzzz is a numbers field with 0 in the left hand side, for example 03.55. For fields having no results, they will present as __.__. Y is a character that has codes from $20 to $7F [8].

From this analysis of message structure, the software interface that has been built by our research team, will automatically receive data from laboratory equipment Sysmex-KX2. Figure 4 shows the interface of this software to display original content of messages from equipment and display laboratory results after analyzing fields within a message [9].

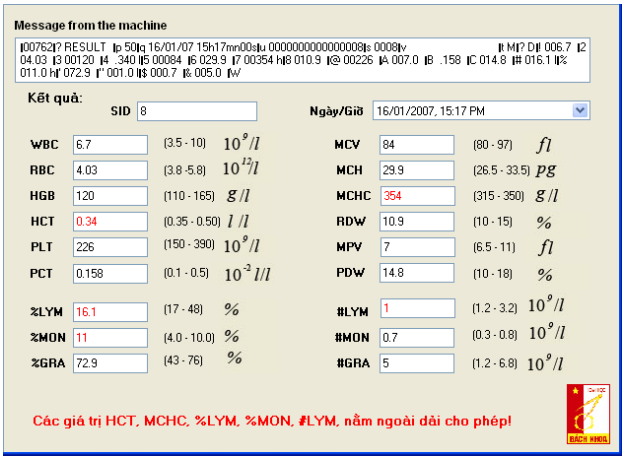


Fig.4 - Automated acquisition laboratory data software from hematology analyzer machine, Sysmex-KX21 model

3) Retrieving waveform data

Measuring and monitoring patient vital parameters has been increasingly important and useful in order to assist doctors and nurses in patient care. Typical waveform data are ECG, EEG, EMG, RESP, SpO2 and IBP. Besides, related parameters including HR, PR, NIBP, TEMP, and EtCO2 are also helpful in diagnosis and therapy. ECG, EEG, EMG, Patient Monitor, NIBP, and SpO2 are widespread – used devices that produce waveforms. However, as in laboratory equipment, Measuring and monitoring devices are now supplied by various companies [3]. A common characteristic among these devices is that they all have output that supports RS-232. Therefore, they can directly connect to the COM port in computers. In laboratory equipment, data format is structured into messages. Because measuring devices produce real-time data, data will be sent to RS-232 continuously. Therefore, each supplier specifies their own protocol in their equipment to send data to output ports. To receive data automatically from equipment, we first need to identify the data frame of sent data. They are normally illustrated in the Service Manual of equipment [10,11]. Tables 2-4 show examples of definition of data frames that are sent to RS232 ports of MMED6000DP-S6 patient monitoring (MMEDCHOICE company) [12].

Table 2 - Transmission Data Protocol (12 bytes)

Pack head		Reserved	Identification	Identified by the STATUS1		
0x55	0xAA	STATUS0	STATUS1	DATA		
ECG wave sample point value				Reserved	Respiration wave	Check sum
ECGW3	ECGW2	ECGW1	ECGW0	SATW	RESPW	SUM

0X55, 0XAA is data pack head, SUM is check sum,
SUM =
(STATUS0+STATUS1+DATA+ECGW3+ECGW2+ ECGW1+ECGW0+SATW+RESPW)/256
The other bytes are explained following.
STATUS0: reserved

STATUS1: is pulse voice indication and identification. Before the next DATA byte, the STATUS1 byte is sent as identification. As a result the corresponding value can be filtered out of the data flow. The different identification represents the corresponding data.

Table 3 - STATUS1 Structure (1 byte)

STATUS1		BIT7 = 1		ECG beep flag
		BIT6 = x		Reserved
		BIT5 = x		Reserved
		BIT4 = 1		The following byte DATA values exceed 255. E.g if BIT4=0 the DATA value is 30, the real value is 30, if BIT4=1, the DATA value is still 30, but the real value is 30+256=286.
BIT3	***BIT2***	***BIT1***	***BIT0***	***The following byte DATA means***
0	0	0	0	ECGS
0	0	0	1	STAS
0	0	1	0	NIBPS
0	0	1	1	Heart rate (0-255)
0	1	0	0	Pulse rate (0-254) from SpO2
0	1	0	1	Pulse rate (0-254) from NIBP
0	1	1	0	ST
0	1	1	1	% SpO2 (0-99%)
1	0	0	0	Cuff pressure value/2 (mmHg)
1	0	0	1	Systolic 0-255 (mmHg)
1	0	1	0	Diastolic 0-255 (mmHg)
1	0	1	1	Mean arterial 0-255 (mmHg)
1	1	0	0	Respiration rate (0-99)
1	1	0	1	Temperature 1 (T1)

1	1	1	0	Respiration wave gain
1	1	1	1	Temperature 2 (T2)

Table 4 - DATA Structure (1 byte)

ECGS	The state of ECG: BIT7=1 means lead off BIT7=0 means normal BIT6 BIT5 mode selection 00: diagnosis mode, bandwidth = 0.05-100Hz 01: monitor mode, bandwidth = 0.5-75Hz 10: operation mode, bandwidth = 0.5-25Hz
STAS	The state of SpO2: BIT7=1 means probe off BIT7=0 means normal BIT6=0 reserved BIT5=1 means drop in SpO2 BIT4=1 means searching too long BIT3-BIT0 Real time Bar Graph, in the range of 0 to 8, < 3 means weak signal
NIBPS	The state of NIBP: BIT7=1 means repeat measurement BIT5, BIT6 reserved BIT3=1 means manual BIT3=0 means automatic BIT4=1 means gas circuit is jam, 0 means normal BIT2,BIT1 mode selection 00: adult mode; 01: pediatric mode; 10: neonate mode BIT0=1 means measuring or calculating 0 means not measured or finished
ST	ST value (show as complementally code in the binary system) E.g. –80 means –0.8mV, 80 means 0.8mV
T1	Channel 1temperature value (0-255) The value should divide by 10 then add 20 and then the result is the temperature value E.g. 235 (235/10)+20 = 43.5^{o}C
T2	Channel 2 temperature value (0-255) same as T1

From the interpretation of this data frame, we have built RS-232 compatible software on computers to automatically receive and process parameters. These parameters include ECG, SpO2 and RESP waveforms. Numbers parameters are HR, PR, NIBP, TEMP, %SpO2 and #RESP. Data are then stored in a way that corresponds to the data frame structure we analyzed above. Data from the patient database system will be retrieved and displayed to support diagnostic and therapy procedures through our designed software. Numbers and waveform results are illustrated in figure 5 [10]:

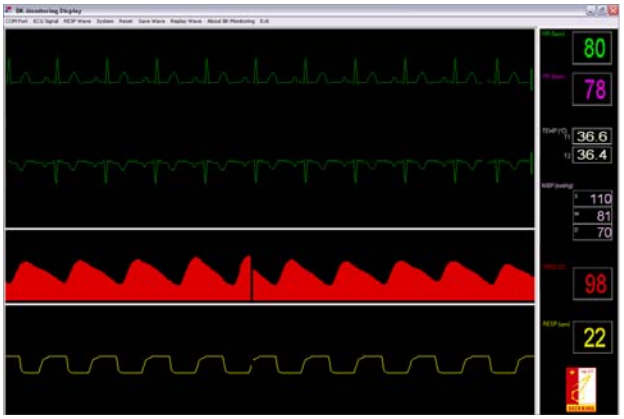


Fig.5 - Automated acquisition and display data software from multi-parameters patient monitor MMEDCHOICE, MMED6000DP-S6 model

3. CONCLUSIONS

Software modules that automatically retrieve data from medical equipment include images, waveforms, video, lab parameters; number data has been built with the above method. These modules can be integrated into information management systems in electronic-based hospitals that have been implemented in Vietnam recently. By automatically receiving data from medical equipment, patient health records will be filled completely (including images, video and waveform data), manual work will be reduced (eliminate film scan and papers) and hence, errors from manually input parameters of clinicians will be reduced (input laboratory results and vital parameters). With more complete and precise health records, the electronic-based hospital model is increasingly useful to assist doctors in diagnostic and therapy procedures.

For retrieving images, video data, this method can be implemented for all medical devices as they all have similar video output. However, for laboratory parameters, waveform, numbers, to retrieve data automatically requires an understanding of the output data framework. This information is normally supplied by suppliers in Manual Services.

Some of our software modules have been implemented in Khanh Luong hospital Hanoi by our research team. They receive many good comments from doctors as it helps them archive patient records more completely, precisely and facilitates them in the diagnostic and therapy process.



Fig.6 - Testing and implementation acquisition ultrasound data modules to create EMR in Khanh Luong hospital

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Detection of Locally Stationary Region for Universal GMM and its Application in denoising X-ray CT Images

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***Abstract*—An adaptive Wiener filter (AWF) for denoising X-ray CT image has been proposed based on the universal Gaussian mixture distribution model (UNI-GMM). The universal model can be estimated by an assumption that the GMM is stationary. In the previous UNI-GMM-AWF method, a fixed observation block size of UNI-GMM has been adopted, assuming smaller block size makes the block more stationary, but the small block tend to suffer observation error due to image noise. Thus in the previous method, the observation region size was not small enough to satisfy the stationary assumption. Inversely the observation region size is not large enough for precise model detection and high denoising ability in stationary region. To overcome the problems, variable observation block sizes of the UNI-GMMs are adopted in this paper. Actually, in the new UNI-GMM-AWF method, two sizes of the UNI-GMMs are applied for each observation region and the most stationary UNI-GMM for each observation region is selected according to the normalized likelihood function, related to the Akaike's information criteria (AIC)[1]. Moreover, the new UNI-GMM which has a observation region with hole in its central region is applied to detect a small point shape structure like a small vessel or a bronchiole. Then the new UNI-GMM using observation region with hole is also selected for each observation block based on the AIC. Simulation results show that the proposed method performs better than median filter as a standard method in terms of the denoising and point like shadow preservation ability. Furthermore a simulation result shows that the new UNI-GMM-AWF is more flexible than the previous UNI-GMM-AWF method in terms of the applicability of fitting the stationary model.**

I. Introduction

Reduction of the patient dose unfortunately degrades the quality of medical X-ray CT Images, because the signal to noise ratio (SNR) on projection data, called sinogram, decrease. In medical examination, the slice thicknesses adjust the resolution of target organs. The thinner slice X-ray CT images provides the higher resolutional interpretations of small objects, decreasing partial volume effect, ex. peripheral blood vessels. In spite of the advantage of the thin slice CT scan, it degrades reconstructed images by the noise appeared on the sinogram. Thus the denoising medical X-ray CT images contributes to not only patient dose reduction but also image quality improvement.

The noise in the X-ray CT image appears with the fluctuation of incident X-ray photon and the linear attenuation coefficients of the objects. Using incomplete filtered back projection (FBP) method to such fluctuated and finite resolution projection data generates visible striped pattern. In the X-ray CT images reconstructed by such incomplete FBP method, noise images take a variety of forms by superposition of the striped patterns [2], [3], [4]. Thus the noise on the X-ray CT images are non-stationary and non-Gaussian, due to the variation of amplitude which varies with linear attenuation coefficients at non-stationary objects.

In the case of white noise removal for ordinary images, an adaptive Wiener filter based on a universal Gaussian mixture distribution model (UNI-GMM) has been proposed as a minimum mean square error (MMSE) filter [5] which is known to be global optimum filter including non-linear filters. In this method, an image is divided into small blocks and each block is classified into one of the Gaussian stationary process in the UNI-GMM, assuming that the smaller block is more stationary.

In the previous UNI-GMM-AWF method [6], the size of observation region of UNI-GMM has been fixed for simplicity. Thus the method failed into two problems. First, the observation region size is not large enough for precise model detection and high denoising ability in stationary region. Second, the observation region size is not small enough for detecting non-stationary region, e.g. cross-section of bronchioles and vessels. In this paper, a new UNI-GMM-AWF for denoising X-ray CT images is proposed to improve the fitness of locally stationary GMM assumption by applying a set of UNI-GMM in various observation region size. In the proposed method, each image block signal is restored using a Wiener filter on the most stationary UNI-GMM, selected from the set of UNI-GMMs. As a parameter to detect the most stationary UNI-GMM, proposed method introduces likelihood function normalized by the size of observation region, which is related to the Akaike's information criteria (AIC). Simulation result shows that the proposed model performs better than the conventional model. It also shows that the normalized likelihood criteria can be

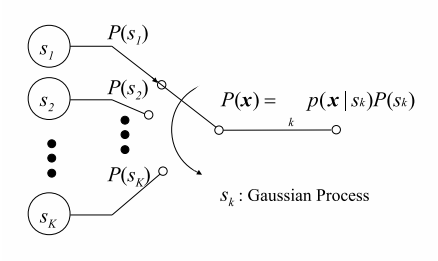


Fig. 1. Illustration of the UNI-GMM

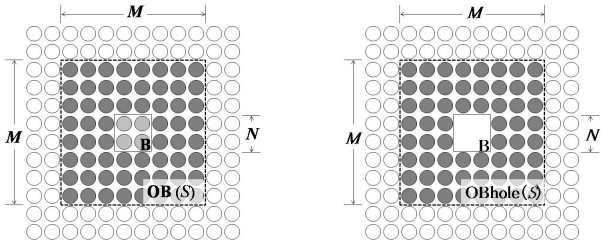


Fig. 2. Illustration for UNI-GMM-AWF. $\mathbf{B}$ and $\mathbf{OB}$ in the left side figure denote block and observation block. $\mathbf{OB}$ denotes also support region. new UNI-GMM-AWF utilizes modified observation block $\mathbf{OB}_{\text{hole}}$, which has hole in the central region, in the right side image.

flexibly applicable to the variably shaped observation detection such as block with hole.

II. PRINCIPLE

In this section, the principle of UNI-GMM-AWF method is reviewed, in the case of white noise removal on ordinary image.

A. UNI-GMM

Fig.1 illustrates the UNI-GMM. In this figure, $\boldsymbol{x}$ denotes the vector of local image signal who has probability density function (PDF) $p(\boldsymbol{x})$, s_k denotes the k'th Gaussian stationary process who has PDF $p(\boldsymbol{x}|s_k)$ and $P(s_k)$ denotes a *priori* probability or mixture weight of s_k.

When an image is divided into small blocks, it is known that the non-stationary statistics of images decreases. This property of ordinary images makes the stationary UNI-GMM profitable [5], [7]. In order to estimate the stationary model, the UNI-GMM employs discrete cosine transform (2-D DCT) AC coefficients as characteristics vector and it is assumed that their covariance matrix is diagonal. Under these assumptions, the PDF of 2-D DCT vector $\boldsymbol{\nu}$ belongs to s_k is modeled as follows,

$$p(\boldsymbol{\nu}|s_k) = N[\boldsymbol{\nu} : \mathbf{0}, \boldsymbol{\Lambda}_k];\ k = 1, 2, \cdots, K, \tag{1}$$

where $N[\boldsymbol{u} : \boldsymbol{\mu}, \boldsymbol{R}]$ denotes the value of Gaussian PDF whose mean vector $\boldsymbol{\mu}$ and covariance matrix $\boldsymbol{R}$ evaluated at $\boldsymbol{u}$. Note that the mean vector is assumed to be zero. In the case of white noise removal for ordinary images, a local image vector $\boldsymbol{y}$ in observed image is modeled as original image vector $\boldsymbol{x}$ plus stationary Gaussian noise vector $\boldsymbol{n}$.

$$\boldsymbol{y} = \boldsymbol{x} + \boldsymbol{n} \tag{2}$$

Because $\boldsymbol{x}$ and $\boldsymbol{n}$ are uncorrelated, PDF of 2-D DCT AC vector $\boldsymbol{\zeta}$ of $\boldsymbol{y}$ can be modeled as follows,

$$p(\boldsymbol{\zeta}|s_k) = N[\boldsymbol{\zeta} : \mathbf{0}, \boldsymbol{\Lambda}_k + \boldsymbol{I}\sigma_n^2];\ k = 1, 2, \cdots, K, \tag{3}$$

where σ_n^2 denotes noise variance and $\boldsymbol{I}$ denote identity matrix.

B. UNI-GMM-AWF

It is known that the MMSE estimate $\hat{x}_{\text{MMSE}}$ that minimize mean square error $E[\| \boldsymbol{x} - \hat{\boldsymbol{x}} \|^2]$ is reduced to the Wiener estimate $\hat{x}_{\text{WF}}$ in Gaussian process. Thus using the finite UNI-GMM, illustrated in Fig.1, $\hat{x}_{\text{MMSE}}$ can be estimated by $\hat{x}_{\text{WF}}$ for each Gaussian process s_k [5]. Because the UNI-GMM models the statistics of local image blocks as Gaussian stationary processes, $\hat{x}_{\text{WF}}$ can be estimated using finite impulse response filter whose support region S is illustrated in Fig.2. In Fig.2, $\mathbf{B}$ and $\mathbf{OB}$ denote block and its observation block, and N and M denote sizes of $\mathbf{B}$ and $\mathbf{OB}$, respectively. It is shown that the $\mathbf{OB}$ covers all support regions for pixels in $\mathbf{B}$ to observe sufficient statistics for $\mathbf{B}$.

The UNI-GMM-AWF coefficients vector $\boldsymbol{a}_k$ for each class s_k is estimated under the constraint that the sum of all coefficients is 1, in order to preserve local average of image as follows,

$$\boldsymbol{a}_k = \boldsymbol{C}_k^{-1}\boldsymbol{c}_k - \frac{\boldsymbol{C}_k{}^{-1}\mathbf{1}}{\mathbf{1}^T\boldsymbol{C}_k{}^{-1}\mathbf{1}}(\mathbf{1}^T\boldsymbol{C}_k{}^{-1}\boldsymbol{c}_k - 1), \tag{4}$$

where $\cdot^T$ denotes transpose of $\cdot$, $\cdot^{-1}$ denotes inverse of $\cdot$, $\boldsymbol{C}$ denotes the covariance matrix of the vector $\boldsymbol{y}_S$ on the support region S in observed image, $\boldsymbol{c}$ denotes the cross covariance vector between original image signal x and its corresponding $\boldsymbol{y}_S$, and $\mathbf{1}$ denotes the vector whose all elements are 1.

The restored signal $\hat{x}$ is estimated by convolving the UNI-GMM-AWF coefficient $\boldsymbol{a}_k$ with the filter support vector in the observation image $\boldsymbol{x}_S$ as follows.

$$\hat{x} = \boldsymbol{a}_k^T\boldsymbol{x}_S \tag{5}$$

C. Issues in previous UNI-GMM-AWF method

The previous UNI-GMM-AWF method had two issues as follows.

i The observation region size is not large enough for precise model detection and high denoising ability in stationary region.

ii The observation region size is not small enough for detecting non-stationary region.

D. AIC and $\overline{\text{AIC}}$

The classification of the observation block is based on the theorem "the larger $\overline{\text{AIC}}$ of the $\mathbf{OB}$, the more stationary the $\mathbf{OB}$ is". Generally AIC is obtained as follows,

$$\text{AIC} = -2\ln L + 2m. \tag{6}$$

$$\overline{\mathrm{AIC}} = 2\frac{\ln L}{m}, \tag{7}$$

where

$$\ln L = -\frac{m}{2}\ln|\mathbf{\Sigma}| - \frac{1}{2}\boldsymbol{y}^T\mathbf{\Sigma}^{-1}\boldsymbol{y}. \tag{8}$$

In the equation (8) $\boldsymbol{y}$, $\mathbf{\Sigma}$ and $|\mathbf{\Sigma}|$ denote the DCT AC vector of the $\mathbf{OB}$, covariance matrix of $\boldsymbol{y}$ and the determinant of $\mathbf{\Sigma}$ respectively. Then m denotes dimension of vector $\boldsymbol{y}$ and is equivalent to M^2-1.

E. Measures in new UNI-GMM-AWF method

To overcome these issues mentioned above, in the new UNI-GMM-AWF method, the fitness of locally stationary GMM assumption is improved by applying a set of UNI-GMMs in various observation block. Thus the new UNI-GMM-AWF method is able to classify $\mathbf{B}$ in more stational manner. The detection of the stationary of the block $\mathbf{OB}$ utilizes the $\overline{\mathrm{AIC}}$ which is related to the AIC to be described as previous section.

i In order to detect the stationary $\mathbf{OB}$, two sizes of the UNI-GMM which is small size (8*8 pixels) and large size (16*16 pixels) are prepared. Then the $\overline{\mathrm{AIC}}$s of the $\mathbf{OB}$s are compared to each other. If the $\overline{\mathrm{AIC}}$ of the large sized $\mathbf{OB}$ is larger than the small sized $\mathbf{OB}$, then the block $\mathbf{B}$ is in stationary local region, that is large $\mathbf{OB}$ is more profitable.

ii Simultaneously, in the UNI-GMM-AWF, a modified observation block $\mathbf{OB}_{\mathrm{hole}}$ showed in fig.2 is prepared in order to detect point-like shadow. $\mathbf{OB}_{\mathrm{hole}}$ has a hole of 2*2 pixels at the central region of the $\mathbf{OB}$. In the case of existing the point-like shadow, like a small vessel or a bronchiole, at the block $\mathbf{B}$, the stationary GMM cannot detect it because small point tends to detect as white noise. If the $\overline{\mathrm{AIC}}$ is larger than $\overline{\mathrm{AIC}}$ without hole, this block is detected as non-stationary block and filtered with AWF.

F. Procedure of the new UNI-GMM-AWF *with* $\overline{\mathrm{AIC}}$

Brief overview of the proposed method as follows.

I Prepare two UNI-GMMs with respect to the size of $\mathbf{OB}$. e.g. UNI-GMM$_{\mathrm{small}}$:$M^2 = 8*8$, UNI-GMM$_{\mathrm{large}}$:$M^2 = 16*16$, are prepared.

II Evaluate four $\overline{\mathrm{AIC}}$s are for each $\mathbf{OB}$s.

III Estimate the class s_k of $\mathbf{B}$ based on each UNI-GMM by maximum a *posteriori* probability (MAP) for each $\mathbf{OB}$s and evaluate four $\overline{\mathrm{AIC}}$s for each $\mathbf{OB}$s.

IV Denoise according to four $\mathbf{OB}$s GMM as follows.

if $\overline{\mathrm{AIC}}_{\mathrm{large}} > \overline{\mathrm{AIC}}_{\mathrm{small}}$,
  if $\overline{\mathrm{AIC}}_{\mathrm{large}}$ of $\mathbf{OB} > \overline{\mathrm{AIC}}_{\mathrm{large}}$ of $\mathbf{OB}_{\mathrm{hole}}$,
    Adopt UNI-GMM$_{\mathrm{large}}$ based on $\mathbf{OB}$.
  else
    Adopt UNI-GMM$_{\mathrm{large}}$ based on $\mathbf{OB}_{\mathrm{hole}}$.
else
  if $\overline{\mathrm{AIC}}_{\mathrm{small}}$ of $\mathbf{OB} > \overline{\mathrm{AIC}}_{\mathrm{small}}$ of $\mathbf{OB}_{\mathrm{hole}}$,
    Adopt UNI-GMM$_{\mathrm{small}}$ based on $\mathbf{OB}$.
  else
    Adopt UNI-GMM$_{\mathrm{small}}$ based on $\mathbf{OB}_{\mathrm{hole}}$.

TABLE I
SCANNING CONDITION OF CHEST PHANTOM FOR PREPARING TRAINING IMAGE SETS.

dose	voltage	slice thickness	image size
40 mAs	120 kV	2.0 mm	512×512 pixel
190 mAs	120 kV	2.0 mm	512×512 pixel

TABLE II
ISNR OF 40mAs PHANTOM IMAGE DENOISED BY THE MEDIAN FILTER, UNI-GMM-AWF AND THE NEW UNI-GMM-AWF.

method	α	model size	filter support size	ISNR
new UNI-GMM-AWF	0.15	1024	5*5	7.5040
UNI-GMM-AWF	-	1024	5*5	7.5027
median filter	-	-	8-neighbors	1.7860

G. Corrected $\overline{\mathrm{AIC}}$

In practice it is difficult to recognize whether the point like signal detected by proposed method is significant signal or noise. To compensate this error, $\overline{\mathrm{AIC}}$ is compensated by adding a correction α. In this paper α is determined experimentally showed in fig.4 described as follows.

III. SIMULATION(RESTORATION OF PHANTOM IMAGE)

A. preparation of the image set for training

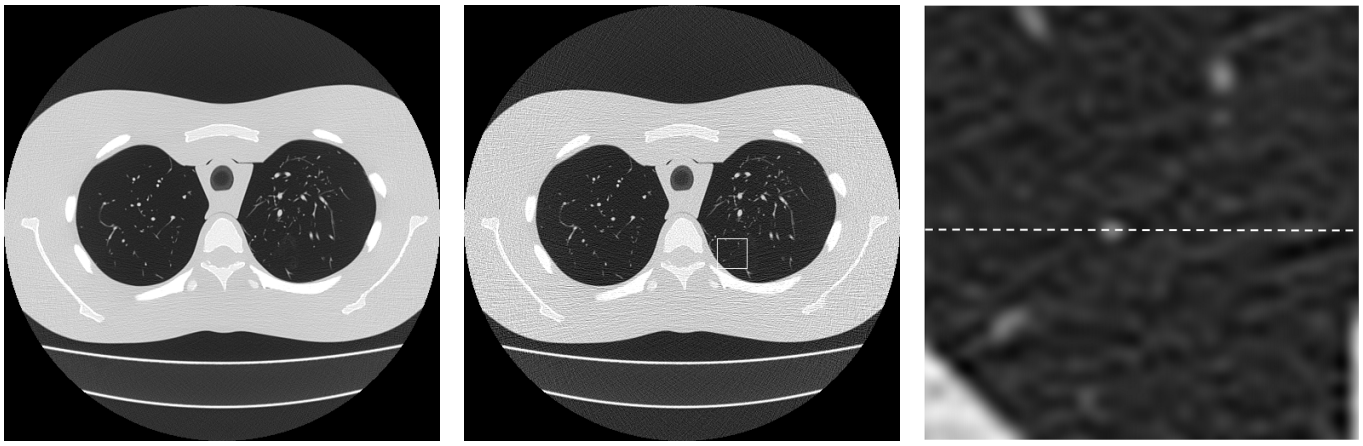
The original image set $\mathcal{O}$ and the observed image set $\mathcal{D}_d$ for training are prepared. 149 chest phantom images are obtained for $\mathcal{O}$ and $\mathcal{D}_{40\ \mathrm{mAs}}$ using 190 milliampere second (mAs) and 40 mAs respectively by scanning chest phantom (N1) developed by Kyotokagaku Co. Ltd. using X-ray CT (Asteion multi$^{\mathrm{TM}}$) developed by Toshiba medical systems and imaging condition is listed in Table I.

B. Experimental conditions

The observed chest phantom image for restoration is prepared to scan using 40 mAs. This observed image is not included in $\mathcal{D}_{40\ \mathrm{mAs}}$ prepared beforehand for training. Using this observed image, we compare the new UNI-GMM-AWF with median filter and previous UNI-GMM-AWF. The images restored by each method are compared by Signal to Noise Ratio Improvement (ISNR) and horizontal profile in restored images. ISNR is defined as follows,

$$\mathrm{ISNR} = 10\log_{10}\frac{\sum(y-x)^2}{\sum(\hat{x}-x)^2}, \tag{9}$$

where y, $\hat{x}$ and x denote the pixels in the observed image, the restored image and the original ($d_0 = 190$ mAs) image, respectively, and $\sum$ is taken on all pixels. Horizontal profile is measured on the white line segment showed in fig.3(c).



(a) original image(190mAs) (b) observed image(40mAs) (c) enlarged image of the white box area in fig.3(b)

Fig. 3. white box area in the observed phantom image fig.3(b) and profile of white dashed line in fig.3(c) are applied to evaluate ability of filters.

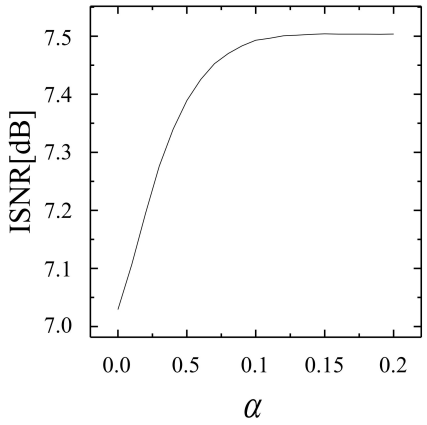


Fig. 4. ISNR vs. α (α is an additive correction for compensation of $\overline{\text{AIC}}$)

C. ISNR vs. Correction of the $\overline{\text{AIC}}$ with α

As a result additive correction with α to the $\overline{\text{AIC}}_{\text{large}}$ does not work in any case. On the other hand additive correction with α to the $\overline{\text{AIC}}$ of $\mathbf{OB}_{\text{hole}}$ which has "hole" in the central region of $\mathbf{OB}$ works functionally. These situations denote that the $\overline{\text{AIC}}_{\text{large}}$ is always larger than the $\overline{\text{AIC}}_{\text{small}}$ for each block. In other words, this means that large size (16*16 pixels) UNI-GMM is always more stationary than small size (8*8 pixels) UNI-GMM. Accordingly in this paper the correction with α to the $\overline{\text{AIC}}$ is just treated whether to adopt the model with "hole" or without.

Fig.4 shows that the highest ISNR is marked when the α is 0.15. Then we see that the new UNI-GMM-AWF(α is 0.15) marks the highest ISNR among the denoising methods showed in table II. Hereinafter we fix the α 0.15 in processing new UNI-GMM-AWF.

D. Denoising and point signal preservation ability of new UNI-GMM-AWF

Upper line in fig.5 shows the comparison of a restored phantom image among median filter, previous UNI-GMM-AWF and new UNI-GMM-AWF. Then for more detailed evaluation of denoising and point like shadow preservation ability, the lower line in fig.5 shows the profiles on the same line segment in fig.3(c). Evaluations of denoising and point like shadow preservation ability are described as follows:

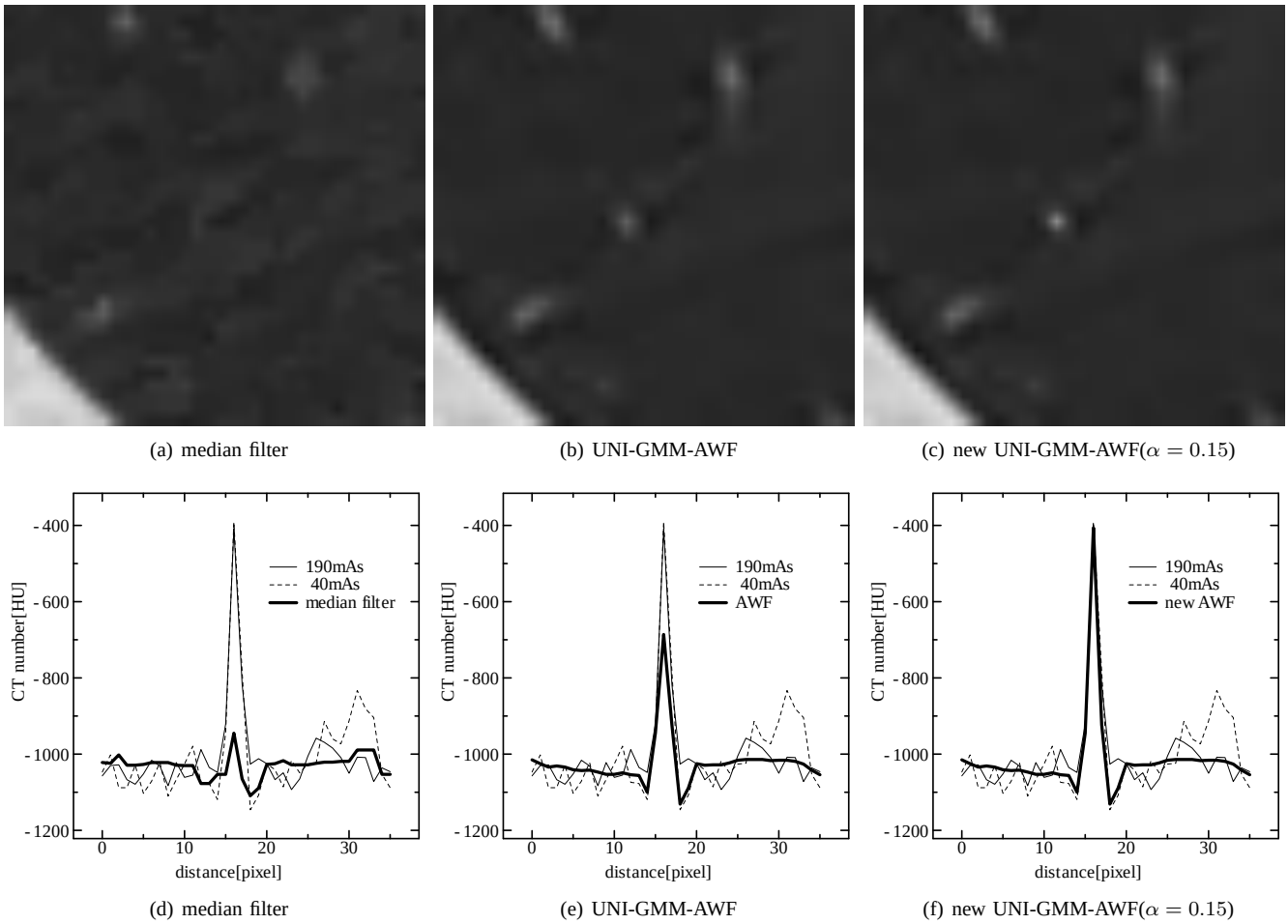
- The comparison of the each profile shows more detail of the point like shadow preservation ability above. Then if taking notice to central peak on the profile, we see the intensity of the central peak of the new UNI-GMM-AWF is higher than the other methods. Furthermore we see that against the foot of the central peak of the new UNI-GMM-AWFs is sharp, the foot of the median filter is dull.
- Denoising ability between the previous UNI-GMM-AWF and the new UNI-GMM-AWF is almost same.
- point like shadow preservation ability of the new UNI-GMM-AWF is higher than the previous UNI-GMM-AWF.

IV. Restoration of clinical thin slice CT image

Fig.6 shows a thin slice chest CT image which is scanned by 2 mm slice thickness, 120 kV and 115 mAs. This thin slice image has a almost same variance of its noise as a 40 mAs phantom images. Thus the image is restored by UNI-GMM-AWFs designed using 40 mAs phantom images. Fig.7 shows restored images of fig.6 by median filter and UNI-GMM-AWFs. Result and discussion is described as follows in DISCUSSION.

V. Discussion

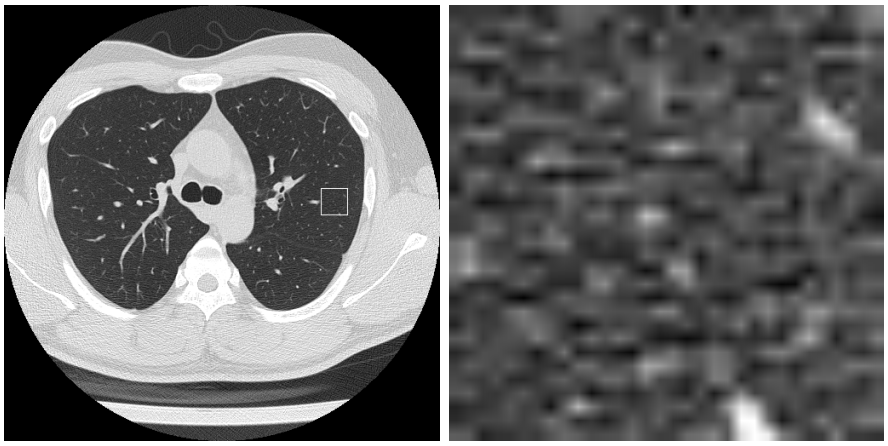
In restoration of the chest phantom image, denoising ability with point like shadow preservation of the new UNI-GMM-AWFs is higher than median filter which is known as a standard denoising method with point like shadow preservation filter. New UNI-GMM-AWF works to leave a point



(a) median filter (b) UNI-GMM-AWF (c) new UNI-GMM-AWF($\alpha = 0.15$)

(d) median filter (e) UNI-GMM-AWF (f) new UNI-GMM-AWF($\alpha = 0.15$)

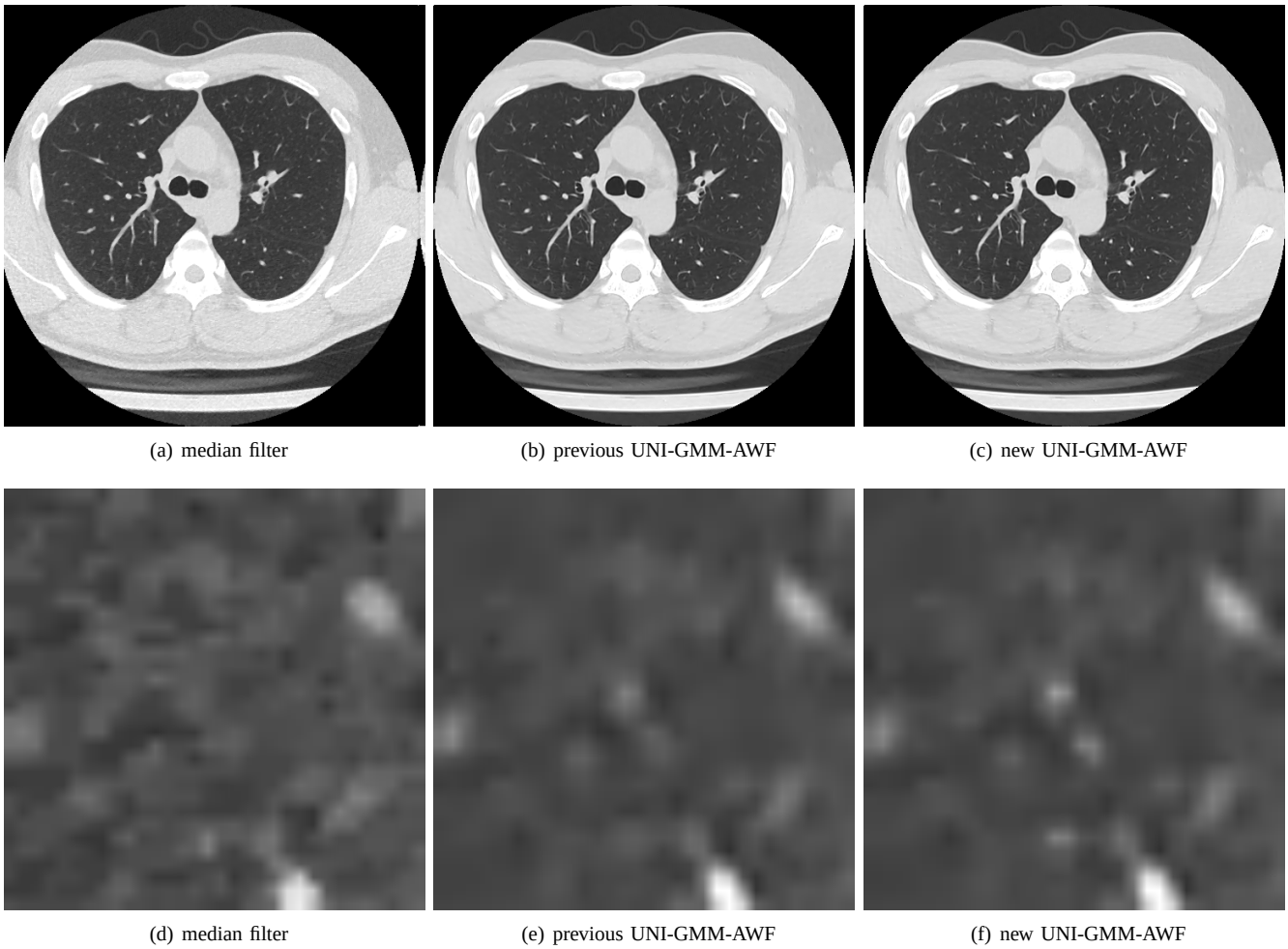
Fig. 5. upper line images : restored chest phantom images scanned with slice thickness 2 mm, dose 40 mAs using the median filter, the previous UNI-GMM-AWF and the new UNI-GMM-AWF. Each image is displayed with Window width 1600, Window level -500. $\alpha = 0.15$ in the new UNI-GMM-AWF. lower line graphs : profiles of CT numbers on the line segment pointed in fig.3(c) in each restored image.



(a) clinical chest thin slice CT image (2 mm-slice thickness, 115 mAs) (b) enlarged image of white box area in fig.6(a)

Fig. 6. fig.6(a) shows an example of a clinical chest thin slice CT image. fig.6(b) shows a enlarged image of white box area in fig.6(a)

like shadow which includes cross-section of a small vessel due to UNI-GMM with ”hole”. For this function new UNI-GMM-AWF is worked on effective restoration of thin slice chest CT images, because they include many axial cross-sections of small anatomical structure. In new UNI-GMM-AWF it can be clearly observed that the removal of noise and streaking artifacts at the dorsal region of the lung does not eliminate any lung nodule structures in the upper line of



(a) median filter (b) previous UNI-GMM-AWF (c) new UNI-GMM-AWF

(d) median filter (e) previous UNI-GMM-AWF (f) new UNI-GMM-AWF

Fig. 7. fig.7(a), fig.7(b) and fig.7(c) show restored images of fig.6 by median filter, previous UNI-GMM-AWF and new UNI-GMM-AWF respectively.fig. 7(d), fig.7(e) and fig.7(f) show enlarged images of white box within fig.6(a).

fig.7. If taking notice to central points in the lower line of fig.7 shows effectiveness of point signal preservation ability in proposed method. However, although it is most important whether new UNI-GMM-AWF recognize a point like shadow as an anatomical object or as a noise, new UNI-GMM-AWF can not recognize it. For this reason it remains a problem that readers must adjust $\overline{\text{AIC}}$ with adding correction α .

On the other hand, as a result small size UNI-GMM does not work functionally because the large size UNI-GMM prepared is always more stationary than the small size UNI-GMM. We need to prepare the larger UNI-GMM for detection of larger stationary region.

VI. Conclusion

Conclusion in this paper is described as follows,

- new UNI-GMM-AWF is effective to preserve a point like shadow with denoising of white noise and streaking artifact.
- Optimization of $\overline{\text{AIC}}$ with adding correction α.
- Preparation of the larger UNI-GMM for detection of larger stationary region.

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GEGEINTOOL: A Computer-Based Tool for Automated Analysis of Gene-Gene Interactions in Large Epidemiological Studies in Cardiovascular Genomics

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ABSTRACT

Current methods of data analysis of gene-gene interactions in complex diseases, after taking into account environmental factors using traditional approaches, are inefficient. High-throughput methods of analysis in large scale studies including thousands of subjects and hundreds of SNPs should be implemented. We developed an integrative computer tool, GEGEINTOOL (GEne-GEne INTeraction tOOL), for large-scale analysis of gene-gene interactions, in human studies of complex diseases including a large number of subjects, SNPs, as well as environmental factors. That resource uses standard statistical packages (SPSS, etc.) to build and fit the gene-gene interaction models by means of syntax scripts in predicting one or more continuous or dichotomic phenotypes. Codominant, dominant and recessive genetic interaction models including control for covariates are automatically created for each SNP in order to test the best model. From the standard outputs, GEGEINTOOL extracts a selected set of parameters (regression coefficients, p-values, adjusted means, etc.), and groups them in a single MS Excel Spreadsheet. The tool allows editing the set of filter parameters, filtering the selected results depending on p-values, as well as plotting the selected gene-gene interactions to check consistency. In conclusion, GEGEINTOOL is a useful and friendly tool for exploring and identifying gene-gene interactions in complex diseases.

Keywords: Genetic Epidemiology, Bioinformatics, Gene-Gene Interactions, Cardiovascular Diseases, Statistical Analysis, Genomics, Polymorphisms.

1. INTRODUCTION

Cardiovascular diseases are the first cause of death in the World, claiming 17.1 million lives a year according to the

World Health Organization [1]. In addition to the well known environmental risk factors for these diseases (tobacco smoking, high-saturated fat diet, sedentary lifestyle, etc.), currently, the genetic factors related to these diseases are increasing in relevance due to the recently published results from dozens of Genome-wide Association Analysis (GWAs) [2] [3] [4]. The results from these GWAs have provided a huge amount of information of new genes associated with intermediate (plasma lipid concentrations, blood pressure, inflammatory markers, etc.) and final (stroke, ischemic heart disease, etc.) cardiovascular phenotypes.

The publication of results from these GWAS, makes hundreds of researchers around the world to conduct studies to replicate associations of the main discovered Single Nucleotide Polymorphisms (SNPs) with the phenotypes of interest in their specific population studies. Up to date, these replication studies included a very low number of SNPs (from one to twenty). However, as the number of discovered SNPs is increasing, as well as the genotyping process performance, it is necessary to increase the number of SNPs to be included in replication studies. Moreover, these SNPs may interact with each other increasing or canceling the final effect on the corresponding phenotype. Nevertheless, to analyze these gene-gene interactions in epidemiological studies including thousands of participants and hundreds of SNPs, current methods of data analysis of gene-gene interactions using traditional approaches are inefficient. High-throughput methods of analysis for these cardiovascular epidemiology studies must be implemented

2. OBJECTIVES

Therefore, our aim was to develop an integrative computer tool, GEGEINTOOL (GEne-GEne INTeraction tOOL), for large-scale analysis of gene-gene interactions, in human studies of cardiovascular diseases including a large number of subjects, SNPs, as well as different intermediate (plasma lipid concentrations, blood pressure, inflammatory markers, etc.) and final (stroke, ischemic heart disease, etc.) phenotypes.

3. METHODOLOGY

That tool uses standard statistical packages (SPSS, etc.) to build and fit the gene-gene interaction models by means of syntax scripts in predicting one or more continuous (plasma total cholesterol, plasma LDL-cholesterol, triglycerides, systolic blood pressure, diastolic blood pressure, fasting glucose, etc.) or dichotomic (diabetes, hypertension, cardiovascular diseases, etc.) phenotypes. Codominant, dominant and recessive genetic interaction models including control for covariates are automatically created for each SNP in order to test the best model. Two-way or high order gene-gene interactions can be computed depending on the sample size and the researcher's choice. Environment variables (tobacco smoking, high-saturated fat diet, sedentary lifestyle, etc.), as continuous or as categorical, can be used as control variables for different confounders. From the standard outputs, GEGEINTOOL extracts a selected set of parameters (regression coefficients, p-values, adjusted means, etc.), and groups them in a single MS Excel Spreadsheet. The tool allows editing the set of filter parameters, filtering the selected results depending on p-values, as well as plotting the selected gene-gene interactions to check consistency.

We implemented the GEGEINTOOL in a real study to validate the tool and to compute the difficulties and limitations. The study in which the computer tool was tested was the PREDIMED Study [5]. The PREDIMED study (PREvención con DIeta MEDiterránea) is a parallel, multi-center, controlled, randomized clinical trial aimed at assessing the effects of the TMD on the primary prevention of cardiovascular disease. The trial is currently taking place with more than 7000 high-cardiovascular risk participants assigned to 3 intervention groups: (1) a traditional Mediterranean Diet (TMD) with virgin olive oil (TDM + VOO); (2) a TMD with mixed nuts (TMD + nuts); and (3) a low-fat diet. This study, started in October 2003, is carried out in several regions of Spain. The Institutional Review Board of the recruitment centers approved the study protocol and participants signed an informed consent. From October 2003 to March 2004, a total of 930 asymptomatic subjects at high risk for CHD, aged 55–80 years, were initially selected in 10 Spanish Primary Care Centers. They fulfilled at least one of the two following criteria: type 2 diabetes mellitus or three or more cardiovascular risk factors (smoking, hypertension, dislipemia, obesity, or family history of cardiovascular disease). Exclusion criteria were: history of cardiovascular disease; severe chronic illness; drug or alcohol addiction; history of food allergy or intolerance to olive oil or nuts; and any condition that may impair participation in the study. Participants' eligibility was based on the review of clinical records and a screening visit in the Primary Care Center by the physician.

The baseline examination included the administration of: a 14-item questionnaire, an extension of a questionnaire designed to assess the degree of adherence to the Mediterranean diet, the Minnesota Leisure Time Physical Activity questionnaire; and a 47-item general questionnaire assessing life-style, health conditions, socio-demographic variables, medical diagnoses, and medication use as previously reported [5] [6]. At baseline anthropometric data were also measured by standardized procedures. Fasting blood samples were obtained at baseline for each participant and serum glucose, cholesterol, and triglyceride concentrations were measured using standard enzymatic reagents (Trinder, Bayer Diagnostics, Tarrytown, NY, USA) adapted to a Cobas Mira automated analyzer (Hoffmann-La Roche, Basel, Switzerland). HDL cholesterol was quantified after

precipitation with phosphotungstic acid and magnesium chloride. LDL cholesterol was calculated by the Friedewald formula. Other biochemical determinations were carried out as previously detailed [5] [6].

Genomic DNA was extracted from buffy-coat with the MagNaPure LC DNA Isolation kit (ROCHE Diagnostics). We determined 100 SNPs in different genes related to cardiovascular diseases using 7900HT Sequence Detection system (Applied Biosystems) by fluorescent allelic discrimination TaqMan assays and OpenArray platforms. Quality control procedures were applied.

4. RESULTS

We implemented our tool to test gene-gene (epistasis) interactions in the PREDIMED study. The mean age of the participants was 67.7 years and prevalence of diabetes, hypertension and dislipemias was high as this is a high cardiovascular risk population. We selected 100 SNPs based on the literature y tested the Hardy-Weinberg equilibrium. Once checked this equilibrium we identified the minor allele for each polymorphism in order to create three variables for the three models of inheritance: additive, codominant and dominant. The 100 selected SNPs were not in linkage disequilibrium and were considered relevant tag SNPs associated with one or more of the selected intermediate cardiovascular risk phenotypes (plasma lipids, fasting glucose, blood pressure, inflammation markers and anthropometric measurements). Figure 1 shows the GEGEINTOOL workflow.

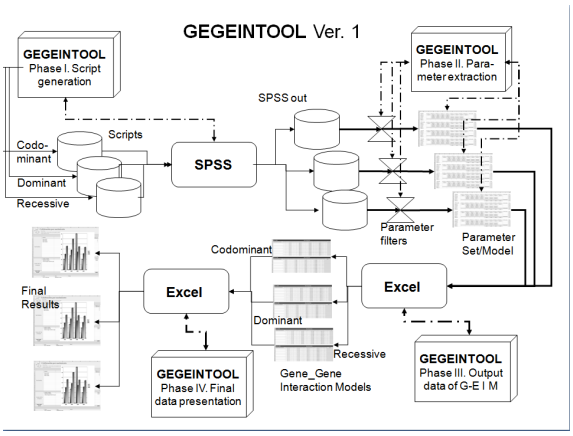


Figure 1. GEGEINTOOL Workflow

We first fitted first order gene-gene interaction models involving two SNPs. To compute these models the computer tool has two options: a) To test every combination of the 100 SNPs two by two; or b) To select only the biologically related SNPs determining the same phenotypical trait. The first option involves more computation time and has the limitation of increasing false positive results because of the multiple comparisons. The advantage is the complete screening of all the analyzed variants. In term of correction of the P values for multiple comparisons, the GEGEINTOOL allows to customize the selected P value ($P<0.05$; $P<0.01$; $p>0.001$; $P<0.0001$, etc) in order to consider a gene-gene interaction term statistically significant. Currently there is not complete agreement among researcher on the best algorithm to correct the P value [8] [9] [10], thus the GEGEINTOOL shows all P values and the researcher can select by order the best ones.

Taking into account that in a gene*gene interaction the effect of one genetic variant in determining a phenotype is modified by the second variant. It is interesting to depict the magnitude of effects and to test the consistency between the different models of inheritance. Our tool conducts figures for the selected gene-gene interactions. In addition it computes both crude and adjusted gene-gene interaction means for continuous variables. The main variables to adjust for are gender, clinical conditions, age, tobacco smoking, diet and physical activity. GEGEINTOOL allows comparing the P values before and after adjustment for a step by step control for covariates.

In addition to the testing of first order gene-gene interactions, GEGEINTOOL is able to conduct higher order gene-gene interaction models. We have computed second and third order interaction models in our data set and we have observed the advantages and the limitations of these models.

When implementing the GEGEINTOOL in the PREDIMED Study, we first analyzed the 100 SNPs in 3000 participants randomly selected. This sample constitutes the training sample and then we have the rest of the participants as an internal replication sample to check the consistency of the first identified gene-gene interactions.

After having applied the GEGEINTOOL to the search of statistically significant gene-gene interactions in the PREDIMED study in determining intermediate cardiovascular phenotypes, we have obtained dozens of statistically significant first order interaction terms among SNPs related with the dependent phenotype. Due to limitations in sample size, we have obtained less statistically significant second and third order gene-gene interactions. The most interesting gene-gene interactions are selected for new genotyping of the involved SNPs and conducting replication in the other PREDIMED participants. Moreover, we are also studying how the gene-gene interactions found are homogeneous or heterogeneous across the different strata of clinical conditions (diabetes, hypertension), gender age-groups or environmental factors (smokers, drinkers, categories of Mediterranean diet adherence, etc). GEGEINTOOL is a

easy tool that allows a wide range of customization of biomedical analysis depending on the requirement of the specific epidemiological study and the measured variables of interest.

5. CONCLUSIONS

In conclusion, GEGEINTOOL is a very useful and friendly tool for exploring and identifying gene-gene interactions in cardiovascular diseases for biomedical researchers using standard statistical packages of statistical analysis.

ACKNOWLEDGEMENTS

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DNA Sequence Visualization and Feature Extraction

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ABSTRACT

The 2010-2011 Jacksonville State University (JSU)-CREU project's focus is on problems in the area of DNA sequence visualization. Specialized software (BLAST, FASTA, etc) are utilized for identifying and aligning nucleotide sequences obtained from sample data provided by the Biology department at JSU. The project team designed and implemented a visualization system that takes, as input, the output of the specialized DNA-analysis software. The output of the visualization system is a visual display of the text-formatted input data. To complete the JSU-CREU project, biology students will be asked to complete a survey on the usability of this and other visualization systems. The results of the survey will be statistically analyzed and an analysis report will be written.

Keywords: DNA Sequences, BLAST, FASTA, DNA Visualization, DNA processing and features extraction.

1.GENERAL PROJECT DESCRIPTION

Recently, the great progress of biotechnology makes the deoxyribonucleic acid (DNA) sequencing more efficient. In general, DNA sequences are stored in the computer database system in the form of character strings. In a human somatic cell, haploid nuclear DNA contains 2.85 billion base pairs (bps), in which a tremendous wealth of genetic information resides [3]. These sequences create large amounts of data that have to be analyzed. Human analysis of this data can cause many errors and oversights. A computer system would provide a consistent analysis of this data. Biologists often need a specific gene sequence which can be difficult and time consuming if one must go through the whole gene by hand. There needs to be an efficient way of searching the database. If these data can be represented visually, then a biologist can recognize the similarities and anomalies more easily than with manual comparison. Further, data mining techniques could be used to augment the discovery of new knowledge on DNA sequences. This project aims to address these issues.

Huge amounts of DNA sequences of various organisms have been successfully sequenced with higher accuracies. By analyzing DNA sequences, the biological relationships such as homologous and phylogeny of different species can be investigated. However, the analysis of DNA sequences by the use of biological methods is too slow for processing huge amount of DNA sequences. Therefore, the assistance of computers is necessary and thus bioinformatics is extensively developed. Efficient algorithms and implemented computer-based tools are desired to deal with the considerable and tedious biomolecular data.

In May 2010, the Collaborative Research Experiences for Undergraduates (CREU) program has funded three undergraduate students at Jacksonville State University to study DNA data analysis and visualization. Specific questions that were proposed in the study are the following:

- What is the most effective visualization technique for DNA sequences?
- Can we find a defining feature that will separate DNA segments into clusters?
- How can visualization be useful for comparing DNA sequences for similarities and differences?
- Can the visualization data be used to assess microbial diversity from environmental samples?

The proposed study was guided by the following research plan:

- Investigate different algorithms for visual representation of a DNA sequence and its nucleotide content, such as: H-curves, DNA walks, Z-curves, Randic's Visualization methods, Dual-Based curves, Dual-Vector curves, fractal-based representations, etc. Investigate various data mining algorithms that are suitable for feature extraction;
- Acquire and test existing software tools used for DNA sequence visualization and data mining;
- Compare results produced by using different software packages;
- Design and test an efficient visualization algorithm for a given problem;
- Implement the feature extraction of DNA sequences using the chosen data mining algorithm;

- Conduct surveys to evaluate the visualization representation by different viewers.

The project, comprising of a team of three undergraduates (one being an African- American student and the other two are female students), was funded in June 2010 and involves the challenges of independent research, analytical thinking, applied statistical analysis, and project management. Furthermore, the inclusion of a woman as one of the faculty advisors extends the goal of the CREU in encouraging a broader participation of underrepresented groups. The experiences gained by working in this project allow the participants to understand the issues involved in research, build new skills, and increase confidence in approaching team projects.

The students were exposed to the state-of-the-art technologies and methodologies in the broad areas of bioinformatics, DNA visualization, DNA data processing and feature extraction. These techniques play extremely important roles in bioinformatics and molecular biology, and they are not afforded in any regular classroom setting. The sponsors, Dr. Guillermo Francia, Dr. Chris Murdock, and Dr. Monica Trifas, have extensive backgrounds in molecular biology, bioinformatics, computational biology, human computer interaction, and image processing. They provided the students with the expert guidance and motivation not only to complete the project but also to pursue graduate studies in the discipline.

2. STUDENT ACTIVITY AND RESPONSIBILITY

The project started with three main tasks: (1) Data Visualization; (2) Feature Extraction and (3) Assessment Tools Development. During the middle of the project timeline, the team decided that feature extraction is no longer viable and necessary. The activities and responsibilities of the students include:

(1) Weekly meetings and direct consultation with the professors (3 hours/week): each student will present a progress report on his/her assigned tasks, and define/discuss his/her goals for the coming week;
(2) Background research and algorithm investigation for data mining (4 hours/week): study the latest development in the field, investigate various algorithms, and get acquainted with the software tools being used in the project;
(3) Project implementation and testing (4 hours/week): this task includes data preparation, utilization of software tools, testing, performance evaluation/improvement, etc;
(4) Website development and maintenance (1 hour/week): develop and maintain the project website and update a weekly online journal to summarize the latest progress.

In summary, the students spent approximately 12 hours per week on this project. Whenever necessary, the students extended their working time to ensure the successful completion of the project requirements.

3. DNA DATA ANALYSIS AND VISUALIZATION TOOLS

3.1 Early Computer Sequencing

Using computer programs to study and manipulate DNA structures is not new. In 1979 Staden at the MRC Laboratory of Molecular Biology in Cambridge, UK noted the use of computer programs in comparing bacterial DNA [7]. However, his work dealt mainly with the joining of small (~200 bp) sequences derived from gel readings [7].

By 1997, computer technology had increased sufficiently to allow for advanced automated sequencing of DNA [6]. This allowed comparison algorithms such as FASTX and FASTY (extensions of the FASTA program which compared sequences) to compare DNA sequences to the protein sequences that are produced (Pearson et al., 1988). FASTX determines how many quasicodons (sets of three consecutive base pairs) are available and then creates a hypothetical coding region (HCR) which consists of those quasicodons [6]. Output from FASTX consists of the HCR and the amino acid (protein) sequence (Pearson et al., 1988). FASTY, on the other hand, takes a more general approach by simply iterating over the given DNA sequence and creates an array of amino acids (Pearson et al., 1988). FASTY is the more accurate of the two methods because it can capture base miscalls and determine a wide range of frameshift errors (Pearson et al., 1988).

Basic Local Alignment Search Tool (BLAST!) is a comparison algorithm used to compare genetic sequences. BLAST will find areas where a genetic sequence similar to other known sequences with different degrees of similarities. Annotated sequences can also be uploaded to the BLAST database. BLAST offers several options for searching through their database including searching by nucleotide, protein, and translated sequences; it provides the choice of several search algorithms as well (BLAST 2011). Although BLAST has an installable command-line application, the web-base is equally functional.

Microsoft Biology Tools (MBT) is a very powerful add-on to Microsoft Excel for Bioinformatics and other types of bio-related research. It offers advance users an easy-to-use interface but still allows novice users to easily interpret genomic data and systematically manipulate sequences. For example, researchers can merge or subtract sequences on genomic intervals. The vast amount of charting and graphing options is also available .Instead

of manual data insertion, sequences can be imported or exported [4].

3.2 Newer Approaches

New methods have been developed in the last several years that have improved even further on these techniques. The methods discussed previously gave character stream output and saved the data in the same manner [2].

3.2.1 Two-Dimensional Visualization

Myllari ([5]) used Mathematica and Maple to visualize DNA sequences. The programs use three algorithms for DNA visualization: random walk, fractal-based, and visualization based on calculated parameters. Random walk takes the base-by-base approach to visualizing the sequence [5]. Each base is assigned a vector (direction and distance) on a two dimensional plane[5]. If the four bases are found in approximately equal numbers then the ending point should remain somewhere near the starting point [5]. However, if there is a disproportionate number of a certain base then the ending point should trend toward the direction of that base [5].

The fractal-based visualization does not take the sequence as a base-by-base chain, but rather looks at how balanced the sequence is [5]. It also gives an idea of the distribution of sections of different sizes (1-8 bases as of 2005) or of the sequence as a whole [5]. The output of this algorithm is a two dimensional plane with colored regions that are darker when the base or word assigned to that region is more abundant [5].

Visualization in Mathematica and Maple can also be done using calculated parameters which are usually calculated using entropy-like characteristics of bases [5]. These parameters indicated how balanced the bases are [5]. Like the fractal-based algorithm the parameter based algorithm does not take the sequence as a base-by-base series [5]. This algorithm uses a sliding window, of a size indicated by the user and calculates the entropy for that window with output in the form of four curves on a two-dimensional plane [5]. Additional works on DNA visualization are found in [8] and [9].

3.2.2 Three-Dimensional Visualization

Today the focus is on 3D visualization. There are several reasons for this. First, with the rapid advances of DNA extraction technology the length of the available raw data strands is too long to display on a computer screen [2] It is also hard to extract any specific attribute from this type of data [2].

Chang et al. [2] propose a scheme called three-dimensional trajectory (TDT) as a method of DNA sequence visualization. In this method, each base (A, T, C, and G) is assigned a point on the 3-D plane. The distance and direction between each base is plotted which is more easily readable than the character stream[2]. Once this is accomplished further processing facilitates the comparison of multiple DNA sequences [2].

4. RESEARCH RESULTS

The undergraduate research team performed a literature review and an extensive research on the different DNA data analysis and visualization tools that are available via the Internet. A discussion on the various tools is presented in the previous section. Further, a survey on the usability of and familiarity on these tools was conducted among Biology students at JSU. The survey results are presented in Tables 1 through 4.

Class Standing	Frequency
Freshman	3
Sophomore	0
Junior	4
Senior	12
Graduate Student	1
Total	20

Table 1. Student Classification

Number of Biology Courses Taken	Frequency
1	0
2	2
3	1
4	3
>More than 4	14
Total	20

Table 2. Biology Courses Taken

Familiarity with DNA Visualization	Frequency
Low-1	1
2	6
3	6
4	5
High-5	1
N/A	1
Total	20

Table 3. DNA Visualization Familiarity

Tool	Output	Preference	Used
BLAST	5	9	9
FASTA	1	0	4
MBT	11	9	2
None	3	2	2
Other	0	0	1
APOLLO	0	0	2
TOTAL	20	20	20

Table 4. DNA Visualization Tools

4.1 Data Analysis

A quick visual data analytics reveals that familiarity with a DNA visualization tool does not translate to its preference or to its usability. Figure 1 clearly indicates that the output of the MBT tool is best preferred among the other tools even though very few students have previously used it. Although the class standing of the population is predominantly at the senior level, the survey data indicate a middle-to-low level confidence or familiarity with the visualization tools.

5. CONCLUSION AND FUTURE WORK

In general, DNA sequences are stored in the computer database system in the form of character strings. These sequences create large amounts of data that have to be analyzed. Human analysis of this data can cause many errors and oversights. If these data can be represented visually, then a biologist can recognize the similarities and anomalies more easily than with manual comparison. In this project, three undergraduate students investigated different algorithms for visual representation of a DNA sequence and its nucleotide content, tested existing software tools used for DNA sequence visualization and data mining and conducted surveys to evaluate the visualization representation by different viewers.

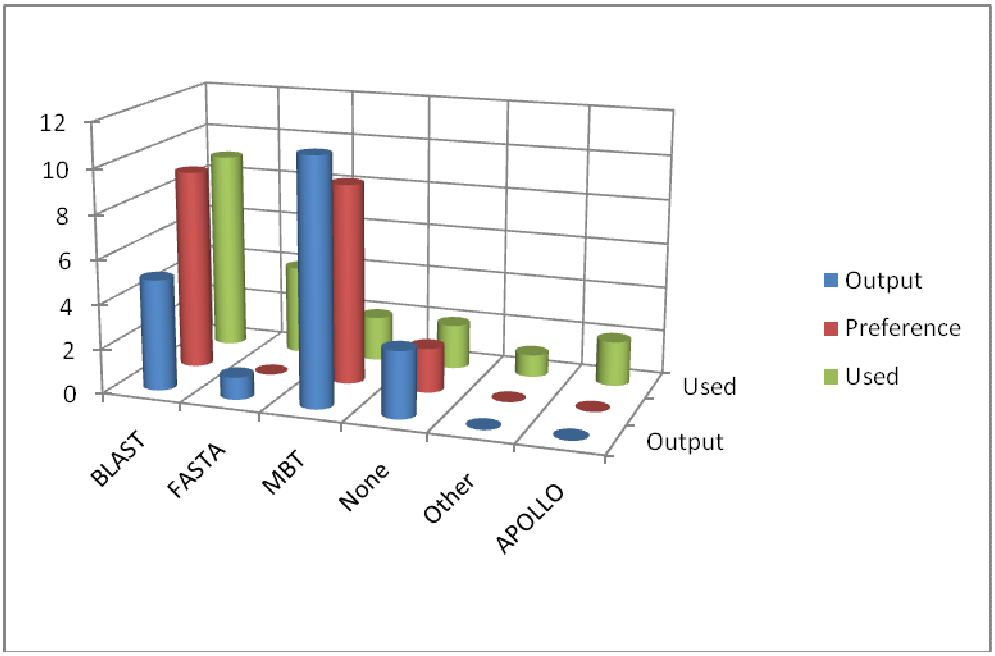


Figure 1. A Comparison of the DNA Visualization Tools.

The possible further studies and future work based on the visualized DNA sequences are summarized:

- Apply mathematical analysis or signal-processing algorithms such as the Fourier and Wavelet transforms to the visualized sequence data for further sequence analysis, clustering, and annotation;
- Develop better human machine interface for scientists in operating the bioinformatics tools based on graphical representation of sequences;
- Cooperate with computer graphics techniques for better graphical representation of DNA sequences;
- Extract the features from the visualized /numerical sequences and then develop feature databases for fast and efficient database retrieval;
- The investigation of the effects of insertion, deletion, substitution, reverse, and complementary in sequences. Find more biological applications and develop various visualization tools such as characterization and classification of species, visualizing regular patterns in sequences
- Adopt the existing visualization methods to protein sequences.

6. ACKNOWLEDGEMENTS

This project was designed to facilitate participation for three students (two women and one African-American) in the undergraduate student research program, Collaborative Research Experience for Undergraduates (CREU) organized by the Computing Research Association's Committee on the Status of Women in Computing Research (CRA-W) and the Coalition to Diversify Computing (CDC). The goal of this program is to provide positive research experience and to increase the numbers of women and minorities who continue on to graduate school in computer science, engineering, and allied disciplines.

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Using Spectral Analysis in Electrophoresis of Nucleic Acids

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ABSTRACT

The aim of the work was to improve performance of agarose gel electrophoresis of nucleic acids by using spectral analysis of the samples. The analysis is based on the use of suitable laser wavelength with the highest absorption by gel components to detect the DNA band before it exits from a gel plate.

Keywords: horizontal electrophoresis, spectral analysis, components of agarose gel electrophoresis.

1. INTRODUCTION

Biologists often faces a problem that small molecular size nucleic acid samples move faster than expected and they exit from a gel plate causing errors in the experiment. In our laboratory, electrophoresis method was redesigned with the use of photoelectric effect. Concentrated monochrome spatial coherence beam (laser) was applied on the opposite end of gel plate which the samples are immigrating toward. In the obverse side, we positioned a photo-detector, so when the loading dye which precedes slightly the first DNA band passes in front of laser, the absorption will increase by at least 50 %. A user-programmed microcontroller made a decision to stop the electrophoresis by switch off high-voltage source from the electrodes and gave sound and light alert. The percentage absorption varied according to gel concentration and color of the used dye. For example, often used bromophenol blue and xylene cyanol dyes migrate through agarose gels at roughly the same rate as double-stranded DNA fragments of 300 bp and 4000 bp, respectively [1].

2. SPECTRAL ANALYSIS

To achieve our aim of conclude the light wavelength which has the maximum absorption, we prepared four types of samples for two concentrations of the gel.

- The first sample contained agarose gel only without any loading dye was transparent.
- The second sample contained agarose gel and ethidium bromide without loading dye and was transparent also.
- The third sample contained agarose gel and ethidium bromide with bromophenol blue dye had blue color.
- The fourth sample contained agarose gel and ethidium bromide with xylene cyanol dye had green color.

We examined the samples in Varian 2200 gas chromatograph - mass spectrometer (Agilent Technologies, USA) in visible and ultraviolet spectral ranges [2]. Varian 2200 ran on auto gain mode during spectral scanning. The transparent agarose sample without ethidium bromide was considered as reference to assay the spectrum of agarose sample with ethidium bromide, then the preceding was considered as reference to obtain the absorption spectrum of dyed samples (bromophenol blue + agarose gel + ethidium bromide) and (xylene cyanol + agarose gel + ethidium bromide).

The results were as following :

- In range from 450 nm to 500 nm, the absorption was 100 %.
- At 600 nm the absorption was 80 %.

As it is explicit in Fig. 1, which indicate the visible light spectrum of blue bromophenol dyed sample, there is almost complete absorbance of the light in blue and violet range and it is self-evident due to the blue color of the sample. And on other hand, there is 80% absorbance at light wave length 600 nm; ie. in the red range.

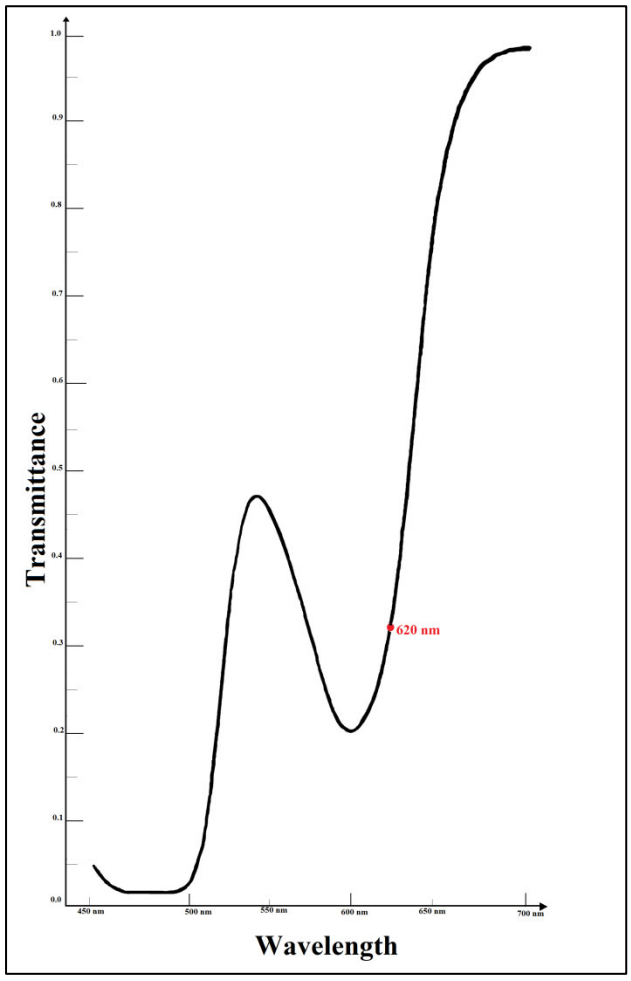


Fig. 1 Transmittance of blue bromophenol dyed sample.

A 620 nm laser was chosen for further testing because of availability and economy price. We tested wavelength 620 nm in Varian 2200 ran on single beam mode to measure transmission. The results are shown in table below.

Concentration of Gel	Color of the Sample	Transmission in 620nm
1 %	clear	76%
	blue	31%
	green	37%
3%	clear	64%
	blue	29%
	green	34%

Tab. 1 Transmittance of samples at 620 nm.

3. AFFECTING FACTORS ON MOLECULES MIGRATION

Mobility of molecules and its migration in electrophoretic electrical field depend on the following factors [3]:

1. Concentrations of gel sample (T, C) where T is concentration of individual agarose molecules, and C is concentration of agarose solvent.
2. Sample size and its shape.
3. Concentrations of buffer solution.
4. Applied electric field strength.
5. Proportion of hydrophobic molecules.
6. Ionization intensity.
7. Buffer temperature.
8. Gel pore size which is resultant from variation of gel concentration.

These factors affect molecules mobility in gel and their diffusion coefficient. The diffusion coefficient of sample molecules in free solution is D_0, and electrophoresis mobility in buffer solution is U_0 are proportionate by constant rate:

$$D/D_0 = U/U_0 = a \qquad (1)$$

where U is electrophoresis mobility in gel, D is diffusion coefficient of sample molecules in gel, a is impedance coefficient.

The distance d that molecules moved during electrophoresis is proportionate with:

- (t) Time is measured in *sec*.
- (g) Potential deviation is measured in $V.cm^{-1}$.

By the following equation:

$$d = U \,.\, g \,.\, t = U \,.\, i \,.\, t \,/\, k \qquad (2)$$

where i is current density is measured in $A.cm^{-2}$, k is qualitative conductivity is measured in $\Omega^{-1}.cm^{-1}$.

In nucleic acids applications U_0 electrophoresis mobility in free solution depends on the weight of the molecules and the viscosity of the medium. D_0 is proportional inversely with the square root of molecular weight of DNA.

From this discussion, the scientists Richards and Lecanidou reached to conclude the value of U_0 and D_0 as following:

$$U_0 = 31 \,.\, 10^{-5} \ \mathrm{Cm}^2 \,.\, \mathrm{V}^{-1} \,.\, \mathrm{S}^{-1} \qquad (3)$$

in 0.05 mol buffer solution and temperature 25°C.

However, D_0 varies from 1.3×10^{-6} cm^2/sec to 1.4×10^{-7} cm^2/sec for nucleic acid molecules which has molecular weight range [10^4 bp - 10^6 bp]. The shape of electrophoretic nucleic acids is considered as fascicular zone during the separation by electrophoresis, and this zone could be described by changing of the concentration C ($m.l^{-1}$) with the position X threw the length of motion axis. And the relation between the greatest concentration $\mathbf{C}_m$ and the width of the band W_{atc} is given by the following equation :

$$2w_{atc} = C_m / 2 \qquad (4)$$

The injected sample volume which applied in the unit of gel cross-section area is v, If the potential deviation g in the sample solution equal to the gel, the primary width of the band at the reference point could be given as the following relation:

$$2w_0 = a \,.\, \upsilon \qquad (5)$$

The application of the potential deviation g in the sample layer mostly is greater than in the gel, so the width of primary band will be lesser that what suggested in previous equation and it may neglect provided that:

$$2w_0 < (2DT)^{1/2} \quad \text{or} \quad \upsilon < (2D_0 t / a)^{1/2}$$

So the applied sample volume is rarely considered as major factor in design. And while $2w_0 < (2DT)^{1/2}$ the relation of band width is given as following:

$$2w = (16\, D\, t\, ln2\,)^{1/2} \qquad (6)$$

Electrophoresis is the movement of an electrically charged substance under the influence of an electric field. This movement is due to the Lorentz force, which may be related to fundamental electrical properties of the body under study and the ambient electrical conditions by the equation given below [4]:

$$F_e = q \,.\, E \qquad (7)$$

where F_e is the Lorentz force, q is the charge carried by the body, E is the electric field.

The resulting electrophoretic migration is countered by forces of friction such that the rate of migration is constant in a constant and homogeneous electric field:

$$F_t = v \,.\, f \qquad (8)$$

where v is the velocity and f is the frictional coefficient.

Migrating ion attains constant velocity at which moving and retarding forces balance:

$$v = E \,.\, q \,/\, f \qquad (9)$$

The electrophoretic mobility μ is defined as followed:

$$\mu = v \,/\, E = q \,/\, f \qquad (10)$$

The expression above applied only to ions at a concentration approaching 0 and in a non-conductive solvent. Polyionic molecules are surrounded by a cloud of counterions which alter the effective electric field applied on the ions to be separated. This render the previous expression a poor approximation of what really happens in an electrophoretic apparatus.

The electrophoresis mobility depends on both:

- The particle properties (e.g., surface charge density and size).
- Solution properties (e.g., ionic strength, electric permittivity, and pH).

For high ionic strengths, an approximate expression for the electrophoretic mobility is given by the Smoluchowski equation:

$$\mu_e = \varepsilon \, . \, \varepsilon_0 \, . \, \zeta / \eta \qquad (11)$$

where ε is the dielectric constant of the liquid, ε_0 is the permitivitty of free space, η is the viscosity of the liquid, ζ is the zeta potential (i.e., surface potential) of the particle.

4. IMPROVED DESIGN

The advantage of the described method is that it was integrated into the device including:

- Electrophoresis tank contains two electrodes (anode and cathode), rest of gel plate and buffer tank.
- Two dark chambers for laser and photo-detector.
- Power supply and control panel.

The device had three control mechanisms: time interrupt, potential selecting, and laser interrupt.

Time Interrupt
The time of electrophoresis could be adjust by user from 1 min. to 99 min. and timer countdown and when it passed, sound alarm issued and the current threw electrodes cut off so electrophoresis of sample stopped. The time unit consists of display, up and down buttons and set button. The up and down button are for adjusting the timer and the set button is for setting the time of electrophoresis.

Potential selection
There are four different potential values could be selected (35 volt, 50 volt, 100 volt, 150 volt) and they are the most common used potentials in applications electrophoresis of nucleic acids.

Laser interrupt
Using laser to detect bands before go away threw the gel plate it is optional choice. So if the laser interrupt button is switched on and when the loading dye which precedes slightly the first nucleic band is detected by laser; as it is explained previously; sound alarm issued and electrophoresis of sample is stopped by turn off the applied potential on electrodes.

Our new design is compatible, convenient and integrated and the following figure shows real image of it:



Fig. 2 Electrophoresis device design

5. CONCLUSION

Based on the measured absorption spectrum of DNA in ultraviolet range, we can use photoelectric effect in horizontal electrophoresis by apply array of focused UV light beams that can determine the exact position of each immigrating fragment. Thus, it is possible to develop an integrated and comprehensive device with no need of the use of an UV documentation camera or florescence dye such Ethidium Promide which is toxic substance causing genetic mutation.

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Identifying Interacting Environmental Factor – Gene Pairs

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ABSTRACT

Most diseases are caused by a combination of environmental and genetic etiological factors, and these factors may interact in causing disease. We conjectured that an environmental factor and a gene that are associated with the same set of diseases are likely to interact. We extracted environmental factor – disease associations and gene – disease associations from freely accessible online databases and the research literature, and identified environmental factor – gene pairs that were similar in being associated with a common set of diseases. For several of these pairs that we examined, we found evidence for plausible biological interactions in the literature. We postulate that that the remaining pairs may represent novel interactions between an environmental factor and a gene.

INTRODUCTION

The etiological factors associated with the development of human disease are broadly categorized into environmental and genetic factors. While infections like community-acquired pneumonia are predominantly influenced by environmental factors and Mendelian diseases like sickle cell anemia are predominantly influenced by genetic factors, many of the common diseases like coronary heart disease are influenced by both environmental and genetic factors that likely interact with each other.

Several freely accessible online databases are now available that collate information on genetic factors associated with disease, such as the Online Mendelian Inheritance in Man (OMIM), the Genetic Association Database [1], and GeneCards. Fewer sources of information are available on environmental factors associated with diseases. A freely accessible database is the CHE Toxicant and Disease Database [2] that contains curated information on chemicals/toxins associated with disease, and another source is the dataset provided by Liu et. al. in their paper on the "etiome" [3].

Collated data on environmental factor – disease associations and gene – disease associations can provide a wealth of information. For example, identifying etiologically similar diseases to a disease of interest may be useful in unraveling the biological mechanisms underlying the disease (based on the already characterized mechanisms in the similar diseases) or in investigating new therapies (based on the therapies in use in the similar diseases).

Several papers have described innovative methods for extracting environmental factors of disease and in analyzing environmental factors in combination with genetic factors. Liu et. al. extracted a comprehensive list of associations between disease and environmental factors using the Medical Subject Headings (MeSH) annotations of MEDLINE articles and combined it with genetic factors of disease to characterize the "etiome" profile of over 800 diseases [3]. Patel et. al. developed a new method called an Environment-Wide Association Study (EWAS) - similar to a Genome Wide Association Study (GWAS) - to extract environmental factors of disease and applied it to Diabetes mellitus type 2 [4]. Gohlke et. al. extracted environmental factors of disease by identifying key molecular pathways that are jointly associated with genetic and environmental factors using a gene-centric database, and validated their new-found associations with known chemical-disease relationships and transcriptional regulation data [5]. We followed the strategies used by Liu et. al. to compile datasets of environmental factor – disease and gene – disease associations.

We conjectured that an environmental factor and a gene that are associated with the same set of diseases are likely to have a biological interaction. In this paper, we computed a similarity measure for an environmental factor and a gene. We then investigated the most similar environmental factor - gene pairs for plausible biological interactions. We defined an interaction as either the environmental factor having a direct influence on the gene, or the environmental factor and the gene (along with the protein product) having a direct influence on a common biological molecule (e.g., gene, protein, metabolite).

METHODS

In this section, we briefly describe the extraction of environmental and genetic factors of diseases, the similarity measure we used and the method we followed for the selection of promising environmental factor – gene pairs.

Environmental Factors. We obtained environmental factors of human diseases from two sources. We obtained chemical-disease associations from the CHE Toxicant and Disease Database [2]. In addition, we extracted environmental factor – disease associations from the MeSH annotations of MEDLINE articles using the strategies developed by Liu et. al. [3]. MeSH is a comprehensive controlled vocabulary that contains over 25,000 descriptors (also known as subject headings) and over 80 qualifiers (also known as subheadings). An article in MEDLINE is typically annotated with several descriptor/qualifier pairs. For example, "peptic ulcer" is a descriptor and "chemically induced" is a qualifier and "peptic ulcer/chemically induced" describes articles on peptic ulcer that are chemically induced (e.g., by a drug like indomethacin). Liu et al. identified several patterns of pairs of MeSH qualifiers to infer environmental factor → disease associations. For example, the association indomethacin → peptic ulcer is induced from the following two annotations of an article: **peptic ulcer** / *chemically induced* and **indomethacin** / *adverse effect* (MeSH descriptors are in bold and MeSH qualifiers are in italics).

Genetic Factors. We obtained genetic factors of human diseases from the Genetic Association Database (GAD) which contains gene-disease associations that have been curated from the literature [1]. The GAD uses standardized identifiers for genes (NCBI Entrez Gene identifiers) and diseases (Medical Subject Headings (MeSH) identifiers) that enable easy machine processing.

Similarity Measure. A similarity measure indicates the strength of commonality between a pair of entities (e.g., an environmental factor and a genetic factor) based on their properties (e.g., associated diseases). We used the Jaccard similarity measure to calculate the similarity between an environmental factor *E* and a genetic factor *G*, as follows:

$$Jaccard(E,G) = \frac{S11}{S11 + S10 + S01}$$

where *S*11 is the number of diseases associated with both *G* and *E*, *S*10 is the number of diseases associated with *E* but not *G*, and *S*01 is the number of diseases associated with *G* but not *E*. The Jaccard similarity measure varies between 0 and 1 where 1 denotes that *E* and *G* are associated with exactly the same set of diseases, and 0 denotes that *E* and *G* have no common associated diseases. We computed the Jaccard similarity measure only for those genetic and environmental factors that were each associated with at least three diseases.

Environmental Factor – Gene Pairs. We examined environmental factor – gene pairs with a Jaccard similarity measure of 0.4 or greater for plausible interactions between members of the pair. We chose a threshold of 0.4 rather arbitrarily so that we had a manageable number of high scoring environmental factor – gene pairs to examine. We used the research literature and Ingenuity (Ingenuity Systems©, www.ingenuity.com) to identify interactions. Ingenuity is a systems biology database that contains manually annotated relationships between biological agents such as chemicals, drugs, genes, and proteins. In Ingenuity, we searched for evidence that the environmental factor in a pair directly influences the gene. We also searched for biological molecules (genes, metabolites, etc.) that are related to both the environmental factor and the gene in a pair.

RESULTS

We extracted 51,994 disease-environmental associations between 1,911 diseases and 5,801 environmental agents from the CHE Toxicant and Disease Database and MEDLINE. We extracted 8,872 disease-gene associations between 889 diseases and 1,891 genes from the GAD. The CHE Toxicant and Disease Database and MEDLINE annotations were downloaded in May 2009. After etiological factors with less than three associated diseases were excluded the number of environmental factors decreased to 2,459 and the number of genes decreased to 1,469. This resulted in more than three and a half million environmental factor – gene pairs for which we computed the Jaccard similarity measure.

We identified a total of 63 environmental factor – gene pairs with a similarity of measure of 0.4 or greater. Table 1 gives a list of the 63 pairs and the common associated diseases. The maximum number of common diseases for a pair was three.

We found evidence for an interaction for 10 of the 63 environmental factor – gene pairs. We now summarize some of this evidence. For th**e** sodium salicylate – KCNQ4 gene pair, Wu et al. [6] showed that salicytate blocks the action of the KCNQ4 gene resulting in hearing loss. For the antithrombins – F3 pair, antithrombin inhibits the complex consisting of coagulation factors III and VII that are produced by genes F3 and F7 [7].

Several of the environmental factor – gene pairs had an influence on the same biological molecule. For instance, in the pair piperonyl butoxide – SMYD3, both piperonyl butoxide, and SMYD3 have an influence on the c-Myc oncogene which has been implicated in the genesis of diverse human tumors. Piperonyl butoxide has been found to increase the activation of the c-Myc oncogene [8], and

Environmental factor / Gene	Common associated diseases
Aminopyridines / HLA-DQB1	Asthma / Occupational Diseases
Androstenes / F13B	Thromboembolism / Venous Thrombosis
Antithrombins / F3	Hemorrhage / Coronary Thrombosis
Carbon Compounds, Inorganic / LAPTM4B	Lung Neoplasms / Stomach Neoplasms
Carmine / HLA-DQB1	Asthma / Occupational Diseases
Cellulase / CYSLTR2	Asthma / Rhinitis
Cellulase / HLA-DQB1	Asthma / Occupational Diseases
Cellulase / IL4R1	Asthma / Rhinitis
Cereals / BIRC5	Cell Transformation, Neoplastic / Uterine Cervical Neoplasms
Cereals / KIR3DL2	Cervical Intraepithelial Neoplasia / Uterine Cervical Neoplasms
Cereals / KIR3DL3	Cervical Intraepithelial Neoplasia / Uterine Cervical Neoplasms
Egg Proteins / HLA-DQB1	Asthma / Occupational Diseases
Escin / HLA-DQB1	Asthma / Occupational Diseases
Fertility Agents / NBS1	Melanoma / Breast Neoplasms / Ovarian Neoplasms / Skin Neoplasms
Food, Formulated / DIO1	Atrophy / Alzheimer Disease
Glycyrrhizic Acid / CYP11B1	Hypertension / Hyperaldosteronism
Meclizine / LEF1	Cleft Lip / Cleft Palate
Meclizine / BHMT2	Cleft Lip / Cleft Palate
Meclizine / C6orf105	Cleft Lip / Cleft Palate
Meclizine / COL4A4	Cleft Lip / Cleft Palate
Meclizine / DLX3	Cleft Lip / Cleft Palate
Meclizine / GLI2	Cleft Lip / Cleft Palate
Meclizine / HDAC4	Cleft Lip / Cleft Palate
Meclizine / MLPH	Cleft Lip / Cleft Palate
Meclizine / SCN3B	Cleft Lip / Cleft Palate
Meclizine / SHH	Cleft Lip / Cleft Palate
Meclizine / SP100	Cleft Lip / Cleft Palate
Methenamine / HLA-DQB1	Asthma / Occupational Diseases
Methyl n-Butyl Ketone / ATP8B1	Cholestasis / Cholestasis, Intrahepatic
Methylenebis (chloroaniline) / ZNF350	Urinary Bladder Neoplasms / Carcinoma, Transitional Cell
Neurotransmitter Uptake Inhibitors / INPP1	Stress Disorders, Post-Traumatic / Bipolar Disorder
Ninhydrin / CYSLTR2	Asthma / Rhinitis
Nitrilotriacetic Acid / RGS6	Lung Neoplasms / Urinary Bladder Neoplasms
Noise / KCNQ4	Hearing Loss / Hearing Loss, Noise-Induced

Table 1. List of environmental factor – gene pairs with similarity score of 0.4 or higher. The pairs that had evidence of plausible biological interactions in the literature are shown in bold font.

the interference of human Smyd3 microRNA has been found to decrease the binding of the promoter between the Tert and the c-Myc genes [9].

Of note, the anti-histamine Meclizine and the HLA-DQB1 gene were present in eleven and eight of the top 63 pairs respectively. This indicates that Meclizine shares a relatively large number of diseases in common with several other genes. Similarly, HLA-DQB1 shares a relatively large number of diseases in common with several other environmental factors. This may be because the pathways which are perturbed by Meclizine and HLA-DQB1 are similar to the ones perturbed by the other environmental factors and genes. Unfortunately, the annotation coverage of pathways perturbed by genes and environmental factors from databases like the Kyoto Encyclopedia of Genes and Genomes (KEGG) [10] is incomplete and we were unable to identify any pathways associated with these factors.

CONCLUSIONS

We presented a method to identify environmental factor – gene pairs that may have plausible biological interaction

Environmental factor / Gene	Common associated diseases
O-Phthalaldehyde / HLA-DQB1	Asthma / Occupational Diseases
Oxalates / CLCN5	Nephrocalcinosis / Kidney Calculi / Kidney Diseases
Papain / IL4R1	Conjunctivitis; Asthma / Rhinitis
Parabens / CYP24A1	Breast Neoplasms / Asthma
Parabens / KDR	Breast Neoplasms / Asthma
Pectins / HLA-DQB1	Asthma / Occupational Diseases
Pentylenetetrazole / KCNMB3	Epilepsies, Myoclonic / Epilepsy, Generalized / Epilepsy, Absence
Pesticide Synergists / CXCL14	Carcinoma, Hepatocellular / Liver Neoplasms
Pesticide Synergists / PTK2	Carcinoma, Hepatocellular / Liver Neoplasms
Pesticide Synergists / SMYD3	Carcinoma, Hepatocellular / Liver Neoplasms
Pesticide Synergists / UGT1A4	Carcinoma, Hepatocellular / Liver Neoplasms
Pesticide Synergists / UGT1A8	Carcinoma, Hepatocellular / Liver Neoplasms
Phenylurea Compounds / HSD11B2	Diabetic Nephropathies / Diabetes Mellitus, Type 1
Phenylurea Compounds / TCF2	Diabetic Nephropathies / Diabetic Neuropathies / Diabetes Mellitus, Type 1
Piperonyl Butoxide / CXCL14	Carcinoma, Hepatocellular / Liver Neoplasms
Piperonyl Butoxide / SMYD3	Carcinoma, Hepatocellular / Liver Neoplasms
Pipobroman / CSF3R	Leukemia / Myelodysplastic Syndromes / Anemia, Aplastic
Pipobroman / CSF3R	Leukemia / Myelodysplastic Syndromes / Anemia, Aplastic
Platelet-Derived Growth Factor / CCNH	Mouth Neoplasms / Precancerous Conditions
Potassium Channel Blockers / KCNJ2	Long QT Syndrome / Arrhythmias, Cardiac
Potassium Channel Blockers / CAV3	Long QT Syndrome / Arrhythmias, Cardiac
Potassium Channel Blockers / KCNE2	Long QT Syndrome / Arrhythmias, Cardiac / Torsades de Pointes
Prostaglandin-Endoperoxide Synthases / IRAK3	Pouchitis / Crohn Disease / Colitis, Ulcerative
Psoralens / APAF1	Melanoma / Skin Neoplasms
Sodium Azide / PRND	Nervous System Diseases / Alzheimer Disease
Sodium Salicylate / KCNQ4	Deafness / Hearing Loss
Tartrazine / HRH2	Angioedema / Asthma / Urticaria
Thionucleotides / RP2	Retinitis Pigmentosa / Retinal Diseases
Tuberculin / HRH1	Angioedema / Urticaria

Table 1 contd. List of environmental factor – gene pairs with similarity score of 0.4 or higher. The pairs that had evidence of plausible biological interactions in the literature are shown in bold font.

from knowledge about environmental factors and genetic factors of disease extracted from freely accessible online databases and the research literature. Among the top scoring environmental factor – gene pairs on the similarity measure, we found evidence for plausible biological interactions in the literature for 10 of the pairs we examined. The pairs for which we found no existing relationships or interactions may represent novel environmental – gene interactions.

There are several limitations to our study. We used a single similarity measure, namely the Jaccard similarity measure. We also used an arbitrary similarity measure threshold of 0.4 to select pairs to examine. In future work, we plan to use other similarity measures and also to analyze comprehensively all pairs for known interactions.

ACKNOWLEDGEMENTS

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Optimal Combination of Glycan-Based Serum Diagnostic Markers Which Maximize AUC

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ABSTRACT

Recently a new high-throughput biomarker discovery platform based on printed glycan arrays (PGA) has emerged. PGAs are similar to DNA arrays but contain deposits of various carbohydrate structures (glycans) instead of spotted DNAs. PGA-based biomarker discovery for the early detection, diagnosis and prognosis of human malignancies is based on the response of the immune system as measured by the level of binding of anti-glycan antibodies from human serum to the glycans on the array. Since the PGA offer a multitude of markers which can have moderate individual diagnostic power they can be combined in order to achieve maximal classification precision evaluated by the popular performance measure area under the ROC curve (AUC). This paper presents an empirical analysis of several combination approaches including those that are specifically designed to maximize the AUC and those that are not, such as Fisher Linear Discriminant, Support Vector Machines and Generalized Linear Model. The analysis is performed on real-life PGA data from three pilot studies involving malignant mesothelioma, lung cancer and ovarian cancer.

Keywords: Printed glycan arrays, biomarkers, AUC, optimal combination of biomarkers, mesothelioma

1. INTRODUCTION

In the last five years a new biomarker-discovery platform has emerged based on glycan arrays [4], that has some advantages over nucleic acid-based and other platforms. The printed glycan arrays (PGA) are similar to DNA microarrays, but contain deposits of various carbohydrate structures (glycans) instead of spotted DNAs. Most of these glycans can be found on the surfaces of normal human cells, human cancer cells, and on the surfaces of many human infectious agents such as bacteria, viruses, and other pathogenic microorganisms. Transformation of cells from healthy to pre-malignant and malignant is associated with the appearance of abnormal glycosylation on proteins and lipids presented on the surface of these cells. The malignancy-related abnormal glycans are called tumor-associated carbohydrate antigens (TACA), [10]. There is growing evidence [1] that numerous TACAs are immunogenic, and that the human immune system can generate antibodies against them. Since multiple glycans arrayed on PGAs are either known TACAs or closely related structures, the antibodies present in human sera that bind to glycans on PGA can indicate the status of response of the immune system to human malignancies [14,15,16]. A prototype of PGA with a library of 200 glycan structures was built at Scripps Research Institute, La Jolla, California, under the auspices of the Consortium of Functional Glycomics (CFG), [3]. Further development and standardization of the PGA with 211 glycans was conducted at Cellexicon, Inc., La Jolla, in collaboration with Nicolai Bovin of Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry, of the Russian Academy of Sciences, Moscow, Russia. The "second generation" of PGA was used in several pilot studies on early detection of cancer and cancer risk supported by the National Cancer Institute. Research and improvement of PGA technology and its relevance in diagnostic and prognostic applications is currently continuing in the Tumor Glycome Research Group at the Thoracic Surgical Laboratory at the New York University, School of Medicine, in collaboration with the Shemyakin-Ovchinnikov Institute.

The advantages of potential PGA-based serum test for early detection of cancer and cancer risk can be summarized as follows: (a) minimal invasiveness of serum sampling; (b) minimal sampling variability, in contrast to well known heterogeneity of solid tissue samples; (c) stability of antibodies, (d) low cost associated with technology; (e) low labor intensity and short duration of the test; (f) broad scope of the test, i.e. the test doesn't have to be narrowly targeted to a particular disease, e.g. cancer type. All these advantages make the PGA platform attractive for early detection of disease and for the potential application in screening of general population.

This study is motivated by the need for combination of several biomarkers due to relatively moderate discriminatory power of individual glycans caused by still limited glycan library of the early generation of PGA arrays, and due to relatively small sample sizes. During the extensive experimentation in pilot studies we have recognized the importunacy of the area under the ROC curve (AUC) as a consistent and robust performance measure of the discriminatory power of classifiers. Therefore we have explored some recently proposed combination approaches that maximize the AUC value, as well as the relevance of popular classifiers such as Fisher Linear Discriminant (FLD), Support Vector Machine (SVM) and Generalized Linear Model (GLM) in the context of maximization of AUC. In addition to these approaches we have also added Ant Colony Optimization (ACO) [6], which is recently gaining popularity in biomarker discovery [22, 25]. Our version of ACO uses AUC as fitness function.

It is important to mention, that the goal of this paper is not to propose PGA-based putative signatures, but rather to evaluate various combination methods in the light of AUC and PGA-based predictors.

2. PRINTED GLYCAN ARRAYS

A printed glycan array (PGA) consists of a glass slide coated with a chemically reactive surface on which various glycans are covalently attached using standard amino-coupling chemistry and contact printing technology [3]. A PGA slide contains several sub-arrays of the entire, currently available glycan library in form of microscopic glycan deposits of size about 80 microns. The version of the PGA used to generate data presented in this paper has two concentrations of glycans (10 and 50 μM) and eight replicates for each concentration, thus resulting in an array of 16 sub-arrays, each containing 211 deposits of unique glycan structures, and biotin spots used as a printing control.

The measurement of binding of human anti-glycan antibodies (AGA) to arrayed glycans is achieved as described in [17]. The PGA slide is first incubated with the subject's serum, allowing the binding of serum antibodies to glycans in PGA deposits. Serum IgG, IgM and IgA immunoglobulins bound to printed glycans are visualized simultaneously with the "combo" biotinylated secondary goat anti human IgG, IgM and IgA antibodies (Pierce Biotechnology, Inc., Rockford, IL) and streptavidin-Alexa^{555} (Invitrogen/Molecular Probes, Carlsbad, CA). Fluorescence signal intensities that correspond to antibodies bound to printed glycans are scanned at 90% laser power, and quantified with ImaGene software (BioDiscovery, Inc., El Segundo, CA). The total relative fluorescence signal intensity values (appx. range: 1,000 – 32,000,000 Relative Fluorescence Units) are used for further data preprocessing and analyses. The preprocessing included signal screening for noise, normalization and normality transformation.

The population size of the initial studies involving the early generation of PGAs with 211 glycans on the array and which are used in this study is shown in **Table** 1. The choice of these studies is made for their diversity in terms of resubstitution AUC and imbalance of control and case samples.

Table 1: Serum samples used in pilot PGA-based studies

Study	*Source*	*Control sample* (n_1)	*Case sample* (n_2)
Mesothelioma	NYUSM	Asbestos exposed (65)	Malignant mesothelioma (50)
Lung cancer	NYUSM	Smokers (49)	Adenocarcinoma (46)
Ovarian cancer	MDACC	Healthy donors (106)	Early aggressive o.c., stage I/II (21)

NYUSM – Department of Cardiothoracic Surgery, School of Medicine, NYU (Dr. Harvey I. Pass)
MDACC – MD Anderson Cancer Center, Univ. of Texas (Dr. Karen H. Lu)

3. OPTIMAL LINEAR COMBINATION WHICH MAXIMIZES AUC

In this section we briefly discuss advantages of using AUC as the performance measure in evaluation of combined multiple marker tests, and formulate the optimization problem.

Suppose a predictor matrix $\boldsymbol{X} = [x_{ij}]$, $i = 1,2,\ldots,n$, $j = 1,2,\ldots,d$ where x_{ij} is the marker value for i-th patient and j-th marker. In our case x_{ij} represents a continuous measurement of the intensity of binding of human antibodies of patient i against glycan structure j deposited on the PGA array. These values are usually normalized and transformed before the diagnostic analysis. The matrix $\boldsymbol{X}$ is associated with a column vector $\boldsymbol{y} = [y_i]$ where y_i are labels for control ($y_i = 1$) and case sample ($y_i = 2$). In many practical situations the individual markers do not provide sufficient discriminatory power, and they have to be combined. Simple approach to this is linear combination $\boldsymbol{z} = \boldsymbol{Xw}$, where $\boldsymbol{z}$ is column vector of combined markers and $\boldsymbol{w}$ is column vector of combination coefficients, usually in normalized form, i.e. $\|\boldsymbol{w}\| = 1$. The diagnostic test of an unknown patient, whose marker values are $\boldsymbol{u} = [u_1, u_2, \ldots, u_d]^T$ can be achieved by testing the sign of $\boldsymbol{u}^T\boldsymbol{w} + w_o$, where w_o is a decision point determined, as well as $\boldsymbol{w}$, from the training set $(\boldsymbol{X}, \boldsymbol{y})$. There are several popular approaches to determine the vector $\boldsymbol{w}$, for example Fisher Linear Discriminant (FLD), Generalized Linear Model (GLM), Support Vector Machines (SVM), which are based on essentially similar optimization criteria, such as Mahalanobis distance between sample means, likelihood of odds to belonging to one of the samples, and margin between samples, respectively. The performance of the classifier $(\boldsymbol{w}, w_o)$ is often measured by the accuracy computed for a test set:

$$Acc = f_1(\boldsymbol{Tw}, \boldsymbol{y}_t, w_o) = \frac{TN + TP}{n_1 + n_2}, \tag{1}$$

where $\boldsymbol{T}$ is matrix of markers of the test set (can be replaced with $\boldsymbol{X}$ for resubstitution accuracy), $\boldsymbol{y_t}$ are labels for the test set, n_1 and n_2 are the numbers of control and case observations in $\boldsymbol{T}$, while TN (true negatives) and TP (true positives) are numbers of correctly classified control and case observations, using the discriminant function $\boldsymbol{t}^T\boldsymbol{w} + w_o$, where $\boldsymbol{t}$ is a column of $\boldsymbol{T}$.

Although this performance measure is somewhat straightforward and natural, it indeed has several drawbacks: (a) the measure depends on the decision point w_o, (b) the measure is largely affected by the sample imbalance, and (c) the measure has low resolution, specially in case of smaller samples, which notoriously occurs in cross-validation tests. These reasons are discussed in [7] and [18].

An alternative measure that doesn't have these drawbacks is the Area Under the ROC curve (AUC). The ROC curve (Receiver Operating Characteristic curve) is introduced [24] as a graphical tool to evaluate discriminatory accuracy of binary classifiers for various decision points. A single number measure for a family of classifiers which entirely eliminates w_o, the area under the ROC, was proposed by [12,5], and is used since as a standard in biomedicine and bioinformatics. The best possible value of AUC (complete discrimination) yields AUC = 1, while AUC = 0.5 means that the classifier has no discriminative power). In addition to the advantages mentioned above, the AUC also captures the ranking ability of the classifier, which is an important notion even more fundamental than classification [8].

As proposed by [11], the AUC value can be obtained for a given training, or test set, ($\boldsymbol{X}$, $\boldsymbol{y}$) and a given combination vector $\boldsymbol{w}$, without previously deriving the ROC curve:

$$AUC = f_2(\boldsymbol{Tw}, \mathbf{y}_t) = \frac{S_2 - n_2(n_2+1)/2}{n_1 n_2} \quad , \qquad (2)$$

where S_2 is sum of ranks of rows of $\boldsymbol{Tw}$ taken for case observations [11].

The optimal combination vector can be now estimated from the training set:

$$\hat{\boldsymbol{w}} = \arg\max_{\boldsymbol{w}} f_2(\boldsymbol{Xw}, \boldsymbol{y}) \qquad (3)$$

Since (2) has no closed form, the optimization must be performed by some global optimization approach, such as Genetic Algorithm. Another approach would be to develop a closed form of (2) under some simplifying assumptions about the distributions of control and case samples. This was shown in [23], under the assumption that the two samples are normally distributed with arbitrary covariance matrices. After using the maximum likelihood estimators for the covariance matrices and means, the estimate of the optimal combination vector can be expressed in terms of sample covariances and means:

$$\hat{\boldsymbol{w}} = (\mathrm{cov}(\boldsymbol{X}_1) + \mathrm{cov}(\boldsymbol{X}_2))^{-1}(mean(\boldsymbol{X}_2) - mean(\boldsymbol{X}_1))^T \quad (4)$$

where $\boldsymbol{X}_1$ and $\boldsymbol{X}_2$ are predictor matrices for control and case samples respectively. We will refer to this method of optimization as Optimal Combination under Normality assumption (OCN).

Computation of optimal combination $\boldsymbol{w}$ which maximizes AUC under less restrictive assumption than normality is investigated by [21,19,20,13]. The approach is based on Generalized Linear Model assumption. The AUC can be generally expressed [2]:

$$AUC(\boldsymbol{w}) = \Pr(\boldsymbol{x}_j^T \boldsymbol{w} > \boldsymbol{x}_i^T \boldsymbol{w}), \;\; i \in I_1, j \in I_2 \qquad (5)$$

where $\boldsymbol{x}_k$ is column vector of markers for patient k from the training, or test samples, I_1 and I_2 are sets of row indices of matrix $\boldsymbol{X}$ which correspond to control and case samples respectively. Equation (5) can be extended to:

$$AUC(\boldsymbol{w}) = \frac{1}{n_1 n_2} \sum_{i \in I_1} \sum_{j \in I_2} I(\boldsymbol{x}_j^T \boldsymbol{w} - \boldsymbol{x}_i^T \boldsymbol{w} > 0) \qquad (6)$$

where I is indicator function. The function (6) is clearly discrete and can not be used by some convenient numerical optimization method. Ma and Huang [19,20] have therefore suggested replacing the discrete indicator function with some smooth, monotonically increasing function, such as sigmoid function $s(z) = 1/(1+\exp(-z/\sigma))$. The optimization of $AUC(\boldsymbol{w})$ can then be formulated as:

$$\hat{\boldsymbol{w}} = \arg\max_{\boldsymbol{w}} \sum_{i \in I_1} \sum_{j \in I_2} s(\boldsymbol{x}_j^T \boldsymbol{w} - \boldsymbol{x}_i^T \boldsymbol{w}) \qquad (7)$$

We have used the Newton-Raphson method which converges very rapidly for a proper choice of parameter σ, which was kept constant throughout the optimization process. This algorithm will be referred to as Optimal Combination under GLM assumption (OCG). The implementation of the algorithm is given in Appendix. As shown in the following section, the execution speed of this algorithm is close to FLD algorithm.

4. EMPIRICAL EVALUATION OF APPROACHES

The comparison of various approaches for finding the optimal combination vector $\boldsymbol{w}$ will be done with the reference to the "best possible approach" obtained with a global optimization. For this purpose we have used genetic algorithm (GA) introduced by [9]. We start with the mesothelioma dataset, for which the library of glycans on PGA appeared to be most complete. For feature selection we have used the univariate non-parametric Wilcoxon-Mann-Whitney rank sum test. The multivariate approach for feature selection is avoided in this study due to relatively small sample sizes and the risk of over-fitting. The five most discriminatory glycans are indicated in **Table** 2. The table also shows the individual AUC values obtained by equation (2). Clearly, the individual AUC values are relatively low which justifies the need for combination of multiple markers.

Table2: Glycan structures for top five glycans determined by Wilcoxon-Mann-Whitney rank sum test, for Mesothelioma study

Glycan Structure	*AUC*
Neu5Acα2-3Galβ1-4Glcβ-sp	0.7274
(Neu5Acα2-8)3-sp	0.6923
GlcNAcβ1-6GalNAcα-sp	0.6889
GlcNAcβ1-4(GlcNAcβ1-6) GalNAcα-sp	0.6868
Galβ1-3GlcNAcβ1-3Galβ1-4Glcβ-sp	0.6548

The observed (training) AUC values for combination of markers for various approaches, AUC_O, are shown in **Table** 3. As seen, the best performance besides the global optimization is obtained for OCG and GLM. These approaches are also very efficient in terms of execution time (ET). Although the differences are relatively small, it is desirable to establish their statistical significance. For this purpose we have used paired bootstrap with replacement with 1000 replications. The box plots of the corresponding empirical resampled distributions of differences are shown in **Figure** 1, and the empirical medians are summarized in **Table** 3 (for the variations of medians are used median absolute deviations, MAD). The figure indicates that the differences are statistically significant. This was also verified with paired ANOVA test for all six groups, and with non-parametric Wilcoxon signed-rank test performed for all combinations of pairs of approaches. In both cases all p values were close to zero.

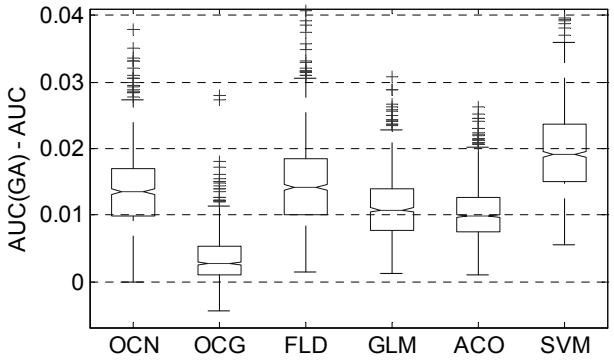


Figure 1: Empirical distributions of paired differences between AUC obtained with GA and other approaches generated by bootstrap with replacement using 1000 replications in Mesothelioma study.

Figure 1 and **Table** 3 are concerned with the resubstitution AUC values. In order to evaluate the generalization power of the approaches considered above we applied the unbiased repeated 10-fold cross-validation with 100 repetitions. The results are shown in **Figure** 2. The cross-validation test was applied for various set sizes which range from a single glycan to combination of seven glycans. The cross-validated AUC value for all approaches has reached the maximum at 5 to 6 glycans. The curves begin to drop after the glycan sets become larger than seven (not shown here) which is result of over-fitting. The cross-validation results are summarized in **Table** 3. It is interesting to notice that SVM has demonstrated the best performance, which is slightly above GLM (for $d = 5$) .

The box-plots for empirical distributions of paired differences between GA and other approaches for resubstitution AUC for the other two studies listed in **Table** 1 are shown in **Figures** 3 and 4. The figures again indicate small differences, which are still statistically significant judging by ANOVA and Wilcoxon signed-rank tests. The ranking in resubstitution performance is basically similar as for the Mesothelioma study.

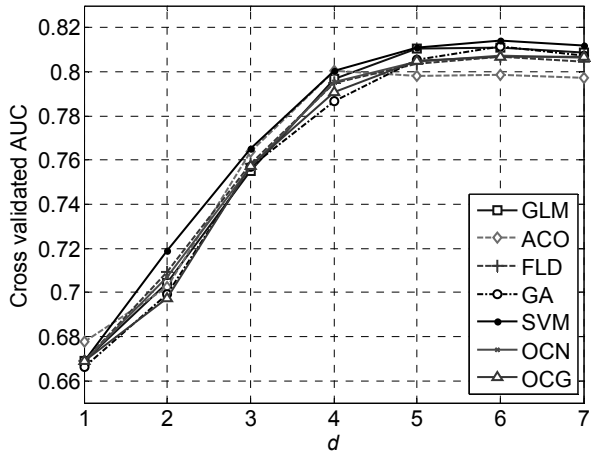


Figure 2: Cross-validated AUC values for various number of markers and various approaches in Mesothelioma study

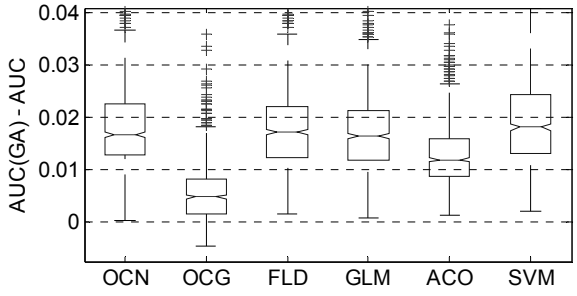


Figure 3: Empirical distributions of paired differences between AUC for lung cancer

Table 3: Observed, bootstrapped and cross-validated AUC for Mesothelioma study ($n_1 = 65$, $n_2 = 50$, $d = 5$)

Method	*AUCo*	*Median AUC*	AUC_{CV}	*ET (sec)*
OCN	0.8582	0.8729 ± 0.019	0.8046	0.036
OCG	0.8649	0.8837 ± 0.018	0.8051	0.114
FLD	0.8566	0.8717 ± 0.019	0.8039	0.105
GLM	0.8637	0.8754 ± 0.019	0.8106	0.123
ACO	0.8559	0.8769 ± 0.019	0.7980	2.744
SVM	0.8578	0.8677 ± 0.018	0.8112	0.324
GA	0.8665	0.8877 ± 0.018	0.8054	3.261

OCN – optimal combination under normality assumption (equation (4))
OCG – optimal combination under GLM assumption (equation (7))
FLD – Fisher Linear Discriminant
GLM – Generalized Linear Model (without interaction terms)
ACO – ant colony optimization
SVM – Support Vector Machine
GA – Genetic Algorithm (global optimization)

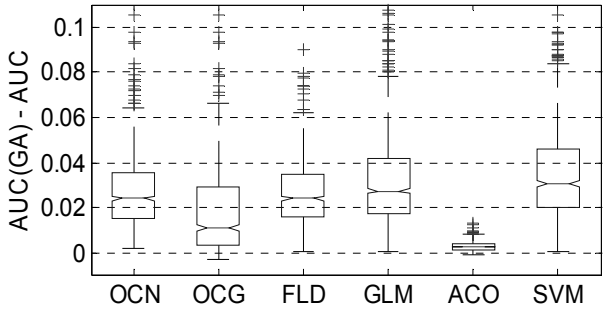


Figure 4: Empirical distributions of paired differences between AUC for ovarian cancer

5. CONCLUSION

The goal of this study was to empirically evaluate several approaches for combination of multiple test markers based on printed glycan array data obtained from three pilot studies, and to conclude whether any of these methods is particularly superior in light of the maximization of AUC value. Three of these methods (GA, OCN and OCG) are specifically designed to optimize AUC, while the others (FLD, ACO, GLM and SVM) are not designed for this purpose but are very popular in diagnostic classifiers. The paired bootstrap tests have shown that there is a small difference in performance of resubstituted AUC value, in favor of GA and OCG, but the difference is not substantial enough to disfavor approaches as GLM and SVM. Moreover, the cross-validated AUC performance evaluated on mesothelioma study has shown that the SVM and GLM provide slightly better predictive precision and predictive AUC value than the approaches specifically designed to optimize AUC. The relevance of these findings will be reexamined in the near future with the next generation of PGA arrays with 300 and 400 glycans, and on larger serum populations.

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APPENDIX

The OCG algorithms based on equation (7) is implemented in MATLAB which supports vectorized functions and rapid array index manipulation. In order to make the pseudo-code below more concise we will define some basic overloaded functions and index manipulation operators, using simple examples.

Suppose vectors $\boldsymbol{a} = [a_1, a_2, a_3]$ and $\boldsymbol{b} = [b_1, b_2, b_3]$,

then: $\exp(\boldsymbol{a}) = [\exp(a_1), \exp(a_2), \exp(a_3)]$,

$\boldsymbol{a} + \alpha = [a_1 + \alpha, a_1 + \alpha, a_1 + \alpha]$,

$\boldsymbol{a} \bullet\!* \boldsymbol{b} = [a_1 b_1, a_2 b_2, a_3 a_3]$,

$\boldsymbol{a} \bullet\!/ \boldsymbol{b} = [a_1 / b_1, a_2 / b_2, a_3 / b_3]$,

$sum(\boldsymbol{a}) = a_1 + a_2 + a_3$, $rep(\boldsymbol{a}, 4) = [\boldsymbol{a} \mid \boldsymbol{a} \mid \boldsymbol{a} \mid \boldsymbol{a}]$

$rep(\boldsymbol{a}^T, 4) = [\boldsymbol{a}^T \mid \boldsymbol{a}^T \mid \boldsymbol{a}^T \mid \boldsymbol{a}^T]$

$row(\boldsymbol{A}) = [row_1(\boldsymbol{A}) \mid row_2(\boldsymbol{A}) ... \mid row_3(\boldsymbol{A})]$,

$\boldsymbol{a}([2,2,1,3]) = [a_2, a_2, a_1, a_3]$.

Also $A(i, *)$ and $A(*, j)$ denote *i*-th row and *j*-th column of matrix $\boldsymbol{A}$ respectively**.** Finally, we need notion of constant vectors $\boldsymbol{e}(n) = [1,1,...,1]$ (*n* repeated 1's), and $\boldsymbol{c}(n) = [1, 2, ..., n]$. Using these definitions the gradient $\boldsymbol{g}$ and Hessian matrix $\boldsymbol{H}$ of $AUC(\boldsymbol{w})$, as well as the optimization process are implemented as follows:

$\boldsymbol{k}_1 = row(rep(\boldsymbol{c}(n_1), n_2))$;

$\boldsymbol{k}_2 = rep(\boldsymbol{c}(n_2)^T, n_1)$;

{$\boldsymbol{k}_1$ and $\boldsymbol{k}_2$ are $(n_1 n_2)$-element constant index vectors which are generated before the optimization}

$\boldsymbol{z}_1 = \boldsymbol{X}_1 \boldsymbol{w}$; $\boldsymbol{z}_2 = \boldsymbol{X}_2 \boldsymbol{w}$;

{$\boldsymbol{X}_1$ and $\boldsymbol{X}_2$ are sub matrices of $\boldsymbol{X}$ which correspond to control and case samples}

$\boldsymbol{z} = \boldsymbol{z}_2(\boldsymbol{k}_2) - \boldsymbol{z}_1(\boldsymbol{k}_1)$;

$\boldsymbol{p} = \boldsymbol{e}(n_1 n_2) \bullet\!/ (1 + \exp(\boldsymbol{z}))$;

{The vector of sigmoid values}

$J = sum(\boldsymbol{p})$;

{The objective function $n_1 n_2 AUC(\boldsymbol{w})$}

$\boldsymbol{Z} = \boldsymbol{X}_2(\boldsymbol{k}_2, *) - \boldsymbol{X}_1(\boldsymbol{k}_1, *)$;

$\boldsymbol{q} = \boldsymbol{p} \bullet\!* (1 - \boldsymbol{p}) / \sigma$; {First derivative of $\boldsymbol{p}$}

$\boldsymbol{Q} = rep(\boldsymbol{q}, d)$;

$\boldsymbol{g} = sum(\boldsymbol{Q} \bullet\!* \boldsymbol{Z})$; {The gradient}

$\boldsymbol{r} = \boldsymbol{q} \bullet\!* (1 - 2\boldsymbol{p}) / \sigma$; {The second derivative of $\boldsymbol{p}$}

$H_{ij} = sum(\boldsymbol{r} \bullet\!* \boldsymbol{Z}(*, i) \bullet\!* \boldsymbol{Z}(*, j))$;

{Elements of the Hessian matrix}

$\boldsymbol{w}_{k+1} = \boldsymbol{w}_k - \boldsymbol{H}(\boldsymbol{w}_k)^{-1} \boldsymbol{g}(\boldsymbol{w}_k)$;

{Iterative process, the initial value $\boldsymbol{w}_1$ is determined by OCN , eq. (4)}

$| J(\boldsymbol{w}_{k+1}) - J(\boldsymbol{w}_{k+1}) | \le \varepsilon$ {The stopping criteria}

The equations above could have been implemented in standard vector notation, which would however result in a couple of hundred times slower execution.

Detrended Fluctuation Analysis of Heartbeats While Engaging in Ergometer Exercise: Checking the Heart Condition by Numerical Quantification Method

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ABSTRACT

Detrended fluctuation analysis (DFA), which was originally developed by Peng et al. (1995) was used to check power-law characteristics in the study of the heartbeats of various living organisms including humans. The objective of this research was to determine whether DFA could function as a useful method for the evaluation of the subject's quality of cardiovascular-related illness and transition to and from a normal healthy state. Here, we report on subjects who underwent ergometer exercise. The perceived level of wellness varies among the subjects because there are no two individuals that are identical physiologically. Present case studies have shown how wellness of subjects can be evaluated using heartbeat recordings. We conclude that DFA is a new, useful numerical method for quantifying the degree of wellness and the transition from sickness to wellness and vice versa.

Keywords: Detrended fluctuation analysis, Heartbeat, Exercise, Scaling exponent, Numerical quantification

1. INTRODUCTION

Cardiovascular disease is one of major social health problems. Heart attack, in particular, is a major social concern because of the unpredictable and silent way it develops. We must acknowledge that while the default setting is good health, there is always an onset of a process to a disease that never returns to good health. This onset results in "silent" angina, and most probably a "silent" attack may finally happen. In fact, Dutch researchers estimated that 43 % of heart attacks went unrecognized [1]. Our ultimate aim was to quantitatively analyze the heart condition, based on the belief that it is possible to predict a heart attack by observing fluctuations in heartbeat intervals. The fluctuation analysis has already appeared in a publication long time ago [2]. One that remains is to collect strong empirical evidence.

Traditionally, cardiac studies employ heart rate variability (HRV) to detect the onset of cardiac problems, including disorders of the autonomic nervous system. Problems arise, however, when patients are usually assumed to be healthy before the appearance of symptoms associated with HRV. An earlier marker is therefore necessary, because early identification of symptoms aids in the prevention of the onset of chronic diseases. The detrended fluctuation analysis (DFA) [2] was proposed as a potentially useful method determining a sign of cardiovascular disease (see ref. [3]) although DFA has not yet developed for practical medical tool such as the electrocardiogram (EKG). (We prefer the word "EKG," instead of "ECG," with due respect to the inventor, Dutch physiologist, Nobel laureate, Willem Einthoven.)

We recently tested practical usefulness of DFA with using the heart of crustacean-animal models. In the test, we

succeeded to show that DFA can distinguish the beating hearts, between intact and isolated hearts [4]. In that study, we found out that the scaling exponent of the isolated hearts shifted and approached to 0.5 without exception. In turn, the scaling exponent of the intact hearts showed a value about 1.0 without exception. As the results, we realized that DFA was reliable and useful, because DFA probably accurately reflects physiology. Unlike HRV, the excelling point for DFA is that it has a baseline value of one (1), like a standard body temperature (37 ^{o}C), a standard blood pH (7.4), and so on. So DFA was simple as a tool, we thought.

One (1) is nonlinearly determined "healthy" outcome resulted from complex interactions between structure and function of molecules, cells and organs.

Thereby we have a hope that DFA can "numerically" determine the state of health. DFA seemed to be reflecting the state of not only the heart itself but also its physiological interaction with the nervous system. We considered that DFA might be a tool to detect the onset of cardiac problems, including disorders of the autonomic nervous system.

In this article, we show case studies of heartbeat analysis of subjects who performed exercise on ergometer stationary bicycle to provide empirical evidence for the practical usefulness of DFA and a new EKG amplification device that facilitates automatic DFA computation in practical use. The fluctuation analysis (i.e., DFA) was a potential helpful tool in medicine for the early identification or physiological disorders, as it reveals information that is not provided by an EKG.

2. MATERIALS AND METHODS

Peak detection of the heartbeat

Interval analysis requires detection of the precise timing of the heartbeat. A consecutive and perfect detection without missing any count is desirable. According to our preliminary test, about 2000 consecutive heartbeats were required for obtaining a reliable scaling exponent computation. We hypothesized that longer recording of the heartbeats would results in a better diagnosis. However, we found that long recording was not useful and recording of about 2000 consecutive heartbeats is preferable.

To detect the timing of the heartbeats, both EKG recording and blood flow pulse recording are useful. Whatever the recording methods were, the obstacle was the drifting of the baseline in the commercial recording system. Due to the drift and the contamination of electric power-line noise, we were totally incapable of detecting 2000 consecutive beats.

Another obstacle was due to the premature ventricular contraction (PVC). Among the "normal" subjects (age over 40 years old), about 60 % of subjects have PVC arrhythmic heartbeats. Normally, this PVC is believed to be benign arrhythmia, and in fact during our recording, we found many healthy-looking individuals who exhibited this arrhythmia. However, this PVC was obstacle to a perfect detection of the timing of the heartbeat, because the height of signal is sometimes very small. If the baseline of EKG recording were extremely stable, the heartbeats would automatically be detectable even when irregular beats appeared sporadically. Unfortunately, in commercial EKG recording devices, baseline of the record is not stable.

EKG recording with stable baseline

To capture peaks without missing any detection, we made an EKG amplifier that stabilizes baseline of the recording. Important issue was: we discovered that time-constant for input-stage of recording must be adjusted to <0.22 s.

This advantage of having stable baseline recording facilitated our DFA research. However, in some cases, inevitable noises could contaminatee the recording. In such case, we removed the noises by identifying them visually on PC screen thus making a perfect (without miscounting) heartbeat interval time series. We have already identified how this inconvenience came about. About one-half of these cases were due to the sweat on the skin under the electrodes. We were able to overcome this problem by cleaning the skin with an appropriate solution.

DFA: Background

DFA is based on the concepts of "scaling" and "self-similarity" [5]. It can identify "critical" phenomena because systems near critical points exhibit self-similar fluctuations [2, 5, 6], which means that recorded signals and their magnified/contracted copies are statistically similar. Self-similarity is defined as follows: In general, statistical quantities, such as "average" and "variance," of a fluctuating signal can be calculated by taking the average of the signal through a certain section; however, the average is not necessarily a simple average. In this study, we took an squared average of the data. The statistical quantity calculation depended on the section size. The signal was self-similar when the statistical quantity was λ^{α} times for a section size magnified by λ. Here, α is the "scaling exponent" and characterizes self-similarity.

Stanley and colleagues considered that scaling property can be detected in biological systems because most of these systems are strongly nonlinear and resemble the systems in nature that exhibit critical phenomena. They applied DFA to DNA arrangement and EKG data in the late 80s and early 90s and discovered the usefulness of the scaling property [2, 6], and emphasized the potential utility of DFA in the life sciences [6]. Although DFA technology has not progressed to a great extent, nonlinear technology is now

widely accepted, and rapid advances are being made in this technology.

DFA: Technique

We made our own computation program based on the previous publication [2] which is described in one of the references [7].

EKG and finger pulse

For human subjects, we used both finger pulse recordings and EKG recordings. For pulse recordings we used a piezo-crystal mechanic-electric sensor connected to a Power Lab System (AD Instruments, Australia). For EKG, 3 AgAgCl electrodes (+, -, and ground, Nihonkoden Co. Ltd. disposable Model Vitrode V) were used. Wires from EKG electrodes were connected to our newly made amplifier. These EKG signals are then connected to a Power Lab System.

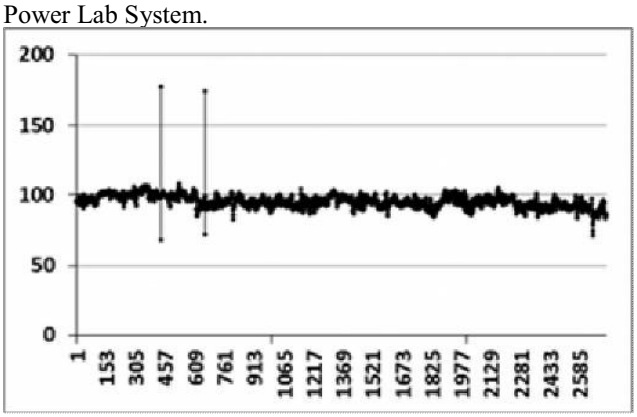


Figure 1. Heartbeat recording from subject one at rest. Heart rate (y axis) and beat number (x axis). Figure shows 2719 beats in total during 28 min, which were 100 % accurately peak-detected, as shown in next Figure 2.

Volunteers and ethics

Subjects were selected from colleagues in our university, volunteers who were voluntarily visited us desiring their heart to be checked. All subjects were treated as per the ethical control regulations of our university, Tokyo Metropolitan University, Tokyo Women's Medical University and Universitas Advent Indonesia.

3. RESULTS AND DISCUSSION

Case study 1

He is a 49-year old healthy looking Indonesian. EKG recordings was performed for 28 min at Indonesian National Olympic training center in Bandung, his resting state was recorded while the subject was sitting on ergometer, relaxing and answering to several questions made by researchers.

Two pre-matured ventricular contractions (so called PVC) can be seen (Figure 1).

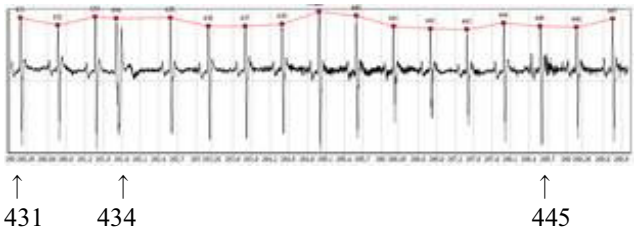


Figure 2. Example recording of heartbeats and accurate peak detections. The heartbeat number 434 is PVC. A time period 260~270 sec from start of recording is shown. The figure shows that our amplifier made steady-baseline EKG even though subject was actively engaging in exercise with ergometer.

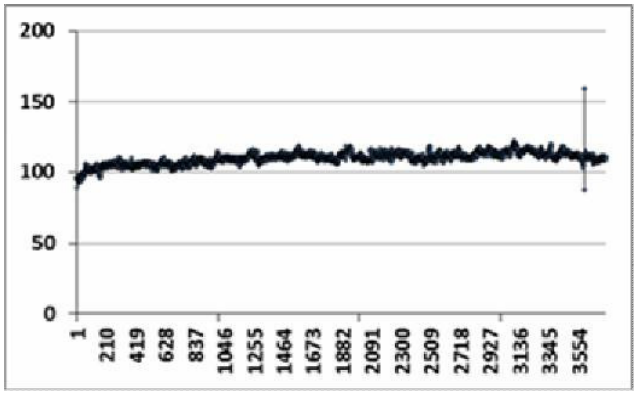


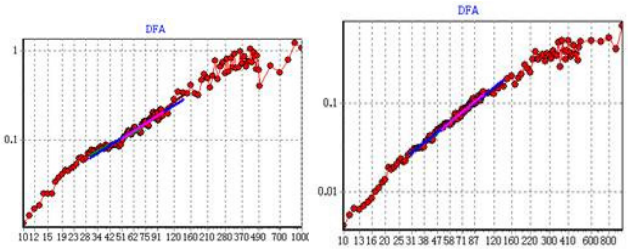
Figure 3. The same subject shown in Fig. 1 and 2. Heart rate (y axis) and beat number (x axis). Continuous recording from Fig. 1. He started ergometer exercise, at the heartbeat number 1 (one) with a 50 watt load strength and a 96 rpm speed, lasting for 32 min. 1 to 3746 beats shown.

These PVCs (see Figures 1 to 3) are a benign type of heartbeat as classified by guidelines used by medical doctors, is observable among 60 % of healthy persons over the age of 40.

Average heart rate was approaching 100 beat per min (BPM) at the start of the EKG recording. His heart rate was about 90 BPM at first (Figure 1). He seemed to be nervous because the measurement procedure and equipment as well as the foreign researcher doing the recording were new to him. After 28 min of resting stage measurement, he got relaxed during conversations and heart rate gradually decreased during the resting stage measurement.

At the start of the exercise stage his heart rate quickly increased to over 100 BPM, and kept slow increment until reaching a plateau before the end of the exercise (Figure 3). After 20 min of the exercise he mentioned to us that he was

not tired yet. One PVC appeared at near the end of exercise. He mentioned at the end of exercise that he can continue this low load (50 watt) aerobic exercise for another 30 min (at 10:50 hours, Indonesian Time).
He is a personal chauffer of a professor in the institution and he looked like having very strong heart though his heartbeat exhibited a few benign PVC during the test.



Rest Exercise

Figure 4. Left graph shows DFA computation results at rest and right graph at exercise. For the same subject shown in Figures 1, 2, and 3. Y axis, variance. X axis, the Box Size from 10 to 1000. Log scale in both axis (see original article for the basics of DFA). The slope of the graph gives the scaling exponent, which is calculated at various "windows," i.e., "Box Size," as shown in Table 1.

Table 1. Comparison between at rest and during exercise.

Rest		Exercise	
Box Size	DFA (α)	Box Size	DFA (α)
51 ~ 100	1.01	51 ~ 100	1.32
30 ~ 140	0.99	30 ~ 140	1.25

Table 2. Our preliminary guideline (Yazawa et al. 2010 [7])

α	
0.5~0.899	— Stressfulness, PVC, Alternans, Naturally dying.
0.9~1.199	— Healthy. 1/f fluctuation
1.2~1.5	— This heart is at risk of catastrophic circulation stoppage.

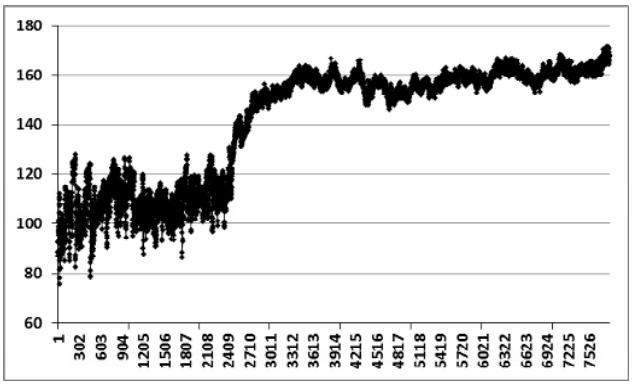
After obtaining heartbeat interval time series as indicated in Figures 1 and 3, we proceeded to next step, we calculated scaling exponents (α) by our computing method the DFA (Figure 4 and Table 1). The DFA values (α) are calculated as shown in Figure 4 and in Table 1. One can see that exercise increased α, which can be seen in overall slops (see Figure 4). It means that the scaling exponents were pushed up by exercise.
At rest, this 49 years old man exhibited healthy scaling exponents nearly 1.0, especially observable in the windows, i.e., "Box Size" both 51-100 and 30-140 (Table 1).
From our previous studies we came up with a guide line (standard) that can be used as reference in interpreting the scaling exponents to define whether an individual is healthy or unhealthy (Table 2). We were surprised by the observation that an apparently healthy person may also get risk as shown by the significance of the scaling exponent indicated by our table of guideline.
Furthermore, we also discovered that the same exercise induced an increase in the scaling exponents of the other subjects (see below).

Case studies 2 to 4

The EKGs of the other three subjects in this study were recorded at rest and while engaging in exercise in the same room at the same environment, temperature about 25 ^{o}C, together with the subject shown in Figure 1.

Case 2: Age 28, an Indonesian female swimmer. Figure 5 and 6 show that the swimmer's heart rate at resting state is rather high, about 100 BPM, with unknown reason. Increase of heart rate induced by exercise is much greater than that of the man shown in Figures 1 and 3. Her heart rate immediately returned to the pre-exercise value at the end of the exercise (see Figure 6).
It is obvious that degree of fluctuation of the heartbeat interval, i.e., variability of fluctuation of heartbeat interval, is greater at rest than during exercise. This must be due to an augmented sympathetic tone to the heart, i.e., we can interpret this as an increased discharge frequency in the acceleratory autonomic nerve fibers innervating the heart. In other words, acceleration-dominant-state is induced by exercise thus resulting in "less variable" state as shown in Figures 5 and 6, at the exercise stage.
From mathematical consideration of DFA technique, we can expect that "less variable state" exhibits a lower value (way less than 1.0) of the scaling exponents, such as the state of stressful condition of living animal, which was previously reported (references).
However, the results of the recording may not be simple as they seen. EKG trace looks like less variable, but, contrary to apparent expectation, the exponents were quite high (Table 3). We are seeing a very strange nature of heartbeat behavior as observed through DFA computation, a new biomedical application method. Mathematics is such intriguing issue and sometimes it is beyond the measure of our instinct. Application of DFA to medicine has just started and is still in a infantile stage.
The scaling exponents of the subject are very low at rest (see Table 3) as can be seen in the left graph where slope is less steep (Figure 7) and the scaling exponents ranges around 0.6 – 0.8 (Table 3) at rest. We already know that if one has perfect health condition, the slope must exhibit 45 degree, i.e., the scaling exponent is 1 (one). This means that her health condition in general and especially the

condition of her heart is not very good, although DFA cannot tell the physiological reason(s) that contribute to this condition (see our guideline Table 2).



←Rest-------→/← Exercise for 32 min----------→ for 28 min

Figure 5. Time series, 2471 beats for 28 min resting state, and 5341 beats for 32 min exercise state. Y axis, heart rate. X axis, beat number. Ergometer exercise was started at the heartbeat number 2472 with a 50 watt load strength and a 96 rpm speed, lasting for 32 min, identical strength in the case study 1.

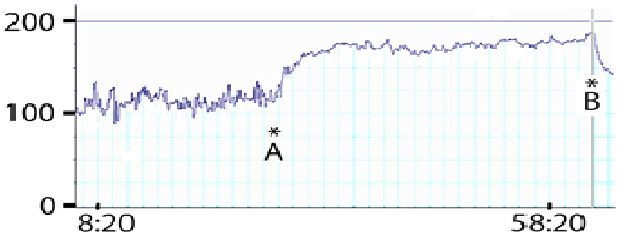
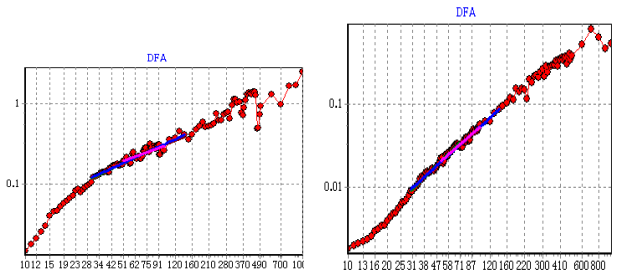


Figure 6. The same record as in Figure 5 but X axis is shown in time (min) instead of beat number. *A, exercise started. *B, exercise stopped. After stopping exercise heart rate quickly decreased. Y axis, heart rate.

When she was engaged in exercise, the slope became steeper in almost entire ranges of window size (Figure 7) and thus computed scaling exponents were significantly increased. The values are astonishingly high, ranging from 1.3 to 1.5 (see Table 3). This significant increase of the scaling exponents during exercise was also found in Case study 1. According to our guideline (Table 2), we may interpret that this high values indicate that her heart is at a risky state during exercise period which is already found in a subject who has ischemic heart such as stent placement and/or bypass implantation [8].

It is obvious that nonlinear interactions inside her body must be contributing to this state. It is obvious that we cannot make pre-decision from EKG trace: "less variable" EKG interval fluctuation does not always exhibit a low scaling exponents: next two case studies also give strong evidence that variability is low but exponent is high during exercise.



Rest Exercise

Figure 7. Left graph shows DFA computation results at rest and right graph at exercise. The same subject shown in Figures 5 and 6. Y axis, variance. X axis, the Box Size from 10 to 1000. Log scale in both axis.

Table 3. Comparison between at rest and during exercise.

Rest			Exercise		
Box Size		DFA (α)	Box Size		DFA (α)
30 ~ 70		0.8	30 ~ 70		1.53
70 ~ 140		0.65	70 ~ 140		1.5
51 ~ 100		0.62	51 ~ 100		1.36
30 ~ 140		0.8	30 ~ 140		1.42

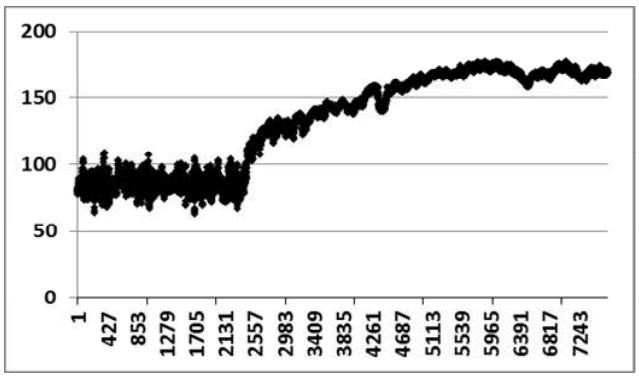


Figure 8. Time series, 2438 beats for 28 min resting state, and 5224 beats for 32 min exercise state. Y axis, heart rate. X axis, beat number. Ergometer exercise was started at the heartbeat number 2439 with a 75 watt load and a 96 rpm speed, lasting for 32 min, identical strength in the case study 1.

Case 3: Age 29, an Indonesian male basketball player. Results from this subject resemble with the subject of case study 2 (Figures 8 and Table 4), but note that here the load

was 75 watt instead of 50 watt in the case of other three subjects. It took time to reach a plateau due to higher load. He mentioned that, at the end of exercise, he was tired and he wished very much to stop exercise.
Here, one can also see that fluctuation during exercise is smaller than at rest. As is in Figure 5, however, again the scaling exponents during exercise were very high (Table 4).

Table 4. Comparison between at rest and during exercise.

	Rest			Exercise	
Box Size		DFA (α)	Box Size		DFA (α)
30 ~ 70		0.84	30 ~ 70		1.44
70 ~ 140		0.83	70 ~ 140		1.51
51 ~ 100		0.76	51 ~ 100		1.62
30 ~ 140		0.81	30 ~ 140		1.52

Case 4: Age 27, an Indonesian futsal player (Spanish Futbol de Salon). In this subject, the scaling exponents were increased by exercise as those shown by the rest of the three cases in this study. However, his heart stayed in a healthy range of the scaling exponent during exercise (see Table 5). He mentioned that, at the end of exercise, he was not tired at all with 50 watt and 96 rpm. We may conclude that he is the most appropriate sports-aspiring person among 4 subjects in this case study, because he has no risky value.

Table 5. Comparison between at rest and during exercise.

	Rest			Exercise	
Box Size		DFA (α)	Box Size		DFA (α)
30 ~ 70		0.94	30 ~ 70		1.03
70 ~ 140		0.89	70 ~ 140		1.07
51 ~ 100		0.85	51 ~ 100		1.15
30 ~ 140		0.89	30 ~ 140		1.12

4. CONCLUDING REMARKS

The results in the present study are new as far as we know. In the present observations with DFA computation we tried to find any apparent correlations between the scaling exponent and the state of heart during exercise. While data of the heartbeat time series were obtained from subjects who were healthy looking individuals, all of four subjects exclusively exhibited surprising results: exercise brings them to a risky state in terms of the scaling exponents. We would like to suggest that their state of heartbeats during exercise is the state that the heart is ready to stop any time, as demonstrated before in animal model experiments and human ischemic cardiac conditions [8]. Four subjects have obviously different genomic structure from each other. However, outcome of control system commanding the heart performance was all identical: exercise increases the scaling exponents to a normal level in one subject and to an alarming level in the rest of three subjects in this study. This is probably normal function of healthy subjects who have complex internal nonlinear physiological interactive pathways.

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In vitro and *in silico* Approaches to the Identification of New Compounds with Antibacterial Profile

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ABSTRACT

The emergence of multidrug-resistant bacterial strains is a world problem that increases the need for new and more effective antimicrobials. On that purpose, derivatives of cyclic systems may serve as new leads for discovering new active molecules. In this work we evaluated the antibacterial profile of 243 molecules derived from the systems thienopyridine, pyrazolopiridine, quinolone, chalcone, hydrazone and lapachone against Gram-positive and Gram-negative susceptible and multiresistant strains also comparing them with antibiotics of clinical use. Our results showed that among the 243 molecules tested, only eight derivatives were active with promissing MIC values (2-64μg/mL). Our theoretical *in silico* analysis showed that all active compounds fulfilled Lipinski rule of five (molecular weight = 344.37–409.24, clogP = 3.15–4.11, nHBA = 6–7, and nHBD = 2), similarly to commercial drugs as well as presented better druglikeness values (from -3.68 to 0.12) than chloramphenicol (-4.61) and linezolid (-4.08). Most of the active derivatives presented a low *in silico* toxicity risk profile, similar to oxacillin, ampicillin, and penicillin G, and even lower than that observed for chloramphenicol and linezolid. Theoretically HOMO and the electrostatic protential distribution may be contributing for this safer profile. This study used computacional tools and may help to deal with an important world health problem.

Keywords: *In silico*, molecular modeling, bacteria, antibacterial, derivative.

1. INTRODUCTION

Resistance to antibacterials has been a serious world problem since the introduction of antibiotics in the early 1940s [1-2]. This problem is getting worse year after year, due to several factors including the inappropriate use of these drugs [2-3] .

Now this challenge is even more critical, due to the growing emergence of multidrug-resistant bacterial strains and exchange of resistance between different species of bacteria (*i.e. Enterococcus faecalis, Mycobacterium tuberculosis, Neisseria gonorrhoeae, Streptococcus pneumoniae and Staphylococcus aureus)* [3-4].

Since its discovery in the 20th century, antibacterial agents have substantially reduced the threat of infectious diseases. The use of antibiotics combined with improvements in sanitation, housing, food production, and immunization programs have led to a dramatic reduction of morbidity and human mortality [3].

The antimicrobials act by interacting at specific sites of the bacteria mainly through inhibition of different processes including cell wall synthesis, protein synthesis or replication of nucleic acid [2-4]. However, the intensive and inappropriate use of antimicrobials, the natural bacterial resistance and other human inappropriate practices increased the level of bacterial resistance. This event reduces the options of treating bacterial infections and affects medical procedures such as organ transplants and application of prostheses, where the complications are of highest incidence [3 -5]

Antimicrobial resistance is the resistance against the effects of an antimicrobial through different and highly efficient mechanisms. Antibiotic resistance occurs when bacteria genetically change in some way and reduces or eliminates the effectiveness of drugs, chemicals or other agents used to cure or prevent infection. Thus, the bacteria survive and continue to multiply, causing more damage or even death [4-6] .

The emergence of antimicrobial resistant organisms is an important public health problem, especially in hospitals and other health institutions [4-6]. The continuous appearance of multiresistant nosocomial pathogens difficult to treat or cure, like multi-resistant *Klebsiella* (KPC), vancomycin resistant *Enterococci* (VRE) and *S. aureus* with intermediate susceptibility to vancomycin and other glycopeptide antibiotics (GISA) threaten hospitalized individuals and those with chronic conditions whereas it dramatically increases health costs. In addition, community-acquired infections and foodborne infections of humans caused by *S. pneumoniae, S. aureus, Salmonella and Campylobacter species, M. tuberculosis,* and *N. gonorrhoeae* clearly pointed to the continuous increase of resistance to therapies that were efficient ten years ago [3-6]

The increased prevalence of pathogens resistant to drugs comes at a time when the discovery and development of new antimicrobial agents occurs slowly [6]. Accordingly, there is a concern that in a near future it may be a growing number of potentially untreatable infections [5-6].

The emergence of multidrug-resistant strains to antibacterial agents such as carbapenemases-producing bacteria (KPCs) increased the need for searching for new molecules that can allow an improvement in the treatment of infections [7]. Towards this search, derivatives of cyclic systems can serve as new leads for the discovery

of antibacterials. Thus, in this work we performed the synthesis, biological identification and theoretical analysis of 243 molecules derived from the systems thienopyridine, pyrazolopiridine, quinolones, chalcones, hydrazones and lapachones, also comparing with antibiotics of clinical use. All these systems are described in literature by their different biological profiles but the antimicrobial activity was not fully explored [8-11].

To explore the possibility of identifying new antimicrobials, three brazilian groups of organic chemistry synthesized these systems derivatives while one group with expertise in microbiological assays, tested them in antibacterial sensitivity tests (AST) and determined the minimum inhibitory concentration (MIC). Antibiotics of clinical use were used as positive controls, and Gram-positive and Gram-negative susceptible (standards) or multiresistant strains provided by the Antonio Pedro University Hospital (HUAP) were tested for sensitivity. Further the molecular modeling group analyzed the structure-activity relationship of these active systems using *in silico* molecular modeling tools .

2. MATERIAL AND METHODS

Antibacterial susceptibility test (AST)

The assays were performed according to the National Committee for Clinical Laboratory Standards (NCCLS), in Müeller–Hinton medium as described elsewhere. Briefly, the 14 strains were grown at 37 _C in Müeller–Hinton medium, and 1 lL of the stock solution (5 mg/mL) of each derivative in dimethyl sulfoxide (DMSO) was placed in Whatman disks (5 mm diameter). The disks were put on exponentially growing plated cultures with appropriate dilution to 1.0x 10^7 colony forming unit (CFU/mL), which were then incubated for 24 h at 37 ^{o}C. The inocula used in growth method were those where turbidity was equal to 0.5 McFarland Standard.

The results were verified by measuring the inhibitory zones surrounding the disk. Ciprofloxacin and vancomycin ere used as positive controls, and the halo >15 mm was considered the minimum value for positive antibacterial activity as it generally leads to a minimal inhibitory concentration (MIC) near that observed for the newest antibiotics which are currently present in the market (MIC = 1– 40 μg/mL) using these assays. Vancomycin and ciprofloxacin presented halos 15–17 and 23–25 mm, respectively, in the strains tested herein ($p < 0.005$).

Minimal inhibitory concentration assays (MIC)

MIC was determined only for active compounds on the AST by using the macro-dilution broth method. All MIC were performed in triplicate as described previously.24 Briefly, after 5 h of the bacterial growth, the culture was diluted to obtain 1.0 x 10^5 colony forming unit (CFU/mL). Then each compound was added to reach a final concentration from 0.5 to 1024 lg/mL, and was incubated at 37^{o}C for 24 h. MIC was defined as the lowest compound concentration preventing visible bacterial growth. All strains were tested at least in duplicate in four separate experiments, and a reference antibiotic (vancomycin) was used as a positive control (MIC = 2 μg / mL).

Molecular modeling and SAR studies

The molecular modeling study was performed using SPARTAN' 08 (Wavefunction Inc. Irvine, CA, 2006) and Osiris programs (http://www.organic-chemistry.org/prog/peo/druglikeness.html) as described elsewhere.9 The conformation analysis was obtained through AM1 and angles of rotation in the range of 30/30. Single Point Calculation in DFT/B3LYP was performed with database 6.31G*. Molecular electrostatic potential maps (MEPs), HOMO, and LUMO eigenvalues and orbital coefficients, and the molecular dipole moments were calculated.

In this work, we also studied the drug-likeness and the drugscore of the compounds, which is based on topological descriptors, fingerprints of molecular druglikeness, structural keys or other properties as clogP and molecular weights. In the case of Osiris Property Explorer (http://www.organic- chemistry.org/), the occurrence frequency of each fragment is determined within the collection of traded drugs and within the supposedly non-drug-like collection of Fluka compounds. Since the compounds are considered for oral delivery, they were also submitted to the analysis of Lipinski Rule of Five, which evaluate some properties of a compound that would make it a likely orally active drug in humans. These structural parameters were performed using Molispiration program (http://www.molinspiration.com/cgi-bin/properties).

3. RESULTS AND DISCUSSION

Our results showed that from the 243 molecules tested, only a few number was active including: a) five derivatives (1a-1c, 1e and 1f) of the system pyrazolopiridine active against *Staphylococcus epidermidis* , b) one hydrazone derivative, active against *S. aureus* and c) two derivatives from lapachone (NORβ and RC-23) active against *Pseudomonas aeruginosa*. The MIC comparison of the active derivatives (2 - 64μg/mL) with antibacterial agents of clinical use (cyprofloxacin, vancomycin, Cefoperazone, Nitrofuratonine, amikacin and Mezlocilins) showed that these derivatives are promising prototypes to be explored in designing new more potent and safe molecules for the treatment of infections caused by multiresistant strains (Table 1).

In this work, the theoretical analysis included the submission of the active compounds to the analysis of Lipinski Rule of Five that indicates if a chemical compound could be an orally active drug in humans. Our results showed that all active compounds (1a, 1b, 1c, 1e, and 1f) fulfilled this rule (molecular weight = 344.37–409.24, clogP = 3.15–4.11, nHBA = 6–7, and nHBD = 2), similarly to commercial drugs (*i.e.* chloramphenicol, oxacill. in, ampicillin, penicillin G, and linezolid) (not shown).

Table 1: Comparison of the antimicrobial profile (Minimum Inhibitory concentration - MIC) of the systems considering the number of the active compounds, suscetible strains and control antibacterials current on the market .

System	Number of Derivatives		Suscetible strains		MIC (µg/mL)	
	Tested	Active	Name	Characteristics	Active derivatives	Control Antibacterials
Pyrazolo pyridine	41	5	*S.epidermidis* 201	β-lactamase-producers, resistant to Penicillin-G, Oxacillin, Gentamicin and Erytromicin	1a,1b,1c ,1e = 16 µg/mL 1f = 64 µg/mL	Vancomycin= 2 µg/mL Amikacin= 16 µg/mL Cefoperazone=16 µg/mL Nitrofurantoine = 32µg/mL
			S.epidermidis 8126		1a,1b,1c ,1e = 16 µg/mL 1f = 64 µg/mL	Vancomycin = 2 µg/mL Amikacyn= 16 µg/mL Cefoperazone=16 µg/mL Nitrofurantoine = 32µg/mL
Lapachone	6	2	*P. aeruginosa 36408*	β-lactamase-producers, resistant to Imipenem, Meropenem and Carbapenens	RC-22 = 2 µg/mL Norbeta = 4 µg/mL	Mezlocylin = 64µg/mL Cefoperazone = 16 µg/mL
Hydrazone	60	1	*S.aureus* ATCC	resistant to Penicillin G	F13 = 64 µg/mL	Vancomycin= 2 µg/mL Amikacin =16 µg/mL Nitrofurantoine =16 µg/mL Cefoperazone =32 µg/mL
			S.aureus 8148	β-lactamase-producers, resistant and Penicillin-G and Gatifloxacin	F13 = 64 µg/mL	Vancomycin= 2 µg/mL Amikacin =16 µg/mL Nitrofurantoine =16 µg/mL Cefoperazone =32 µg/mL
Quinolone	42	0	-	-	-	-
Chalcone	68	0	-	-	-	-
Thiene-pyridine	41	0	-	-	-	-

Currently there are many approaches that assess a compound drug-likeness based on topological descriptors, fingerprints of molecular drug-likeness structure keys or other properties such as clogP and molecular weight. In the Osiris program (http:// www.organic-chemistry.org/prog/peo) the occurrence frequency of each fragment is determined within the collection created by shreddering 3300 traded drugs as well as 15,000 commercially available chemicals (Fluka) yielding a complete list of all available fragments. In this case, positive values point out that the molecule contains predominantly the better fragments, which are frequently present in commercial drugs but not in the non-drug-like collection of Fluka compounds.

In this work, we used the Osiris program for calculating the fragment based drug-likeness of the active compounds also comparing them with penicillin G, chloramphenicol, oxacillin, ampicillin, and linezolid. Interestingly, the pyrazolo derivatives (1a, 1b, 1c, 1e, and 1f) presented better drug-likeness values (from -3.68 to 0.12) than chloramphenicol (-4.61) and linezolid (-4.08) (Figure 1).

In this study we also verified the drugscore, which combines drug-likeness, clogP, logS, molecular weight, and toxicity risks in one value and this may be used to judge the compound's overall potential to qualify for a drug (Figure 1). Our theoretical data showed that 1a–f derivatives presented values once again higher than chloramphenicol and linezolid.

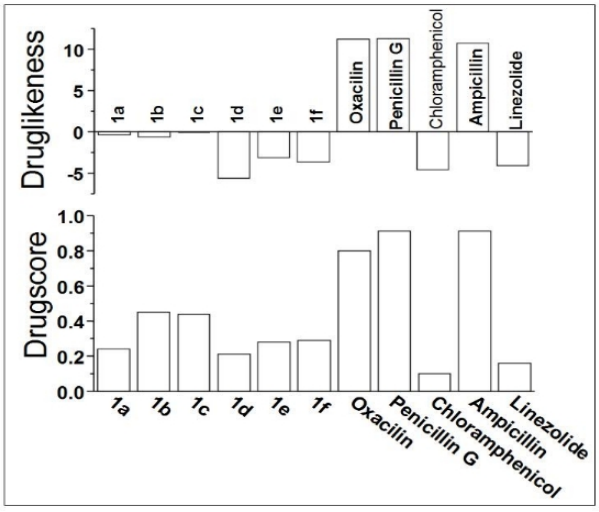


Figure 1: ADMET evaluation of the pyrazolo[3,4-b]pyridine active derivatives with the comparison of the Drugscore and Druglikeness of **1a, 1b, 1c, 1e,** and **1f** and clinic antimicrobials using molecular modeling tools.

Drug toxicity is a factor of great importance for a potential commercial drug, since a significant number of drugs are disapproved in clinical trials based on their high toxicity profile. Herein, we used the Osiris program to predict the overall toxicity of the most active derivatives as it may point to the presence of some fragments generally responsible for the irritant, mutagenic, tumorigenic, or reproductive effects in these molecules.

Interestingly, most of the active derivatives presented a low in silico toxicity risk profile, similar to oxacillin, ampicillin, and penicillin G, and even lower than that observed for chloramphenicol and linezolid. These theoretical data reinforced the cytotoxicity experimental data described in this work pointing these compounds as lead compounds with low cytotoxicity (not shown). The HOMO and electrostatic protential distribution may be contributing for this safer profile (Figure 2).

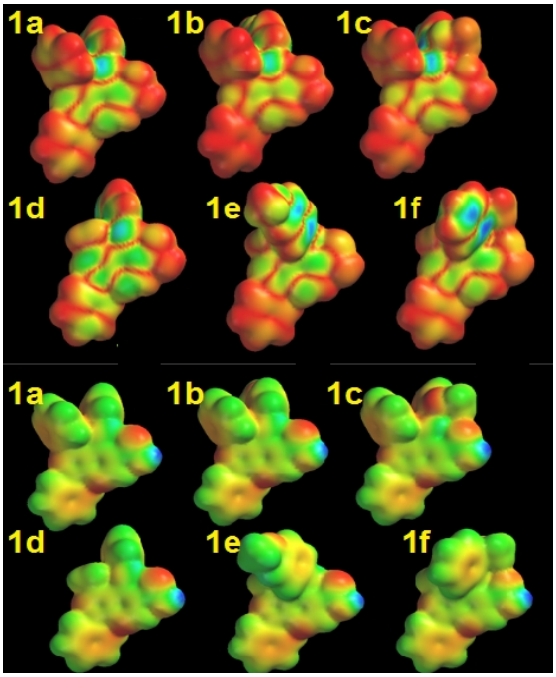


Figure 2: Comparison electronic and structural features of the active series of pyrazolo[3,4-b]pyridine derivatives. HOMO (up) and eletrostatic potential map (down) of the derivatives using molecular modeling tools.

4. CONCLUSION

In this work we evaluated the *in vitro* antimicrobial and *in silico* toxicological profiles of new series of thienopyridine, pyrazolopiridine, quinolones, chalcones, hydrazones and lapachones, Among the 243 products evaluated, the antimicrobial analysis against 14 strains Gram-positive and Gram-negative revealed 8 new active derivatives against different strains. The derivatives had a significant potential profile (MIC = 2-64µg/mL). The pharmacokinetic and toxicological *in silico* analysis of the 8 derivatives suggest a direct relationship between activity and HOMO and electronic distribution. The analysis reinforces the promising potential of these molecules, due to their similary with the antimicrobial agents currently in use in the market with reasonable druglikness drugscore, toxicity and fulfilling the theoretical Lipinski Rule of five.

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Quantifying Stability Using Frequency Domain Data from Wireless Inertial Measurement Units

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ABSTRACT

The quantification of gait stability can provide valuable information when evaluating subjects for age related and neuromuscular disease changes. Using tri-axial inertial measurement units (IMU) for acceleration and rotational data provide a non-linear profile for this type of movement. As subjects traverse various surfaces representing decreasing stability, the different phasing of gait data make comparisons difficult. By converting from time to frequency domain data, the phase effects can be ignored, allowing for significant correlations. In this study, 12 subjects provided gait information over various surfaces while wearing an IMU. Instabilities were determined by comparing frequency domain data over less stable surfaces to frequency domain data of neural network (NN) models representing the normal gait for any given participant. Time dependent data from 2 axes of acceleration and 2 axes of rotation were converted using a discrete Fourier transform (FFT) algorithm. The data over less stable surfaces were compared to the normal gait NN model by averaging the Pearson product moment correlation (r) values. This provided a method to quantify the decreased stability. Data showed progressively decreasing correlation coefficient values as subjects encountered progressively less stable surface environments. This methodology has allowed for the quantification of instability in gait situations for application in real-time fall prevention situations.

Keywords: Biomechanics, Biomedical Informatics, Inertial Measurement Units, Stability, Neural Networks.

1. INTRODUCTION

Using wireless inertial measurement units (IMUs) and neural network predictive software to monitor stability in aged adults or those with neuromuscular compromise presents a novel approach to fall risk reduction. These devices provide acceleration, rotation, and magnetic field parameters for characterization unlike current wearable acceleration only monitors. This paper is designed to examine the feasibility of using a NN model of an individual's normal gait for comparison to real-time frequency domain gait data over less stable surfaces to attempt quantification of instabilities. Measuring human body segments for static and dynamic balance and postural sway using three axis accelerometers in a clinical setting in the young and elderly has been shown to be reliable [1]. The quantification of motions of everyday living using accelerometers can provide useful classification data and include sitting, standing, walking, stair climbing and cycling [2]. Combining accelerometer and gyroscope data has been demonstrated by measuring knee movement during gait utilizing body mounted sensors [3]. Magnetometers have been used with gyroscopes and accelerometers to determine the posture in real time of human body segments [4]. As individuals age, there is a general degradation in balance control,

either from changes in sensory perception or muscle effectiveness [5]-[6].

Research has also shown the efficacy of combining IMU data and back-propagation Neural Networks (NN) for predicting movements [7]-[9]. The complex scenario of trying to predict movements of any given individual when their normal gait data is known is shown in Fig. 1. In this case, a back-propagation neural network was trained with historical tri-axial gyroscope and accelerometer gait data from a 19 year old male. IMU Data from the subject were used in a supervised training mode with the NN. Five seconds of normal gait comprised the training set. New acceleration gait data from the same subject were presented to the network for feed-forward classification.

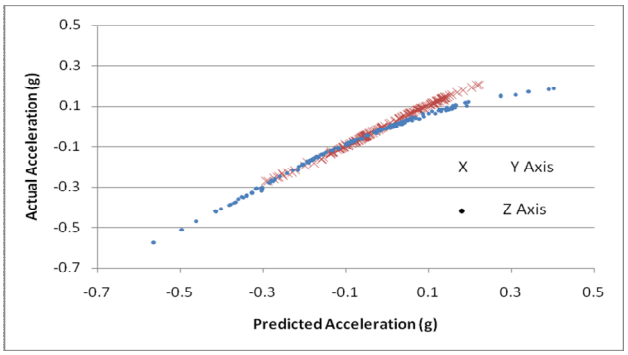


Fig. 1. Scatter plot showing actual gait data versus the NN prediction of new gait data from the same subject with Pearson product moment correlation coefficient (r) > 0.90.

There are predictable protective motions exhibited when an individual falls [10]. Research into the relationship of horizontal and vertical velocities when distinguishing normal activities from fall activities has demonstrated the potential for reducing falls [11]. This leads to the idea of establishing biomarkers that represent tracking data for when an individual is becoming unstable when involved in activities of everyday living.

Comparing "fingerprint" gait data from the same subject in good health works well when traversing similar surfaces. As stability is reduced it becomes more difficult to quantify the degree of instability since the non-linear data in time domain no longer aligns. Data involving the analysis of jaw movement has shown the efficacy of using Fast Fourier Transform for evaluating mechanical movements [12]. Abnormal gait detection utilizing Discrete Fourier Transform has been demonstrated with video motion analysis in relation to lower extremity joint angle compromise [13]. Converting to a frequency domain via Fourier analysis may eliminate the problem of correlating non time aligned data, allowing for valid correlations between a developed NN model and data derived from a subject with stability reduction. We have attempted to develop a methodology to quantify the amount of instability introduced into a gait pattern.

2. METHODS

A wireless IMU (MEMSense, L.L.C., Rapid City, SD 57702) was utilized for testing. This device has a 30 meter range (line of sight) and transmits via Bluetooth communications protocols. The IMU measures acceleration, rotation and magnetic field in 3 axes. It is a ± 5g, 600°/s, ±1.25 gauss unit with a sampling rate of 150 Hz and measures 42.8mm x 54.2mm x 11.1mm (W x L x D). The weight is 23 grams. Power is provided by a 9 volt battery.

Normal gait was performed by 12 healthy young male and female adults (20.1 ± 1.24 years). Subjects walked for 6 meters on a hard surface, sand (approximately 75mm deep), and heavy growth vegetation (approximately 225mm deep) while wearing an IMU at the level of their center of mass (COM) or their umbilical region. In addition, 6 subjects walked on a randomly stable elevated (0.5m) platform. The relative stability on different surfaces was reported. Data recorded included x-y-z acceleration (g), x-y-z rotation (°/s), magnetic field (gauss), and time (s) using the IMU. The initial and last steps were discarded to address anticipatory effects. With acceleration and magnetic field the y axis orientation aligned with lateral movements, z axis aligned with front to back movements, and the x axis aligned with up and down movements. The gyroscope recorded rotational movements about the corresponding axes shown in Fig. 2.

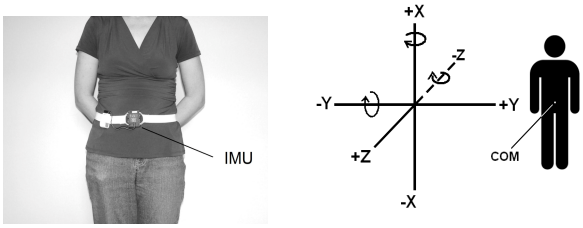


Fig. 2. Left is the orientation of IMU when worn as a belt on human subject at the COM on the right.

A back-propagation NN was used to model the 3 axis acceleration (ax, ay, az) and gyroscope (gx, gy, gz) data. A back-propagation NN was used to model the 3 axis acceleration (ax, ay, az) and gyroscope (gx, gy, gz) data. It was trained with all 6 axes of hard surface gait data. Supervised training typically required from 1000 to 2000 epochs in order to minimize the network error to < 0.005. A log-sigmoid activation function and from 0 to 12 nodes in a hidden layer were assigned. New hard surface gait values for the same subject were presented for feed-forward prediction. The goodness of fit between the actual gait data and the NN model was shown using the Pearson product moment correlation coefficient (r).

Movement data from acceleration in y and z and rotation in x and z were transformed from time domain to frequency domain utilizing Fourier analysis. The

resulting frequency magnitudes seen as the subject walked on various surfaces were correlated with the NN model output frequency components. The correlation coefficients for ay, az, gx, and gz in each case were then averaged. The frequency spectrum describes the magnitude and phase of a signal or the response of asystem. The phase information is discarded to generate a frequency spectrum by examining only the magnitude or absolute value of the complex number generated by the Fourier analysis. FFTsize = 256 samples and frequency resolution fres = f/FFTsize = 150 Hz / 256 = 0.5859 Hz. The Nyquist-Shannon sampling theorem dictated 128 points for evaluation. The sample size was further limited to data below 28 Hz.

3. RESULTS

Frequency domain acceleration and rotational data in the y / z axis and x / z axis respectively showed a consistent decrease in correlation when comparing hard surface gait data from the NN model with data from the progressively less stable surfaces as shown in Table I. As the subject walks on the less stable surfaces, r values exhibit a statistically significant decrease. All participants were able to traverse the various surfaces without falling, though compromised stability was reported on the sand/vegetation and even less on the unstable platform. This indicates that small to moderate changes in stability can be predicted in gait situations.

To support the uniqueness of the frequency-domain output, NN frequency-domain models from 4 different subjects were compared. These models represent their normal gait. Average correlation coefficients between subjects were $r \leq 0.7$ (ay), $r \leq 0.3$ (az), $r \leq 0.3$ (gx), and $r \leq 0.3$ (gz), showing weak inter-model correlations.

TABLE I
Average r from ay, az, gx, gz compared to NN model.

Surface	Avg. r	S.D.	p	Reported Stability
Hard	0.9922	0.0129	0.0001	Greatest
Sand	0.7609	0.0814	0.0026	Moderate
Vegetation	0.7141	0.0777	0.0065	Moderate
Platform(6)	0.3619	0.2082	0.2270	Least

Conversion of the x and z axis rotation data to frequency domain signals is shown in Fig. 3. When comparing the NN model with the axes rotations in gait over sand, r = 0.8769 (gx) and r = 0.8409 (gz). These strong correlations suggest little but distinguishable differences in rotation over hard and sand surfaces. Increased frequency components are seen at the lower frequencies (< 7 Hz). Higher frequency components are also shown in Fig. 3. By ignoring the phase information, the problem of peak alignment in correlating various levels of stability is minimized.

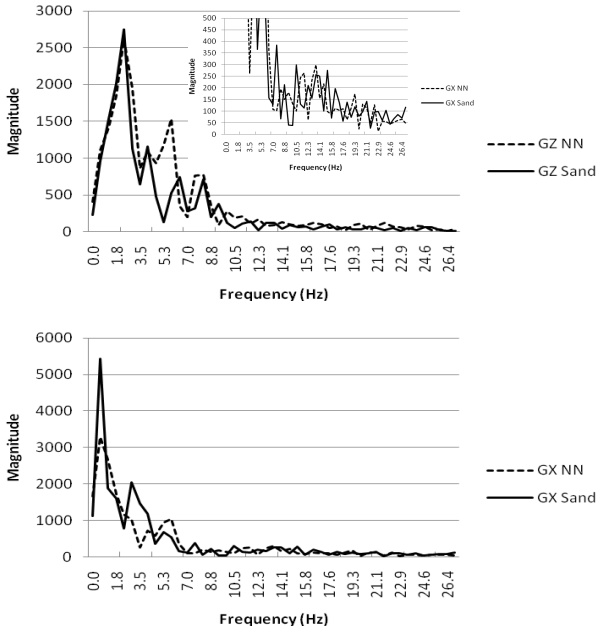


Fig. 3. Top graph shows Fourier transform data of rotation about the x axis during gait with an insert higher resolution graph, illustrating frequency components at higher frequencies. The bottom graph shows Fourier transform data of rotation about the z axis during gait.

Participants reported their perceived stability when moving over the sand, vegetation and unstable platform surfaces. 10 participants reported that the sand surface was more stable than vegetation surface. The data showed that in 8 of the 12 cases, the sand was more stable. All 6 of the unstable platform participants reported significantly less stability than either the sand or vegetation surfaces.

When the data are examined from all 12 subjects, the degraded stability can be shown when gait is on less stable surfaces. The average r values from each surface are plotted in Fig. 4.

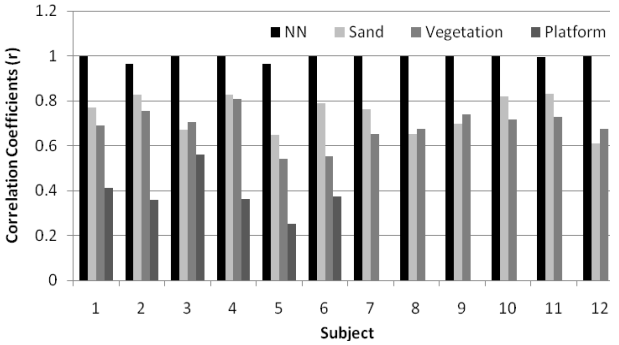


Fig. 4. For each of the 12 subjects the r value sequence is NN, sand, and vegetation (left to right). The first 6 also contain platform data (far right bar).

The frequency data shows similar correlations between sand / hard surfaces and between the vegetation / hard surfaces. The IMU acceleration and rotation values on the unstable platform are shown in Fig. 5. Notice that subject 3 showed close average r values between sand, vegetation, and the unstable platform. This individual was an athlete who exhibits superior balance control. The ay, az, gx, gz axes appear to characterize gait in such a way that meaningful quantification of stability can be attempted in gait and possibly other activities of everyday living.

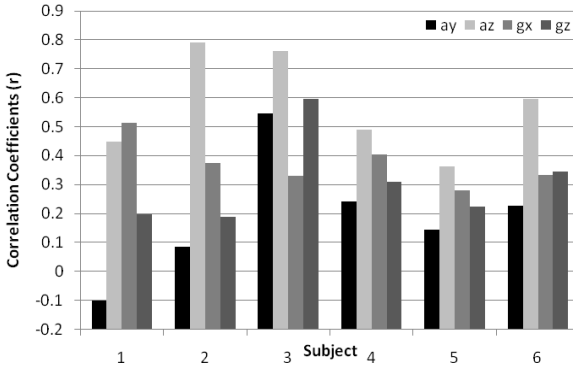


Fig. 5. For each of 6 subjects, the r value sequence over the unstable platform surface is ay, az, gx, and gz (left to right).

4. CONCLUSIONS

Using frequency domain data to compare different gait characteristics proved to be a valid method for estimating the degree of instability. Subjects reported decreased stability when walking over the sand or vegetation surfaces but not to the extent that a fall was eminent. The unstable platform was reported as the least stable surface. The corresponding correlation coefficients decreased in a predictable manner. This data indicates that wearable wireless IMU devices for real-time fall prevention in gait situations are feasible.

ACKNOWLEDGMENT

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Interdisciplinary platform for screening program management: an example of audiometric and ECG testing

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ABSTRACT

The idea of screening dates back to the late nineteenth century. However, over time the objectives, methodology and basic assumptions of screening programs have significantly changed. The basic aim is still the same: to reduce the health risk for the individual, and to develop a wider and improved understanding of the long term health of a population. Due to the complexity of conducting programs, the large amount of data necessary for processing, and the long-term nature of such programs and its follow-up, the effective conduct of modern screening programs is extremely difficult without the use of customized systems. The goal of these systems is to support the implementation of screening programs at each stage, from the choice of the population to be screened, to collecting, evaluating and analyzing test results and other data relevant to the screening program. It also allows close monitoring and quality assurance of the research program. The vast majority of the functionalities are not specific to certain medical fields, and can therefore be adapted and built to support any screening program. This study presents an interdisciplinary system that allows the migration and analysis of research results by various users of the system with different access rights. An example of a theoretical screening program for audiology and cardiology is provided to present the research benefits of using such a system.

Keywords: telemedicine, e-health, screening examination

INTRODUCTION

The definition of a screening examination has evolved over time as the awareness and experience of experts in the field of screening has increased. The National Screening Committee in London defines screening as follows:

„Screening is a public health service in which members of a defined population, who do not necessarily perceive that they are at risk of, or are already affected by, a disease or it's complications, are asked a question or offered a test to identify those individuals who are more likely to be helped than harmed by further tests or treatment to reduce the risk of disease or its complications" - Health Departments of the United Kingdom (2000) Second Report of the UK National Screening Committee. Health Departments of the United Kingdom, London.

An important element of this definition is to identify the persons for whom further action under the screening program will bring more benefits than harm. Modern screening programs must therefore be evidence-based and quality-assured. Conducting an effective screening program on a large scale is a huge organizational challenge, and it is not possible without the use of an informatics systems. Using an informatics system to store patient information and the results of the screening is not a novel concept, but the challenge is the full

computerization of the processes related to the screening program.

This study describes the system to support the conduct of screening programs. It will present each aspect of the screening program and the accompanying system functionalities.

DESCRIPTION OF SYSTEM ARCHITECTURE

The global system architecture to support the operation of the screening programs is presented in Figure 1. An essential element of the system is the central web application, which gathers the results of screening and provides management and reporting functionalities. The application communicates with mobile screening devices and performs various tests, such as audiograms, electrocardiography tests and questionnaires, all of which have been developed in accordance with the central application templates. It has the ability to communicate via data bus, with external systems, usually systems of public administration, in order to import and update data necessary to conduct screening tests. This data could include registers of persons eligible for the screening program, lists of schools in the area, and information on medical history. It also manages the system's users and user permissions. These devices automatically configure themselves to the selected screening program by downloading the necessary information, dictionaries and templates from a central system.

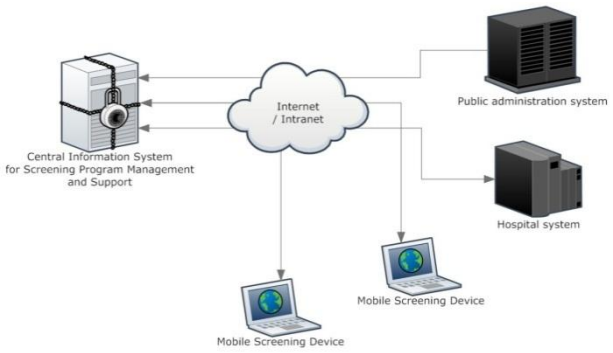


Fig. 1 Global architecture of centralized information system for screening program management and support

The central application consists of a set of modular web applications logically dividing the functionality of the central system. The core of the application is the data exchange bus serving communication with all external systems and mobile devices. It is equipped with communication monitoring to ensure the system administrator has all the information. An electronic record manages all patient data, including demographic patient data, their screening and diagnostic test results and all other related information. The operation of this data is done using a number of process applications. The most important of which are Screening Program Management and Screening Examination Evaluation Module (fig. 2).

The Screening Program Management Module is responsible for the implementation of processes related to the planning and supervision over the implementation of screening programs. As a part of the functionality, it allows users to enter and manage the resources involved in carrying out screening tests such as researchers, screening equipment and other necessary equipment. It organizes tests scheduling and the monitoring of conformity tests. It also provides basic tools for analyzing the quality of studies providing reports saying for example about average time of testing and any deviation from the median.

The Screening Examination Evaluation Module is responsible for supporting the process of qualifying patients for further action in accordance with the established screening program standards. It provides components for displaying and describing test results and uses algorithms to speed up the description. It also supports a multi-step description of the processes of research results taking into account the participation of doctors with different roles in the description of the study, as well as consultation process in the case of abnormal results. All transactional data modules of the central system are stored in a relational database. The database supplies data to a data warehouse through the ETL process. This warehouse is the basis of the analytical tools to support quality assurance and research processes, which collects data related to screening programs. The analytical tools create advanced reports and statistics based on data stored in the warehouse and build communication strategies through appropriate, automated distribution of reports.

EXAMPLE OF A SCREENING PROGRAM

In order to better illustrate a computer system's operation of procedures, a hypothetical screening program will be described. The program involves two medical units: a specialized auditory hospital and a specialist cardiac hospital. Associated with the program are a number of

disease entities in audiology and cardiology, which conduct audiogram, ECG, and survey screens. The program is expected to last three years, concentrated on one region, with its target group being junior students of high school.

The system to support screens has been implemented for the employees of both institutions involved in the screening program and scientific and research activity related to the results of screening.

The tests are offered in schools. The screening program manager sets the research agenda with the help of a computer system – researchers are assigned to schools and dates are set for testing in each school. Prior to the tests, researchers are supplied with and trained on the system of mobile screening equipment for testing, audiograms, ECG and interviewing. At the beginning of the program, researchers perform screens using mobile equipment. After defining and publishing the data, the system automatically configures the device to download all the necessary information from central system via the Internet. The results, together with information on the patient and test conditions, are sent to the central system using encrypted transmission via the Internet. Specially designed algorithms ensure compatibility of the data with established standards and requirements, and monitor compliance with schedule of activities. In the case of deviations from the projected timetable, the screening program administrator is informed via email. At this stage, a preliminary data analysis takes place to ensure the completeness of the data required for the screening program and its compliance with agreed objectives. For example, the system does not allow for the adoption of results of screening individuals whose age precludes them from being a gymnasium student. The process of screening may also include performance based testing on healthy people, in order to verify the environmental conditions at the test in relation to the standards adopted in the screening program - it is particularly important in the case of audiology tests where the background noise can affect a large number of false-positive results. The testing process is completely automated in order to minimize the role of the human factor in the quality of the results of screening.

Collected results are described using the basic processes of the screening program, and then the research results are classification according to further action. The system provides algorithms to support such classification in accordance with screening program standards and sensitivity tests. Results are reported in accordance with established program processes using the tools and algorithms provided by the central system. Finally, classified results are exported to the documents based on established templates and sent to the legal guardians of the students tested.

An important element of the system is to support quality-assurance screening programs. The necessity of quality-assurance in modern screening programs is indisputable, the most compelling justification being the popularity paradox. Sensitivity screening slightly off tune can send too many screens to further diagnosis, leading to high numbers of false positives. The effect of this is unjustified increased expenditure on diagnosis but also a heightened awareness of the false-positives and the belief that patients had escaped a disease through screening. This latter effect can lead to over diagnosis and overtreatment. On the other hand, the sensitivity could be too low, increasing the number of false-negatives and reducing the effectiveness of the screening program overall. Quality assurance support by the computer system involves the monitoring and reporting of indicators defined at the design stage of the screening program, for example, the maximum number of subjects who may be eligible for diagnostic tests after the screening phase. This monitoring is done using analysis tools working on the data collected in the data warehouse, which are fed by a transactional database that operates in the central web application. Screening data, together with the diagnostic data and other information concerning the health of screening participants with ETL processes, are transferred to the warehouse. Based on online analytical processing (OLAP cubes), reports, indicators and thresholds are created, which allows the user to monitor and take decisions and actions aimed at preserving the projected level of quality in the screening program.

The system also supports the evaluation processes of results in the screening program using RCT (Randomized Controlled Trials). For RCT based on data from systems of public administration, it supports the creation of control groups, and then based on data from screening and external hospital systems, collects and analyses the relevant outcomes.

As a result of various screening programs, a knowledge base can develop over time and provide a powerful source of information, not only for those responsible for the screening with the objectives to improve public health, but also for researchers and specialists in various

medical fields. Interdisciplinary screening programs enable the opportunity to collect huge amounts of medical data on populations, and therefore create an invaluable resource for research. The supplied analytical tools can facilitate the creation of cross-sectional analysis, by comparing a number of research programs at the same time, including all data collected on health status, diagnostic processes and the medical treatment of patients. This data can further refine screening programs and can potentially allow for the detection of unexplored correlation between the diseases.

The computer system also supports communication and information flow between all stakeholders in the screening program. The system provides an application programming interface (API) to allow the construction of publicly available portals with information related to selected research programs automatically updated with the progress of the screening program. The communication of results can be done via email, traditional mail or direct access to the computer system.

CONCLUSIONS

This paper includes examples of applications of a multi-solution system for screening examination. The system has been implemented as a pilot.
Options for conducting as many studies as possible with high quality patient data protection are currently being tested. An important feature is the connection of data from multiple screen programs to examine potential correlations. It is an opportunity to use the data for further research on diseases and their relationships in large populations.

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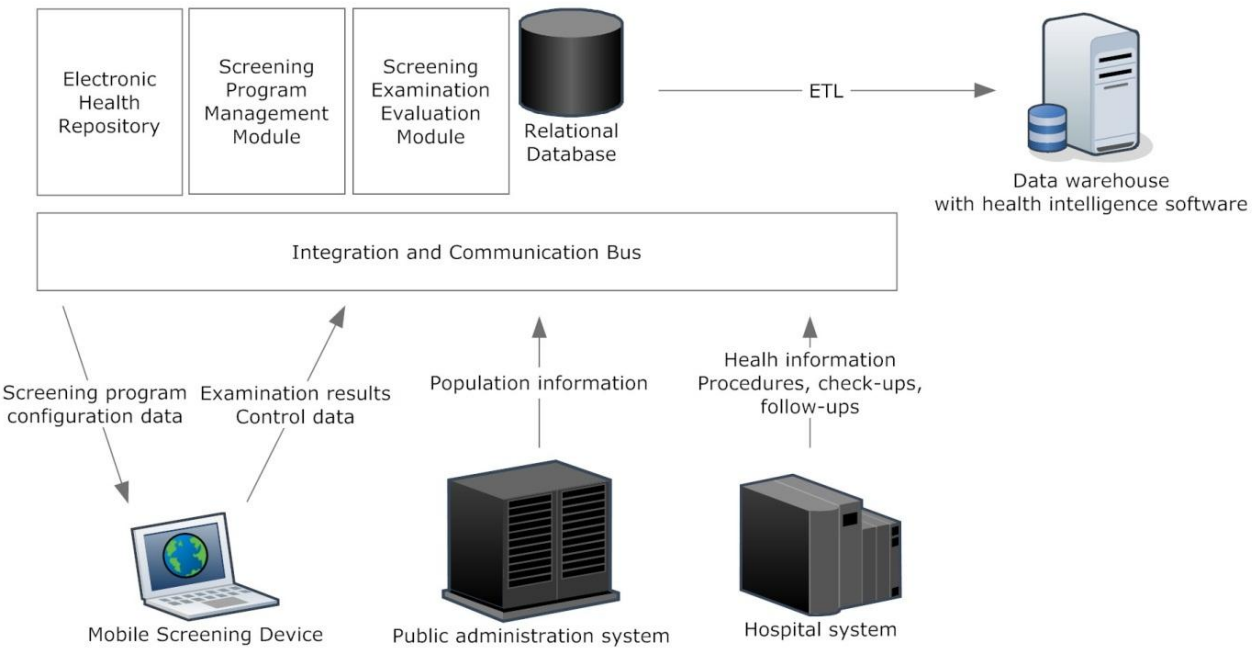


Fig. 2 Architecture and general data flow

Delivering Chronic Heart Failure Telemanagement via Multiple Interactive Platforms

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Abstract
Existing telemonitoring systems provide limited support in implementing personalized treatment plans. We developed a Home Automated Telemanagement (HAT) system for patients with congestive heart failure (CHF) to provide support in following individualized treatment plans as well as to monitor symptoms, weight changes, and quality of life, while educating the patient on their disease. The system was developed for both a laptop computer and a Nintendo Wii. The system is designed to be placed in the patient's home and to communicate all patient data to a central server implementing real-time clinical decision support. The system questions the patient daily on their condition, monitors their weight, and provides the patient with instant feedback on their condition in the form of a 3-zone CHF action plan. Their medication regimen and suggested actions are determined by their care management team and integrated into the system, keeping a personalized approach to disease management while taking advantage of the technology available. The systems are designed to be as simple as possible, making it usable by patients with no prior computer or videogame experience. A feasibility assessment in African American patients with CHF and without prior computer or videogame experience demonstrated high level of acceptance of the CHF HAT laptop and Wii systems.

Keywords: *telemedicine, congestive heart failure, self-management*

Introduction

Congestive heart failure (CHF) is a major public health problem which affects over 5 million Americans and costs $33.2 billion annually [1]. CHF morbidity is reaching epidemic proportions and African Americans are disproportionately affected [1-3]. Repeated emergency room visits and rehospitalizations for symptom relief contribute to CHF being the most costly cardiovascular illness in the US [1, 4-5]. Common reasons for CHF rehospitalization include delays in symptom recognition, medication and dietary noncompliance, and lack of knowledge and skills for competent self management [6-8].

Telemedicine approaches will be useful in patients with CHF for several reasons. First, telemedicine will improve disease monitoring through more frequent assessment of symptoms. Second, use of patient self-management plans will accelerate treatment in the setting of CHF symptoms and thus decrease the utilization of health care resources [8]. Home Automated Telemanagement (HAT) is a telemedicine system designed to assist health care practitioners treat patients according to current clinical guidelines, to assist clinicians in educating patients, to assist providers in monitoring patients, and to assist patients in following individualized self-care plans [9-14].

Gaming platforms gain significant acceptance in different population sub-groups including elderly [16, 17]. However, the feasibility of such gaming platforms as Wii for chronic disease management has not been explored systematically.

The Nintendo Wii is a popular videogame console which uses a motion sensitive controller. Adobe Flash allows content to be created and viewed on the Wii console through the Wii Internet Channel. The simplified controls, popularity, and internet connectivity make the Wii a promising platform for the development of CHF telemanagement systems.

The CHF HAT Wii home unit was created for the Adobe Flash platform to be able to be accessed using the Nintendo Wii videogame console. We attempted to take advantage of the simplicity, popularity, and low cost of the Nintendo Wii to deliver a comprehensive telemanagement system capable of being placed in a patient's home.

The CHF HAT laptop home unit was designed to run on Windows XP laptops. The low system requirements of the application and the ability to connect it to a digital scale allows for an inexpensive and simple telemanagement solution.

Our aim was to design a low cost telemanagement system on a laptop computer and the Nintendo Wii for CHF patients and to perform an initial assessment of patient acceptance of such a system.

System Design

The HAT system is based on Wagner's model of chronic disease care [15] and supports patient self-management, comprehensive patient-provider communication, and multidisciplinary care coordination. The CHF HAT system comprises a home unit (laptop or Wii), a decision support server and a web-based clinician portal. The HAT home unit consists of a notebook computer or a Nintendo Wii videogame console and an electronic weight scale. CHF patients answer questions regarding symptoms, side effects, adherence, and receive disease-specific education using the home unit. The home unit automatically transmits the results to the decision support server after each self-testing session. Data transmitted from patient's home are de-identified and encrypted. For the laptop home unit, the data transmission can be carried out via Internet or direct modem-to-modem communication. For subjects without an active phone line, a cell phone is provided to transmit self-testing results over a secure wireless network to the server in a similar manner. The Wii home unit transmits the information securely over the internet.

The web portal provides an interface for the collected patient data for both platforms. The web-based care management portal is used to set up customized clinical alerts and individualized action plans based on patient disease severity and other individual factors. The care management team individualizes alerts and action plans for each patient on-line whenever warranted. The updated action plans are automatically transmitted to patient home units. If certain clinical conditions are met, email alerts are sent to the nurse coordinator. The coordinator reviews the information and if necessary consults the medical provider and the patient for management changes.

The HAT server runs Internet Information Services (IIS) which collects the patient's data and integrates it into a website which can be accessed by the patient's primary care management team. The web page was developed using Microsoft's .NET framework. This is a framework for developing dynamic websites which offers extensive built-in functionality and is supported by most browsers.

The CHF HAT laptop home unit was developed in Visual Basic 6.0 and runs on Microsoft Windows XP. The laptop home unit uses an active phone line or internet connection to send and receive data from the server.

The CHF HAT Wii home unit application was developed using Adobe CS3 with Flash 7.0 and runs on the Wii Internet Channel. Using the Wii Internet Channel with an active internet connection allows the user to access Adobe Flash 7.0 content through the internet. The system uses the Wii Remote for input and allows a patient to run a self-test which asks the patient a series of symptom questions, records their weight, sends the information to the server, informs and tests their CHF knowledge, then gives the patient instant feedback on their current condition based upon their symptoms and weight measurement.

Results

The CHF HAT laptop home unit was successfully designed and implemented on an IBM T30 notebook computer running Windows 2000/XP connected to a Lifesource 321P digital scale through the serial port. Information was successfully sent and received from a remote location to the IIS server using an active landline and cell phone connection. The web portal was successfully launched and provides full functionality. The home unit runs the HAT program when it starts up and the user can navigate through the menu using the labeled arrow keys and the enter button. The text is

large and easy to read while all the instructions are kept as simple as possible.

The Wii HAT home unit was successfully designed and implemented on the Nintendo Wii videogame console a Lifesource CHF-321P digital scale was used for weight measurement.

The Nintendo Wii home unit allows the user to connect through the Wii Internet Channel to the site with the Adobe Flash application. The application can be navigated using the Wii Remote to select options and move between screens.

The home unit options are broken into six sections. The first section is self-testing. In this section the patient will begin with a self-testing portion where they answer a series of questions pertaining to their chronic condition. A symptom diary question screen is show in Figure 1.

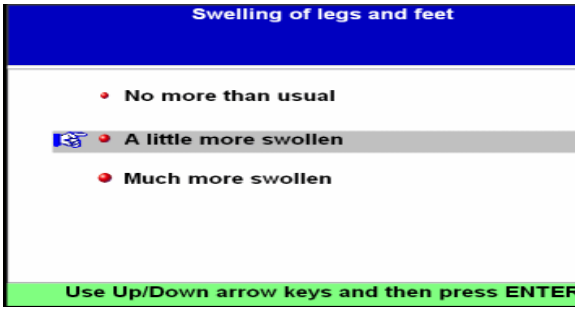


Figure 1. Symptom diary question

The responses are used to gauge the overall health of the patient, as well as to raise flags when the patient may be experiencing congestive heart failure symptoms that require immediate attention and treatment. After answering general symptom questions the patient is prompted by voice and text to correctly mount a weight scale. On the laptop home unit, the weight is automatically collected by the computer from the attached digital scale. On the Wii home unit, the patient uses a digital scale to weigh themselves, then enters the data through an on-screen interface. The scale instructions for the laptop home unit are shown in Figure 2.

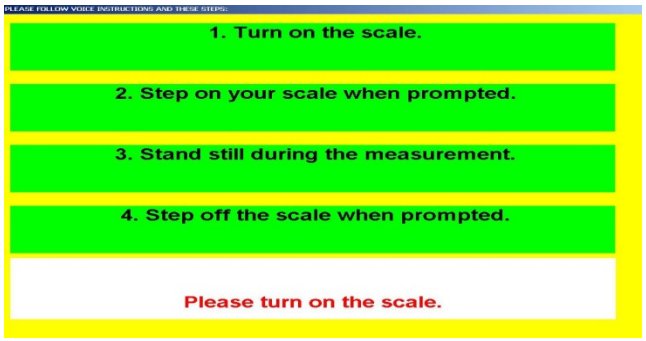


Figure 2. Weight scale instructions

The current patient's action zone is then immediately calculated and displayed. A screen displays weight and an absolute weight change from the previous day. The zone of the action plan is determined using the information provided earlier in the self-test. A sample action plan is seen in Figure 3.



Figure 3. Sample "Yellow Zone" action plan

After completion of the self-testing portion the patient is given an educational "Tip of the day." Each successive educational portion will end with a question about the previous day's tip. The question will be repeated each session until the patient is able to answer correctly. Then a new question is offered during the next self-testing session. At the end of an educational section, the patient will be asked several questions from the specific section. Upon completion of the educational portion, the symptom diary responses as well as the results of weight monitoring are stored for transmission. The system connects to the server using an active landline or wireless connection and relays all stored results/messages. This is shown on the laptop home unit in Figure 4. After transmission

the main menu is displayed.

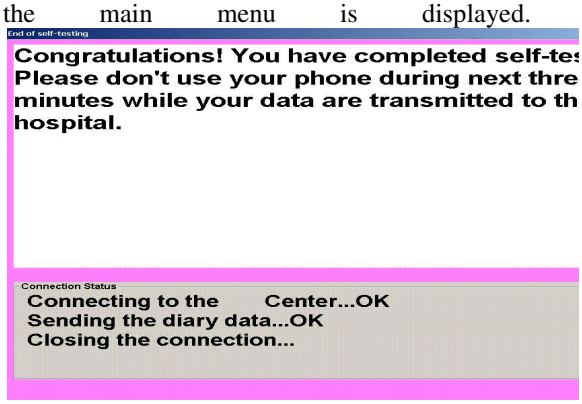


Figure 4. Data transmission screen

The HAT system also allows the patient to access their Action Plan. The patient can view their current action plan and their other plans for different zones. They can also view a graph of their recorded weights or action plan zones and the medications currently prescribed to them. The patient can also send either a personal or pre-written message to the care management team.

The CHF HAT website is hosted on our servers and can be accessed securely by the care management team using any computer with a web browser and an internet connection. The care management team can also view a monthly report which displays graphs and statistics of the patient's information collected over the past month. A section of a sample report is seen in Figure 5.

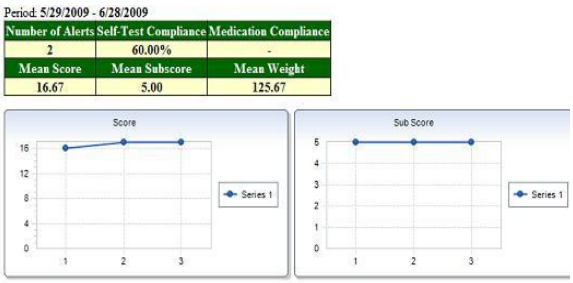


Figure 5. Sample monthly report data

The website also shows any current alerts for the patient and allows the care management team to log their response to the alert as shown in Figure 6.

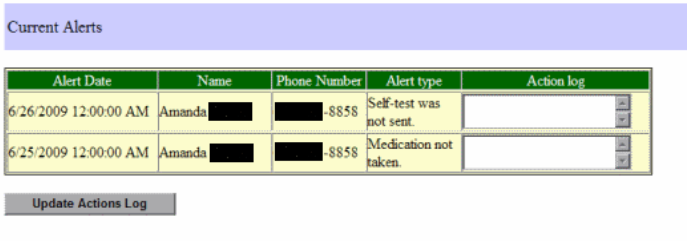


Figure 6. Current Alerts

The care manager can change their alert parameters for the patient, send a message to a patient, or view a list of the messages sent from the home unit to the server as seen in Figure 7.



Figure 7. Messages from the patient

Pilot study

Pilot studies of both systems were conducted with ten African American CHF patients. Patients were given a demonstration of either the laptop or Wii home unit and then asked to perform a self-test by themselves.

After successfully using the laptop home unit, patients were asked to complete demographics, attitudinal survey and qualitative interview. Average age of patients was 56 years, and they completed an average of 13 years of education. 60% of subjects were females, and 100% were African Americans. About 50% reported that they had moderate heart failure symptoms, and 50% answered that their heart failure had been about the same during the last 12 months. 60% and 70% never used the computer and internet respectively, and 30% reported that they never used ATM machine.

After successfully using the Wii home unit, patient response overall has been positive. Patients commented, "I like the way it feels," "…the Wii makes it more interesting," and "Making me use a device that may be more fun in a way could make me pay attention more." 60% (6) of the patients had no prior computer use while 40% (4) used a computer once a month or less. 90% (9) of patients stated that the answering the symptom diary questions was "Not difficult at all," while 10% (1) reported that it was "Slightly difficult." Overall we have

concluded that the interface is sufficient for people with no history of computer or videogame use.

All patients were able to complete the self-testing procedure by themselves with little or no difficulty. 100% of subjects responded that they didn't have any difficulty working with the computer and answering the symptom diary questions. Also patients reported that length of self-testing was appropriate that it would not interfere with their usual activities. All the patients we have interviewed did not consider themselves computer literate and did not own a computer. Patients responded favorably to the educational portion of the self-test, indicating a desire to learn more about their condition. The content and interface also received positive feedback in patient responses. Patients commented that they believed the CHF HAT system would help them better manage their congestive heart failure and reduce their amount of hospital visits. 70% (7) of patients preferred the Wii version to the laptop version, commenting that "…the Wii makes it more interesting," and "Once you get used to it this one is easier to use."

Discussion

The CHF HAT system's ease of use and convenience can provide reluctant patients with an easy way for care management teams to receive daily feedback from the patient. While care management team visits would still be important to the patient's care, allowing the patient to monitor their health frequently and educating them on their condition will hopefully increase their condition awareness, self management, and quality of life. The CHF HAT system can successfully provide support to patients in following their CHF action plans and to aid them in being adherent to their treatment regimens. Providing the system on different platforms can help to reach as many patients as possible. We are also looking toward expanding the HAT system to other computer platforms. Mobile computing is becoming smaller, faster, and cheaper, creating more potential environments for the HAT disease management system. Systems such as the Apple iPhone, iPod Touch, Blackberry, and mobile phones are becoming viable options for the CHF HAT platform.

The system can be adapted for other chronic diseases such as hypertension [18], asthma [19], chronic obstructive pulmonary disease [20], ulcerative colitis [21], multiple sclerosis [22] where the same principles can be applied to aid in patient care and adherence to treatment regiments [23]. The telemanagement platforms could be integrated into cyberinfrastructure to facilitate patient-centered chronic disease prevention and management [24].

Conclusion

The CHF HAT laptop and Wii systems are viable systems to test in the management of CHF patients. These systems can be efficiently implemented for CHF, as well as other conditions, and is recommended for future use and expansion. A comprehensive evaluation using a clinical trial design is warranted for the CHF HAT systems.

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Attrition of Knowledge Workforce in Healthcare in Northern parts of India – Health Information Technology as a Plausible Retention Strategy

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ABSTRACT

Faced with a global shortage of skilled health workers due to attrition, countries are struggling to build and maintain an optimum knowledge workforce in healthcare for delivering quality healthcare services. Forces that affect healthcare professional turnover needs to be addressed before a competent uniformly adoptable strategy could be proposed for mitigating the problem. In this study we investigate the effect of the socio –demographic characteristics on attrition of healthcare knowledge workforce in northern parts of India that have a wide gradient of rural and urban belt, taking into account both public and private healthcare organizations.

The data for the study has been obtained from the Healthcare-professional Attrition Tracking Survey (HATS). Out of 2000 healthcare professionals approached for the survey, 40% of the respondents were able to participate in the study. Structured questionnaires were utilized as the data collection tools. Both public and private healthcare organizations in urban and rural areas were covered for the survey.

Data was analysed by means of Factor Analysis on Rotated Factor Matrix using Principal Components Analysis (PCA) in SPSS 16.0 package to determine relationships between factors influencing attrition. Six factors of attrition namely Compensation and perks, Work Life Balance, Sense of Accomplishment, Work load leading to exhaustion, Need for automation and technology improvement, Break Monotony of Work have been identified with a data reliability of 0.809%. Based on the survey response and further analysis, simplification of work processes using Healthcare Information Technology (HIT) tools to reduce time, stress, complexity at work, increase core competency, quality and job satisfaction has been identified as a plausible retention strategy for reducing attrition.

Keywords

Attrition, knowledge workforce, retention, healthcare information technology, e-health, human resource.

1. INTRODUCTION

Health care industry relies a lot on advanced medical technology, but it is also a labour-intensive industry. As the Indian healthcare industry experiences phenomenal growth, hospitals are moving forward towards excellence rather than survival and gearing up to fulfil the gaps in three key areas of people, process and technology. Despite being the 2nd most populous country with larger population in rural areas[1] and with greater number of health care professionals viz, doctors, nurses, pharmacists, paramedics geting trained the Indian healthcare sector is suffering from acute shortage of healthcare professionals and facilities delivering quality healthcare services to the citizens[2]. According to survey carried out in 2008-09, India has only around 85,000 doctors practicing modern medicine and 1.5 million nurses to serve its more than one billion population. It has 0.8 beds/ 1000 population, and 0.6 doctors / 1000 population (lowest in the world). This means 6 doctors per 10,000 patients with a doctor/nurse ratio of 0.83 compared to china having 20. This large disparity has indicates a high attrition of knowledge workers in healthcare.

Many strategies have proposed for reducing attrition among healthcare professionals [3-6]. It has been argued that opportunities for professional training, higher salaries and perks and better living conditions act as “pull” factors, surplus production of health personnel, resultant unemployment, less attractive salary, stagnation or underemployment coupled with

lack of infrastructure act as "push" factors for the youth to migrate.

Implementation and utilization of information technology in healthcare (commonly identified as Health Information Technology or HIT) has proven to be of immense benefit like, improved patient care, reduced waste and inefficiency in services, reduction in adverse drug effects and medical errors etc [7-10]. Healthcare professionals trained in health informatics are able to work in many alternative healthcare facilities like Ambulatory Care Centres, Rehabilitation centres, Public Health Facilities, Home Health Agencies, Insurance Companies etc. This overwhelming opportunity increases the job satisfaction and also adds to the job enrichment and motivation of the employees thereby reducing attrition. A recent study[11] examined the relationship between use of HIT and physician career satisfaction. Using more information technology was the strongest positive determinant of physicians' being very satisfied with their careers, which lends support to the importance of resources for physicians in patient care.

While there are reports and literature that indicate there is greater danger of brain drain in the area of healthcare in India, there are no detailed studies that explores this thought and offers an effective retention strategy for reducing the attrition. There are many questions that still loom about the causes of attrition in Indian healthcare scenario. With recent technical advances in the medical word using HIT to reduce attrition has not been dealt with. Specifically, this study is based on the pilot survey work done in the area of northern India to address these.

2. MATERIALS AND METHODS

Data for this study came from the phase I of Healthcare-professionals Attrition Tracking Survey (HATS) a multistage research program conducted to address the issues regarding attrition among healthcare professionals in India and to determine if implementation of HIT can be identified as an effective retention strategy in India. HATS was conducted among skilled healthcare professionals such as doctors, paramedics, administrative and managerial staff. A total of 40 healthcare organizations, both public and private covering rural and urban regions of Northern India were surveyed.

2000 respondents were randomly selected to have a non-biased representation. Each participant was screened to determine survey eligibility based on the following criteria:

Criteria 1 (origin): Health care professionals who are of Indian origin and trained solely in India were considered.

Criteria 2 (Completion of Training): Respondents should have completed their training and licensed.

Criteria 3 (Job Satisfaction): Respondents were initially questioned regarding their current job satisfaction. Participants who responded "don't know" or "refuse to answer" were excluded from the HATS survey.

The selected respondents were provided a two part questionnaire that contained questions that could provide insight to their job satisfaction, reasons for leaving job, future plan, practical knowledge, attitude and usage of HIT The respondents were asked to indicate their response on a five-point Likert scale from 1 (strongly agree) to 5 (strongly disagree).

The above measures allowed the investigators to examine which type of HIT was utilized by the respondents and to later relate if adoption of HIT would be deemed as job enrichment thereby increasing their satisfaction.

Statistical Analysis: A random 5% sample of responses was checked for coding errors. Wherever the data was left uncompleted and unclear the respondents were approached individually to recollect the data. The Reliability Test on Data was 0.809%. Data were analyzed by means of Factor Analysis on Rotated Factor Matrix using Principal Components Analysis (PCA) in SPSS 16.0 package to determine the relationships between factors influencing attrition. Descriptive statistics included percentage rates for categorical variables, means and standard deviations. The categorical variables considered were gender, marital status, age, education, work nature, location, organization type, work experience and income. Chi-square tests to find the associations between the reasons indicated for leaving a job and the number of respondents and t-tests to compare the contribution of each categorical variable on the forces of attrition were performed. Descriptive statistics were performed to analyze the knowledge, usage and the type of HIT used by the respondents.

3. RESULTS

An overall response rate of 40% was achieved in this study with a total of 807 responses after filtrations of respondents based on selection criteria and incomplete questionnaires. **Table I** illustrates the descriptive statistics of the various parameters considered for the HATS.

The sample was predominantly male and the proportion ranged 57.6 ± 0.5% . The respondents were mostly middle-aged (52.1%) in the range 26 to 35 years and mostly married (62.4%) living with family. Almost two-thirds of the participants were doctors, paramedics, nurses, administrators who had less than a year of practice in the current organization

and also middle-aged. 54.7% of the participants were graduates while the postgraduates were 34.5%. Undergraduates were few (11.6%). Approximately nearly equal number of doctors and nurses, paramedics participated while the administrators were less. There was not much difference in the number of participants based on their income. 39 % of the respondents were from the public hospitals. 79 % of the respondents were from urban areas.

TABLE I Demographic details of the respondents

		N=807
1	Gender	
	Male	57.6% (461)
	Female	43.2% (346)
2	Age	
	17-25	18.7% (150)
	26-35	52.1% (417)
	36+	30% (240)
3	Marital Status	
	Married	62.4% (499)
	Unmarried	38.4% (307)
4	Work Experience	
	< 5 years	76.1% (609)
	> 5 years	24.7% (198)
5	Education	
	undergraduate	11.6% (93)
	graduate	54.7% (438)
	postgraduate	34.5% (276)
6	Nature of Work	
	Doctors	38.9% (312)
	Nurses & paramedics	37.1% (297)
	Administrators	24.7% (198)
7	Income (Rs)	
	upto 10,000	20.5% (164)
	10,000-20,000	18.9% (151)
	20,000-30,000	26.6% (213)
	30,000-40,000	16.6% (133)
	>40,000	17.9% (143)
8	Type of Hospital	
	Public	39.2% (316)
	Private	60.8% (491)
9	Location of Hospital	
	Urban	72.6% (586)
	Rural	27.4% (221)

During the survey it was identified that many respondents had shifted job within a year and some have decided to do so within short period of time. Through open ended questions the reasons for shifting and their future plan to shift were ascertained. The effect of socio-demographic details on the responses were calculated and plotted in graphs. Chi-test was performed to ascertain the significance of these on migration.

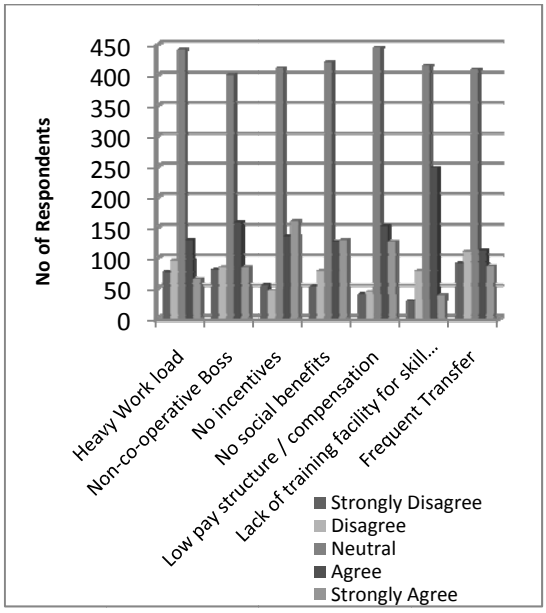


Fig .1. Reasons provided for shifting jobs within last 1 year

The above figure illustrates the distribution of various responses provided by the respondents. The main reasons identified were heavy work load, no social benefits and low pay structure. All the six factors identified were compared with the descriptive parameters considered. Gender, marital status, age and education did not contribute much. Time spent by a healthcare professional at an organization does contribute to the attrition. Two factors namely how the organization contributes to the work – personal life and extent of the work load seem to be the major contributors.

Stress due to over workload was majorly affected by the age, education and nature of the healthcare organizations ie. private versus public. Nature of the work of the respondents considered seems to throw significant contributions to attrition. Four factors namely, Compensation and Perks, Work -Life balance, Sense of accomplishment and Need for Automation and Technology were significant at 0.01 level (**Table II**). Irrespective of the salary package five out of the six factors of attrition identified were significantly found to contribute to attrition. Need for implementing automation and technology seemed to be major affecting factor.

Table II Effect of Nature of Work Group on Forces of Attrition

Although the proportion of health professionals who did not plan to change jobs in near future were more than those who did, it was identified that the doctors were more prone to shift jobs compared to others (**Figure 2**). Female health professionals especially those who were married and health professionals with low income packages and middle aged professionals were more keen to shift indicating job satisfaction and salary as the prime reasons.

Forces of Attrition				
Compensation and Perks	2.88	3.03	2.53	11.52**
Work life balance	2.65	2.80	2.44	7.77**
Sense of accomplishment	2.67	2.77	2.6	3.39**
Work load leading to exhaustion	2.88	2.94	2.9	.24
Need for Automation and technology improvement	2.17	2.40	2.17	4.24**
Break Monotony of Work	2.94	2.92	2.92	.03

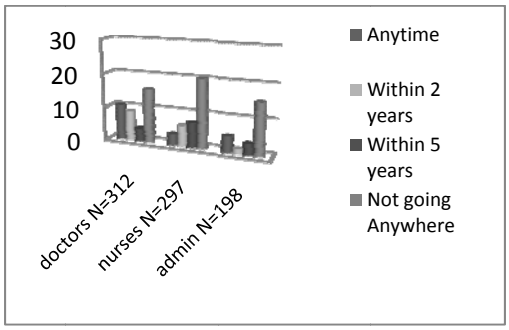


FIG 2 Proportions of Respondents planning to shift jobs

The respondents were also tracked regarding their usage of HIT in order to determine their awareness and willingness to adopt HIT to increase the job efficiency**(Fig 3).** It was also observed that health professionals within minimum postgraduate education and those who were middle aged had greater computer awareness. The respondents were further questioned to ascertain the need of HIT in their work and their willingness to undergo further IT training. 80% of the respondents felt the need of implementing HIT to simplify their work and almost all of them were ready to undergo training with overall percentage of 60% respondents being favourable.

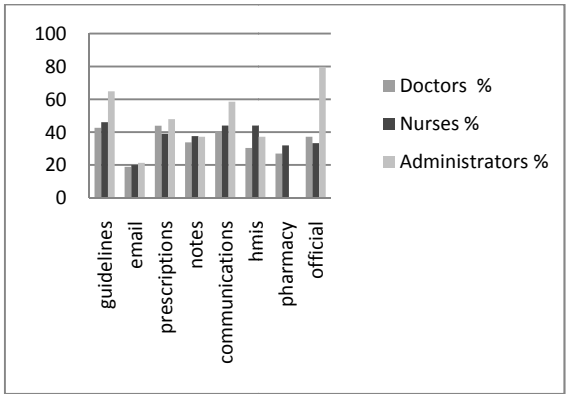


FIG 3 Proportions of Respondents using IT

4. DISCUSSION

Results show a significant difference in attitudes towards factors affecting attrition. The results provide evidence to demonstrate that economic motivation as a factor for changing jobs is not an independent, stand-alone factor in itself, but rather a component of broader factors that takes into consideration the yearning to improvise both developments in both professional and personal front. This finding is a departure from the previous studies that indicate the intention of healthcare professionals to frequently change jobs and migration to foreign countries are mainly dependent on remuneration [12,13].

Based on a broader framework of understanding derived from the results of this study, a number of inferences can be drawn relating to strategies to encourage retention.

Factor 1 Compensation and perks that refers to providing incentives and extra income in terms of benefits need to be structured through contested policies of public and health sector reforms that would induce the health care workers to continue in the existing organization [14].

Factor 2 Work life balance depends on the nature of the work, type of the workplace and issues in the workplace. Introducing strategies like flexible work options, specialized leave policies, paid maternal leave, paternal leave, etc. can increase the satisfaction level of the healthcare professionals. Doctors and administrators who spend greater time of the day in the hospital are affected by work life balance issues.

Factor 3(Sense of accomplishment) is about job satisfaction felt by the healthcare workers. This does not depend upon the monetary issues and it deals with the sense of achievement and fulfilment felt by the employees. A key to build such a culture is by involving the medical staff members to make

collaborative decisions in clinical and operational issues[15].

Factor 4 (Work load leading to exhaustion) and ***Factor 6*** (Break monotony of Work) refers to the overworked health care professionals. While this was not much of the problem in urban hospitals interviewed, it was more prominent in the rural areas. This is due to higher workloads, coverage of large geographic areas, lower access to specialists, and to a broad array of patients. This specifies the need to improve working conditions and the professional interface with other health professionals and society in the rural areas. Planned interventions could employ non-financial incentives such as recognition by management, performance review and improving inter-professional working relationships, to uphold and strengthen the professional ethos of health professionals [16].

Factor 5 (Need for Automation and Technology Improvement) implies the requirement of HIT implementation in the health care industry. The supply of good support, education and training is a key approach to attracting and retaining allied health practitioners, especially in rural locations[17,18]. HIT enables health care professionals to confidently access, interpret, and apply organisational knowledge, patient care procedures, professional workforce competencies, best practice knowledge and other skills information in a manner that improves patient satisfaction, achieves positive clinical outcomes, and maximises cost savings for the organisation [19,20]. In this present study irrespective of gender, age & education , location the importance of implementing HIT was stressed by almost all respondents. The nature of work done by respondents seems to play a significant role in assigning the need for automation and technology as a major factor of attrition. The doctors seemed to be the preferred users of computers, than the healthcare administrators and the nurses and paramedics. Also it was identified that the HIT usage was more prevalent in urban hospitals than in rural hospitals. Moreover, the difference in the salary does not seem to detract the fact that implementation of HIT was seen as a basic requirement of healthcare professionals.

Based on the discussions with the respondents it was understood that the healthcare professionals leave their jobs due to the greater job opportunities and higher pay packages in abroad. Attrition of post graduate doctors is seen to be in lure of attractive salary packages, better technologically equipped healthcare facilities besides higher studies. Medical professionals working in rural private health set ups found reasons for leaving their job in search of opportunities that not only provides good financial benefits but also better professional development through adoption of newer technologies. Given the industry standard salary, they still were ready to shift jobs to organizations that were endowed with advanced technologies of healthcare delivery.

Based on the observation the following it can be understood that for any hospital and health care system the planning of manpower (human resources) is very vital[21]. Detailed planning of human resources and a plan of action for their selection, training and deployment are very important factors to be considered right from the project planning to implementation and should be undertaken at the inception of the project.

Other than better salary packages and financial benefits, better work environment etc implementing HIT to reduce work load stress, enrich knowledge and core specialization, improve quality in service can work as an ideal strategy to increase job satisfaction of healthcare professionals thereby reducing attrition. This also reduces medical errors and increases quality in healthcare delivery [22,23]. Healthcare is rapidly becoming an interconnected ecosystem, with IT as its circulatory system. While the above strategies can be uniformly followed among all healthcare professionals irrespective of their nature of work and location the following guidelines may be followed especially in India. Since all the processes of recruitment and selection are critical and attrition rate of knowledge workers in Healthcare is significant, the healthcare industry should focus on employing right talent and develop the talent to increase retention in the organization for a longer period of time.

A potential solution to bridge acute shortage of healthcare workers and reduce attrition rate is through providing accessibility to online healthcare, which has emerged as very important tool for offering healthcare services that can be accessed by patients across boundaries. Online healthcare connects patients and doctors via internet services. Online health portals can reduce workload and streamline processes for consultations, booking appointments, maintaining patient health records, getting second opinions, among various other services offered.

Healthcare professionals must be provided financial help and resources to further their knowledge in the realm of HIT, mandatory practical exposure to using computer and internet etc. They should be offered incentives to encourage them to use the technologies implemented. They should be made aware of the benefits that would increase by using computers to reduce their work load, increase quality of service etc. They should also be trained to use the technology to learn about guidelines, surf medical and health databases to retrieve vital information, to retrieve information from journals, e-books, to keep in touch with professional groups etc. Training should be provided to them to reduce the fear of increase in work complexity through the use of technology.

Implementation of Technology and adoption of Healthcare Information Technology applications and

best practices would result in simplifying processes. The benefits would be in terms of Unique Health Identification Number (UHID) for each patients, Electronic Medical Record (EMR), Telemedicine, Reduction in Physician Errors, Time Savings in processes such as information retrieval, Adoption of International Standards and best practices, Instant Availability of Administrative Data, increased Financial Savings and Clinical Trials & Research. This in turn would bring in transparency in the system and healthier working conditions. Improved efficiency and profitability would lead to better employee compensation and working condition thereby leading to retention of knowledge workers in healthcare.

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A New Approach to Information Security Assessment: a case study in a Brazilian healthcare organization

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ABSTRACT

Information security is an important issue in today's business. Information has become a vital asset of organizations and it is necessary to protect it, ensuring its confidentiality, integrity and availability (CIA). The ISO 27000 family of standards related to information security is designed to help organizations to keep their information securely. Risk management, comprising its identification, analysis and assessment is extremely important and can be crucial to the success or failure of an organization. However, the proper management of risks is not easily achieved. The aim of this study is to present an information system designed to help organizations in assessing their information security level based on ISO standards. The system proposed is named Information Security Assessment (ISA) and uses a scoring scheme that assigns a value to each control. ISA was used during the implementing process of an Information Security Management System (ISMS) in a Brazilian hospital. The case studied has shown that ISA yielded consistent results and that it helped to identify priorities in the institutional information risks treatment.

Keywords: information security, information system, ISO standards, assessment, health informatics.

1. INTRODUCTION

Information is an asset which, like other important business assets, has value to an organization and consequently needs to be suitably protected [1].

Nowadays, there is a great emphasis on security issues related to information technology, but it is frequently forgotten that security goes beyond that. It must be remembered that information can exist in many forms. It may be printed or written on paper, stored electronically, spoken in conversation and so on. It can also be transmitted by post, by using electronic means or simply by conversation between different people.

Information security must always take into account three elements: confidentiality, integrity and availability. Their definitions can be found elsewhere [2 – 4]. Professionals from information security should find a good balance for these elements in their respective environments.

In order to protect the information from any sort of threats, knowing the environment and its risks is necessary. The risk assessment can be performed by using quantitative methods, qualitative methods or with any combination of these methods, as described by Cuihua & Jiajun [5]. After the analysis and risk assessment phases, we must find methods to address the risks found and international reference standards can play an essential role for drawing this roadmap.

ISO/IEC 27001 and ISO/IEC 27002 are essential standards for information security. As explained by Boehmer [6] and Tonga *et al*. [7], they emerged from the

well known British Standard BS 7799, and are used today by different organizations around the world. Those norms list a series of controls that can be used to achieve a safe environment. In addition, it is possible to obtain a certification on ISO/IEC 27001 standard. This assures that an adequate information security management system is available, therefore increasing the level of information reliability to the customers.

This paper presents a method for evaluating the information security management based on ISO standards. We use standards translated and approves by ABNT NBR, an acronym in Portuguese to Brazilian Norm approved by the Brazilian Association of Technical Norms. The standards used are:

- ABNT NBR ISO/IEC 27001:2006. Information technology - Security techniques - Information security management systems - Requirements.
- ABNT NBR ISO/IEC 27002:2005. Information technology - Security techniques - Code of practice for information security management.

The establishment of this method arose from the need to assess the information security level achieved and to further refine the evaluation of the level of compliance with ISO standards in a Brazilian hospital.

2. ORGANIZATION STUDIED

The organization chosen for the development of this project is a large tertiary university hospital complex in Brazil, with 9 institutes and approximately 3000 beds and 15000 employees in its staff. It counts with an Information Technology directory that is responsible for the planning, implementation, monitoring and control of the institutional IT politics.

The organization has a computer network with about forty servers, 3000 dock-stations connected and about twenty systems in operation, covering virtually all different areas and sectors of the hospital complex. Some examples of those systems are: materials and equipment management, patient scheduling appointments, electronic patient records, medication, medical imaging, laboratory and record of diagnoses and procedures.

According to the best practices in information security, an area of the hospital and a scope were chosen in order to define a proper environment for the field study.

3. METHODS

We created an information system based on Django [8], a high-level Python Web framework. Figure I shows the home screen from ISA system.

The reference norms chosen (ABNT NBR ISO/IEC 27001 & 27002) contain 133 controls, distributed along 11 sections (see Figure II). The system is basically a checklist created to verify which controls were already being used by the organization analyzed and also which of them were in accordance with the requirements of ISO/IEC 27002. The information obtained was saved in a PostgreSQL database [9], but can be used with any other relational database management system. ISA classifies each control according to the following criteria: implemented; partly implemented; not implemented; and not applicable. A second analysis is performed with the implemented controls. In that analysis, the controls are classified as: adherent to ISO standards; partially adherent to ISO standards; and not adherent to ISO standards.

Figure I – ISA system home page.

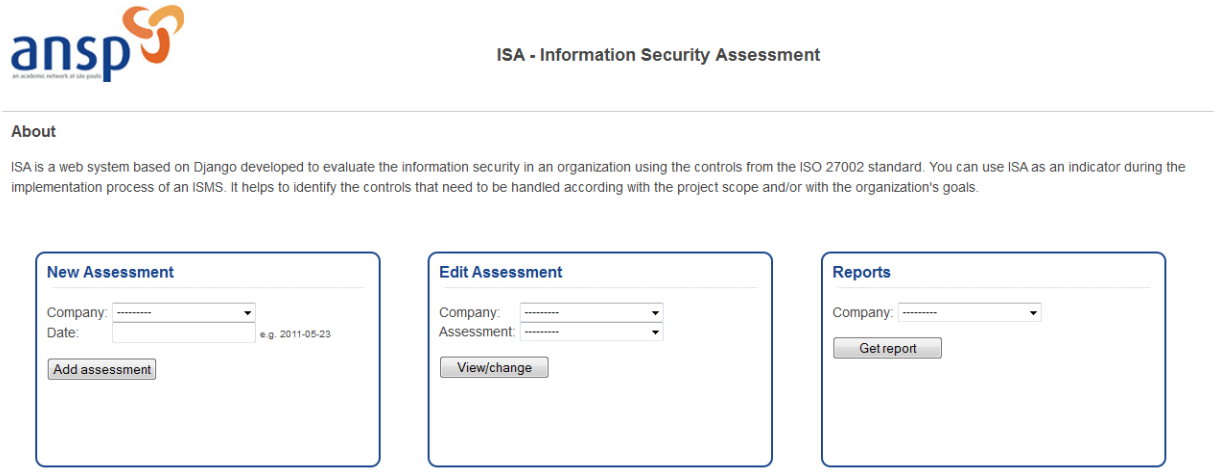
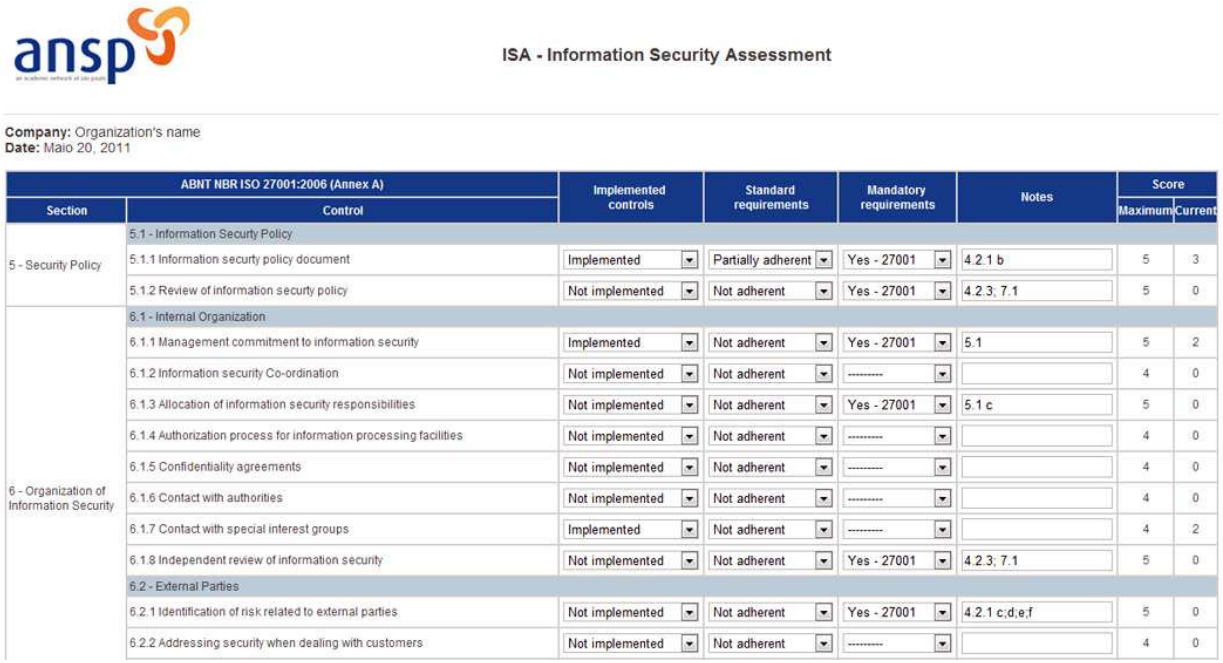


Figure II – ISA system. Shows a sample of the results based on the actual organization situation.



ISA - Information Security Assessment

Company: Organization's name
Date: Maio 20, 2011

ABNT NBR ISO 27001:2006 (Annex A)		Implemented controls	Standard requirements	Mandatory requirements	Notes	Score	
Section	Control					Maximum	Current
5 - Security Policy	5.1 - Information Security Policy						
	5.1.1 Information security policy document	Implemented	Partially adherent	Yes - 27001	4.2.1 b	5	3
	5.1.2 Review of information security policy	Not implemented	Not adherent	Yes - 27001	4.2.3; 7.1	5	0
6 - Organization of Information Security	6.1 - Internal Organization						
	6.1.1 Management commitment to information security	Implemented	Not adherent	Yes - 27001	5.1	5	2
	6.1.2 Information security Co-ordination	Not implemented	Not adherent	---------		4	0
	6.1.3 Allocation of information security responsibilities	Not implemented	Not adherent	Yes - 27001	5.1 c	5	0
	6.1.4 Authorization process for information processing facilities	Not implemented	Not adherent	---------		4	0
	6.1.5 Confidentiality agreements	Not implemented	Not adherent	---------		4	0
	6.1.6 Contact with authorities	Not implemented	Not adherent	---------		4	0
	6.1.7 Contact with special interest groups	Implemented	Not adherent	---------		4	2
	6.1.8 Independent review of information security	Not implemented	Not adherent	Yes - 27001	4.2.3; 7.1	5	0
	6.2 - External Parties						
	6.2.1 Identification of risk related to external parties	Not implemented	Not adherent	Yes - 27001	4.2.1 c;d;e;f	5	0
	6.2.2 Addressing security when dealing with customers	Not implemented	Not adherent	---------		4	0

According to the answers, the system automatically assigned a value (Table I) to each control and, in the end, added the maximum score possible for each control and the current score of all controls.

Table I – Possible values to each control

Description	Points
The control does not apply	-
Control not implemented	0
Control partially implemented	1
Control implemented, but without evidence or not adherent to ISO standards	2
Control implemented with evidence, but only partially adherent to ISO standards	3
Control implemented with evidence and adherent to ISO standards	4
Control implemented with evidence and adherent to ISO standards. Required item (ISO 27001 or scope)	5

It was established that the controls that were not applied to the case study would not be scored and therefore would not influence the results.

It was assigned the maximum value (5) only to controls that were implemented according to the standard sets and that were also considered mandatory due to at least one of the following reasons:

- Controls which the ABNT NBR ISO / IEC 27001:2006 determined as mandatory.
- Controls not classified as mandatory in the reference norm but considered so within the established scope for the project.

Thus, mandatory requirements can be classified as so either by ISO 27001 or by the scope defined. The mandatory controls in accordance with ISO 27001 were previously identified and the system shows these fields filled by default, while the mandatory controls according to the scope of the project should be identified during the evaluation.

In this case study, the organizational assessment was performed through a consensus meeting with all members of the Information Security Committee. At that meeting, each control was individually examined and scored using the system proposed.

Therefore, the method proposed here allowed two distinct analysis of adherence to the reference norm. First, it allowed a general performance of the adherence by the total score achieved. Secondly, it allowed a more specific analysis of the adherence of the organization to each section of the reference standard, thus permitting the Chief Security Officer to discriminate which items or sections of the norm should be primarily addressed.

4. RESULTS

In general, the organization has implemented 28.4% of the controls of the norm, partially implemented 6.9%, whereas 64.6% of the controls were not implemented.

Figure II shows a part of the results of the ISA proposed in the healthcare organization, for illustration purposes. Using the classification proposed, the sum of the values assigned to each control resulted in a maximum achievable score of 550 points for the 133 controls of the standard norm.

In the case studied here, the environment analyzed scored 86 points, which correspond to 15.6% of the maximum score possible. In addition, there was a great heterogeneity in the levels of adequacy in relation to the various sections of the reference standard used. The results for each section can be seen in Table II.

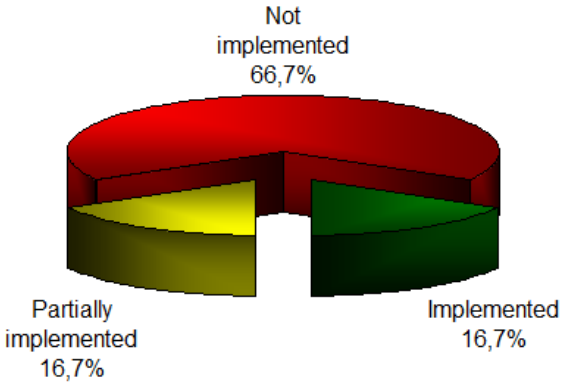
Table II - Score Obtained

Item	Max	Obt
Security policy	10	3
Organization of information security	48	4
Asset management	22	1
Human resources security	39	2
Physical and environmental security	58	12
Communications and operations management	126	23
Access control	101	30
Information security acquisition, development and maintenance	64	11
Information security incident management	21	0
Business continuity management	20	0
Compliance	41	0
Total	**550**	**86**

Max = maximum score, Obt = score obtained

With respect to the mandatory controls, the performance of the organization studied was a little worse than expected when considering the proportion of implemented controls in general. Figure III shows the proportion of implemented controls amongst the 30 mandatory controls identified for the organization.

Figure III - Percentage of mandatory controls implemented, partially implemented and not implemented.



5. CONCLUSION

The ISA proposed was able to show the weaknesses of the organization in respect to the information security management. The proposed method was efficient in the analysis of information security as it indicated the controls that need to be handled by the organization in accordance to the project scope and to the organization's goals. It also allowed an evaluation of what sections of the reference norm were more uncovered, therefore allowing the establishments of priorities in the planning of an ISMS implantation.

The work of implementing an ISMS in that Brazilian hospital is on course. New information security assessments shall be done in the future, during and after the implementation of the ISMS, using the same ISA described here. The result of the future analysis, in comparison with this initial one, will serve to point out the gains of the organization in terms of information security and also in respect to the compliance with the reference standards.

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Development and Validation of a Remote Image Transmission System for Prehospital Emergency Care

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ABSTACT

Objective: The aim of the study was to validate the effectiveness of a newly-developed video transmission system using a commercially available video-inubation device, a transmission device, and mobile telephone networks for prehospital emergency care.

Methods: We designed a three-step approach for the study. As a pilot study, we examined the possibility of remote transmission of airway management images, i.e. tracheal intubation, using a rigid video-laryngoscope and mobile phone networks. Next, we developed a prototype system using a video-laryngoscope, a specially developed transmission device, and mobile telephone networks, which combined multiple images from devices installed in an ambulance and transmitted them to a remote hospital. Finally, we verified the feasibility of the image transmission system in a simulated concurrent multiple emergency. Image information from 4 ambulances in Hiroshima city was transmitted to a virtual control center in Tokyo.

Results: In the pilot study, image transmission of tracheal intubation using the commercial available devices was successfully performed. Our prototype transmission system promptly transmitted the multiple visual data from the scene to our hospital or the remote virtual control center.

Conclusions: Our system promptly transmitted multiple visual data from the scenes to the control center in a distance. The incorporated images transmitted from multiple emergency scenes were found to be quite useful for medical control and quality assurance of emergency care.

Keywords: Remote image transmission system, Prehospital emergency care, Communication system, Medical control, Ambulance crew.

1. INTRODUCTION

The role of the pre-hospital emergency care has become more important as it has become more sophisticated. In Japan, the emergency medical service personnel are non-physicians, therefore medical control is prerequisite to assure quality of emergency care. We have a one-tiered system and the ambulance is staffed by three crews trained in rescue, stabilization, transportation, and advanced care of traumatic and medical emergencies. Among them, the most advanced level ambulance crews called Emergency Life Saving Technicians (ELSTs) have been expected to play a large role in the initial emergency care. In addition to perform appropriate evaluation of patients, the ELSTs are permitted to perform high-level emergency care, such as tracheal intubation and intravenous administration of emergency medicines. Although their activities are based on pre-set protocol, on-line communication between the pre-hospital scene and the medical director is essential to guarantee the quality of the emergency care. However, limitations have been pointed out regarding conventional verbal-based interfaces, therefore a video-image transmitting system has been sought. The major obstacle to develop video-image transmitting systems includes cost and the quality of video image transmitted using available wireless networks. We have developed a video transmission system using commercially available medical devices, video-image transmitting devices and mobile telephone networks, and are working toward practical use of this system in the Japanese pre-hospital settings.

2. METHODS

Pilot study: We examined the possibility of remote transmission of airway management image, i.e. tracheal intubation of a rigid video-laryngoscope, the PENTAX-AWS® (HOYA Corp., Tokyo, Japan; AWS) in this pilot study. By using the AWS, the laryngeal images on the screen can be shared by not only the practitioner but also assistants or teaching staff during the procedure [1]. In addition, the AWS has a video outlet through which the image can be transmitted to other monitor screens. This function can be used to transmit the image via a mobile phone to other mobile devices or a remote computer [2]. We experimentally developed an image transmission system using a commercially available remote monitoring system (Portable EYE C, Mitsubishi Electric Corp., Tokyo, Japan) and a 3G mobile telephone network (FOMA, NTT DOCOMO Corp., Tokyo, Japan). Thereafter, we planed remote transmission of tracheal intubation images of the AWS, because practical applications of this system would enable medical directors to verify the procedures performed by ELSTs in a distance. To determine the feasibility of video-transmission using this system, we attempted to transmit video-images during intubation attempts of a manikin model (Heartsim® 4000, Laerdal Medical, Stavanger, Norway) using the AWS to our critical care

center 12 km away from the firefighter academy.

Clinical test: We designed a system which combines multiple images from devices installed in an ambulance and transmits it to a remote hospital. Informed consent was obtained from all of the patients and their families for participating in this study. The ambulance used in this study was equipped with a video camera (CX560V, Sony Corp., Tokyo, Japan), a bio-monitor (WEC-5003, Nihon-Koden, Tokyo, Japan), the AWS and a specially designed transmission device (RVT-SD100, SONY Corp., Tokyo, Japan), which transmits high-resolution images via a conventional telephone network. We combined visual and digital information from these equipments and incorporated them into the tetrameric screen display, then transmitted the information to our critical care center. With collaboration with SONY Corp, we developed the RVT-SD100 that uses a 3G mobile phone networks and the Internet to transmit high quality video images (Figure). This device uses the H.264/MPEG-4 AVC Main Profile codec and supports video resolution up to 352 x 240. Also, the system enables to send images from up to 12 transmitters to one receiver at the same time. Two to 10 seconds delay for transmission would be expected for coding process.

System development: Finally, we developed the aforementioned high-resolution image transmission system and used it in a simulated multiple emergency. Four ambulances were equipped with a video image transmission system, a bio-monitor and the AWS, and then deployed at 4 different points in Hiroshima city. We set up a virtual information control center in Tokyo approximately 900 km away from Hiroshima city to monitor all images transmitted from multipoint emergency scenes using a receiving device (RVT-MR212, Sony Corp., Tokyo, Japan), which could simultaneously incorporate information from up to 12 transmission devices. Each ELST in 4 ambulances in Hiroshima city simultaneously performed evaluation procedures and emergency care for simulated patients, such as advanced life support, assessment of a trauma victim with open fracture of lower leg and an acute abdominal condition. Image information from each ambulance was incorporated and transmitted to the virtual control center in Tokyo.

3. RESULTS

Pilot study: Ninety percent of the video-image transmissions during intubation attempts were successfully performed and the laryngeal anatomy during the procedure was clearly recognized at the medical center. Four percent failed because of poor connection of mobile telephone networks.

Clinical test: Three emergency patients, i.e., a multiple trauma, an acute abdominal condition and a panic syndrome, were enrolled. The video images of the patients, vital monitoring data were transmitted to the center. No transmission failure was encountered, and all the combined images transmitted from the

ambulance were clear enough to examine and evaluate appearances or conditions of the patients and medical care provided by ELSTs through transmitted images at our critical care center. Especially in a trauma patient, the transmitted image was found to be quite useful for recognition of the severity of the injuries.

System development: The images simultaneously transmitted from 4 ambulances in Hiroshima city were clearly recognized on the PC screen at the virtual information control center in Tokyo. The medical director at the control center was able to examine and evaluate conditions of the simulated patients appropriately, and tracheal intubation procedures performed by ELSTs were clearly confirmed via transmitted video images. The advising medical director participated in the initial assessment in multiple emergency scenes in parallel, and individually gave instructions to ambulance crews as required.

4. DISCUSSION

The system developed in this study promptly transmitted the high-resolution visual data from the scene to the medical director in the hospital or the remote information control center via mobile phone networks. Furthermore, the incorporated images transmitted from multiple emergency scenes were found to be quite useful for medical control and quality assurance of emergency care.

In this study, we used a commercially available medical device, i.e. a video-laryngoscope, with combination of a monitoring and a transmission device. The transmission device transmits large volume of data such as video images via mobile phone networks by using an encoding-decoding program. The time delay required for this process ranges from 2 to 5 seconds depending on the availability of mobile phone lines. The total cost to develop this system was approximately $ 40,000 per unit, and appears to be quite reasonable considering the functions it provides.

Limitations in this system include the time delay in transmission by coding process, operability of the transmission device, and information security. We are now in the process for solution of these problems and refining this system for practical use in the pre-hospital setting.

5. CONCLUSIONS

Our system promptly transmitted multiple visual data from the scenes to the control center in a distance. The incorporated images transmitted from multiple emergency scenes were found to be quite useful for medical control and quality assurance of emergency care.

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The remote image transmission system for prehospital emergency care



Prehospital scene

Critical care center



Ambulance



Remote-operated vehicle camera



Monitor system for vital signs





Image transmission device



Field-portable camera and image transmission device



Bring out

Disaster scene



Video recording



Bidirectional information transmission

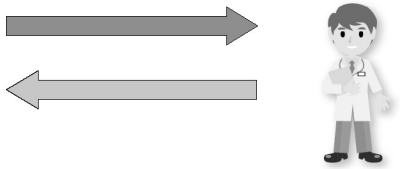


Verbal information is transmitted via mobile phone.





ELSTs



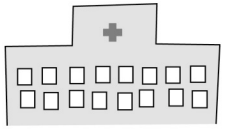
Doctor

Screen display



Portable terminal





Mobile phone network

Data center



Internet

Vital signs data are transmitted as medical waveform encoding rules (MFER).

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Aspects of Clinical Decision Support Systems

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ABSTRACT

The envisioned role of computer programs in health care is perhaps the most important. Everything we know today in medicine might not have been possible without the valuable contribution of computers. Medical knowledge in modern health care is vast and constantly changing, as well as expanding. The provisioning of Clinical Decision Support Systems (CDSSs) would enable the discovery of patterns in health data which might be important for the fight against incorrect diagnosis. Medicine uses empirical knowledge about superficial associations between symptoms and diseases. Uncertainty is a central, critical fact about medical reasoning. Many of intelligent CDSSs are based on the fuzzy set theory, which describes medical complex systems mathematical model in terms of linguistic rules. Considering the fuzzy nature of the data in a medical environment, it becomes obvious that the ability of managing uncertainty turns to be a crucial issue for CDSSs.
Since the potential of medical decision making was first realized, hundreds of articles introducing CDSSs have been published in the last three decades. But even today, only few systems are in clinical use. Even fewer are in use outside their site of origin.
This paper addresses, works out advantages and disadvantages of several approaches and compares them against possible alternatives. Finally, experiences, gained by clinical use of two introduced systems, are used to analyze the little use of CDSSs in today's clinical routine practice.

Keywords: Knowledge acquisition, medical decision support, fuzzy control, medical applications.

1. INTRODUCTION

Over the two past decades, medical treatment has made enormous progress, resulting in new medical data about the patient's condition and an increase in the complexity of medical protocols.
A computerized Intensive Care Unit (ICU) especially is an extremely data-intensive environment, resulting in enormous databases. Physicians and nurses are still performing time-consuming manual data analysis for making the most optimal medical decision for each individual patient [1-5]. Moreover, current ICU platforms are not offering an infrastructure for decision support, data-driven guidance, infection surveillance or modeling of critical illness. The provisioning of a Clinical Decision Support Systems (CDSS) in such an environment would enable the discovery of patterns in health data which might be important for the fight against nosocomial infections, incorrect diagnosis, unnecessary prescriptions, and improper use of medication.
In addition to the huge amount of data, in this special environment, the complexity of these biological systems makes the traditional quantitative approaches of analysis inappropriate. Medicine uses empirical knowledge about superficial associations between symptoms and diseases. Also, many data, symptoms, or diagnosis can be affected by incompleteness, subjectivity, and inaccuracy. In many areas the main characteristic of medical information is uncertainty.
In other words real world knowledge is characterized by uncertainty, incompleteness and inconsistency. Fuzzy set theory, which was developed by Zadeh [6], [7], makes it possible to define inexact medical entities as fuzzy sets. Considering the uncertainty or fuzzy nature of the data in a medical environment, it becomes obvious that the ability of managing uncertainty turns to be a crucial issue for CDSSs. The implications of this approach, equal with or without the fuzzy set theory, where promised to be that CDSS or Decision Support Systems (DSSs) in general deal with complex and difficult problems, and make better and more reasoned decisions. Over the years' the experience has shown that the expectations were not always fulfilled.
This paper surveys on two applications the capabilities as well as limitations of CDSS. The systems are established as real-time applications in an ICU and have reached the state of extensive clinical integration and testing at the Vienna general hospital.

2. DECISION SUPPORT SYSTEMS

Generically DSS are any type of application that support the decision making process. A DSS receives a certain amount of data as input, processes it using a specific methodology and offers as a result some output that can help the (physicians) decision-makers [5], [20]. A typical therapeutic cycle in a simplified view is shown in Fig.1.

In principle a DSS can be classified into the following six frameworks [21]: Text-, Database-oriented, Spreadsheet-oriented, Solver-oriented, Rule-oriented, and into a Compound DSS. A compound DSS is the most popular classification for a DSS [22], [23]. It is a hybrid system that includes two or more of the five basic structures of DSSs. The input data could be clinical, administrative or financial. In addition, the input data can also be a signal automatically acquired from medical devices. Depending on the methodology used by the DSS some additional data should also be available such as certainty factors for uncertainty handling by either symbolic or connectionist based DSS.

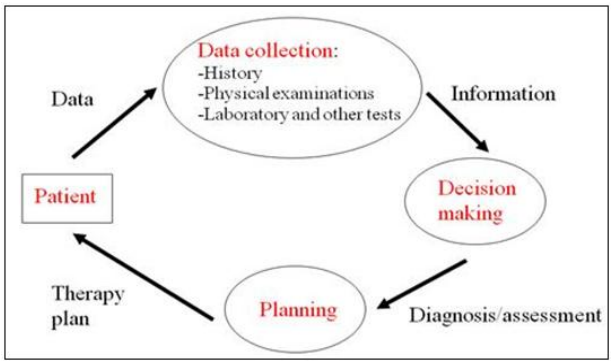


Figure 1: The Diagnostic-Therapeutic Cycle (a simplified view)

Expert or knowledge-based systems are another type of DSS capable of being programmed to perform decision making at the level of a domain expert. These systems represent the most prevalent type of DSSs used in medical clinical practices today [19].
Though CDSSs can include different components, and though domain knowledge can be structured in a variety of ways, certain elements are common to all: a user interface, a knowledge base, a database, a knowledge acquisition facility, and an inference mechanism.

2.1 Clinical Decision Support and Fuzzy Control

The concept of fuzzy set theory, which was developed by Zadeh (1965), makes it possible to define inexact medical entities as fuzzy sets [6]. The Fuzzy set theory [7], [23] derives from the fact that most natural classes and concepts are of fuzzy rather than crisp nature. On the other hand, people can approximate well enough to perform many desired tasks. By generalization of usual set theory an object cannot only be seen as an element of a set (membership value 1) or not an element of this set (membership value 0), but it can also have a membership value between 0 and 1. Therefore fuzzy sets defined by their *membership function* μ which is allowed to assume any value in the interval [0, 1] instead of their characteristic function, (Fig. 2).
A more far-reaching concept of modeling relationships was introduced by Sanchez 1979. Sanchez postulates the concept of "medical knowledge" based on a relationship between symptoms and diagnoses [14], [27].

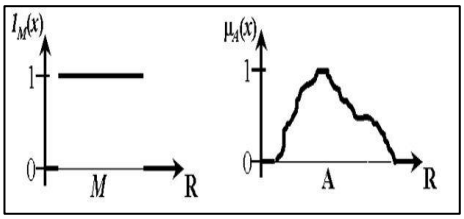


Figure 2: Characteristic function of a set *M* and membership function of a fuzzy set *A*.

Using this composition formula as an inference rule, Assilian and Mamdani developed the concept of f*uzzy control* in the early 1970s [12].
Mamdani's development of fuzzy controllers in 1974 gave rise to the utilization of these fuzzy controllers in ever-expanding capacities [13], [24]. What is needed is a system which can process quantitative and qualitative data of varying levels of precision and, by reasoning, transform this data into opinions, judgments, evaluations and advice. These new intelligent Fuzzy CDSS must be able to expect a tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, low solution cost, and better rapport with reality.

2.2 PDMS based Medical Applications

Based on the use of a Patient Data Management System (PDMS) the medical applications SIRS Detection and FuzzyKBWean are realized in the cardiothoracic ICU at the Vienna general hospital.
The PDMS is in routine clinical use in the cardiothoracic ICU and collects data from all available monitoring devices in intervals of 1 minute [8-10]. The system came up to more than 2 million data entries; laboratory data and blood gas analysis was done according to institutional standards; the data of daily balance and treatment was recorded every day (Fig. 3).

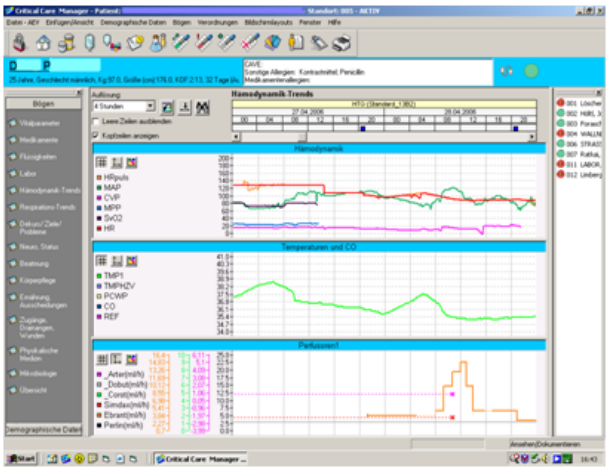


Figure 3: Cardiothoracic PDMS-chart, University Hospital of Vienna

The PDMS is the platform, the data-source, for several CDSSs, used at the General Hospital of Vienna.

2.3 Early SIRS detection

The syndrome of generalised inflammation is defined as Systemic Inflammatory Response Syndrome" (SIRS) or severe SIRS if hypotension is present simultaneously. After major surgery many patients develop signs and symptoms of generalised inflammation. The term's SIRS, sepsis, septic shock and MODS (multi organ dysfunction syndrome) are used to describe the different extents of inflammation and infections [11]. SIRS was proposed to define sepsis and its sequelae clearly in 1991, in order to make early detection of the disease possible, and to improve the ability to compare innovative potential diagnostic modalities by standardizing terms. Clinicians are facing the challenge to differentiate between post-operative inflammation a condition considered to be benign and early signs of infection [15-17].
Regardless of etiology, SIRS manifests itself through two or more of the following symptoms (Table I).
Sepsis is defined as SIRS when the systemic response is the result of an infection [15]. The development of a SIRS and sepsis are well known complications after cardiothoracic surgery. The management of sepsis based on elimination of the causative infection by surgery, antibiotics, and supportive treatment has not sufficiently changed the mortality rate over the past decades.

TABLE I: SIRS SYMPTOMS

- heart rate > 90 per minute
- body temperature < 36 or > 38 °C
- respiratory rate > 20 per minute or pCO_2 < 32 mmHg
- white blood cell count (WBC) < 4 or > 12 billion cells/liter

Sepsis remains an important and life-threatening problem and the most common cause of death with mortality between 20 to 50% for severe sepsis and 45 to 80% for septic shock [16], [18]. The progression from sepsis or severe sepsis to a septic shock with its increased mortality may be prevented by the initiation of appropriate therapy.
Implemented as a CDSS we tried to use SIRS in the ICU as a predictive tool, to prevent the risk of sepsis.
We determined in the first phase the moment of the first occurrence of SIRS and severe SIRS. In the following phase, we determined the number of SIRS episodes on the individual patient and investigated the influence of this parameter on the outcome of patients. At last we tried to discover a possibly existing relationship between the treatment and the development of SIRS in order to find an optimal time for the SIRS intervention. At the Vienna University Hospital 1925 patients were admitted during the time period mentioned above. Among those patients, we identified some cases as the second and some as the duplicate admission of the same patients. The admissions in succession of the same patients were considered as one admission, if the pause was less than 24 hours. Otherwise they were considered as two independent admissions. Severe SIRS was defined as SIRS with at least 2 of the following criteria for organ dysfunction as defined in the SOFA score [18], shown in Table II.

TABLE II: SIRS SEVERE CRITERIA

- systolic arterial pressure (SAP) < 90 mmHg or mean arterial pressure (MAP) < 70 mmHg or dopamine medication
- PaO_2/FiO_2 < 400
- bilirubin greater than or equal to 1.2 mg/dl
- creatinin greater than or equal to 100 mmol/l or urine output < 500 ml/day
- platelet count < 150000/mm^3

For prediction of severe SIRS, the knowledge base was constructed with the following input variables: body temperature, heart rate, pCO_2, WBC, SAP, MAP, PaO_2/FiO_2, bilirubin, creatinin, platelet count, and CRP. The output variable was the presence of severe SIRS in the following two hours.

2.4 Ventilator Weaning Application

The majority of patients requiring mechanical ventilation in the intensive care unit are safely weaned from mechanical ventilation within a short period of time.
Patients require mechanical ventilation during surgery, when they are anaesthetized, and must be slowly weaned from mechanical ventilation after major surgery to a point when they can breathe spontaneously. At this point, the patients can be extubated. In other words, the tube that is placed in the trachea to ensure proper ventilation is removed [8], [10]. The aim of an improved weaning process would be to make the transition from controlled ventilation to total independence (extubation) as smooth and brief as possible.

2.4.1 FuzzyKBWean Application

The in the ICU implemented CDSS FuzzyKBWean is an open-loop application that contains the knowledge and expertise of experienced intensive care physicians in computerized form.
It offers decision support for ventilator control during the weaning process of patients after cardiac surgery. The respirator changes effected by the physician have to be entered into FuzzyKBWean as a feedback for this open-loop system. The ventilator mode used for weaning must allow spontaneous breathing and a gradual reduction of the amount of ventilator support [8], [9].
The BIPAP (Biphasic Positive Airway Pressure) mode is a mode equipped with a standard ventilator [10]. This mode allows spontaneous inspiration during the entire respiratory cycle and, consequently, a very smooth and

gradual change from controlled to spontaneous breathing. The fuzzy knowledge bases consist of variables, values, and rules. The variables represent the physiological parameters of the patient and the respirator settings. The values are described in linguistic terms that are formalized by fuzzy sets.

2.4.2 PDMS Data Input

The respirator settings and physiological parameters are taken as input at one-minute intervals from the Patient Data Management System (PDMS) Picis®. The PDMS is in routine clinical use, at the cardiothoracic ICU of the General Hospital of Vienna, and collects data from all available monitoring devices. The system analyzes these data and makes suggestions for appropriate respirator setting adjustments. The attending intensive care specialist (physician) is free to decide whether he will follow the given advices.

3. RESULTS AND DISCUSSION

3.1 Early SIRS Detection

With the current system it could be showed that SIRS was present in 1544 patients (92.2%), SIRS with hypotension (SAP < 90 mmHg or MAP < 70 mmHg) in 1315 (78.6%) and severe SIRS in 1175 (70.2%) of the total of patients. The time points of first fulfilment of SIRS and SIRS severe are shown in Table III.

TABLE III: FIRST FULFILLMENT OF SIRS SEVERE

time delay after surgery (h)	patients	severe SIRS	severe SIRS / severe SIRS total (%)
<6	1207	669	56.9
6 – 12	150	233	19.8
12 – 18	64	76	6.5
18 – 24	48	55	4.7
24 – 30	20	30	2.6
30 – 36	10	21	1.8
36 – 42	16	22	1.9
42 – 48	7	15	1.3
48 – 54	4	10	0.9
54 – 60	4	4	0.3
60 – 66	2	4	0.3
66 – 72	2	6	0.5
>72	10	30	2.6
total	**1544**	**1175**	100.0

The analysis of the treatment of the patient population also showed that the repeated episodes in the SIRS process are also a crucial factor of rising costs for the ICU, because the patients with several SIRS episodes received significantly more frequent and longer medical treatment than those patients who had no SIRS or only one SIRS episode. The resulting mortality SIRS to severe SIRS is shown in Fig. 4.

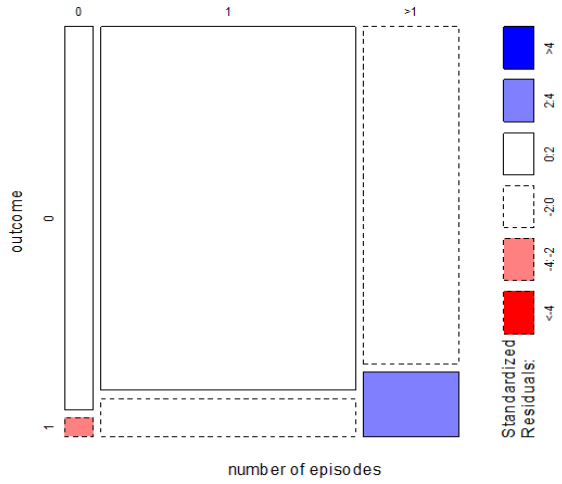


Figure 4: Mortality from SIRS to severe SIRS.

3.2 FuzzyKBWean System

The bedside real time application of FuzzyKBWean is shown in Fig. 5. The user interface has two main- units. The online (real time-data) unit, and a so called history (data base related) unit. It is possible to toggle between these units, so that always one or both of them have the focus. The top panel displays actual values and proposals, middle panel allows data review from any previous time point and, bottom panel displays key variables of the ventilation process together with the proposed new settings.



Figure 5: FuzzyKBWean frame application

The system is continuously being tested with prospective randomized cases currently undergoing treatment. It can be found that the clinical staffs react with a longer delay to hyper- or hypoventilation then the program does. The mean delay in case of hyper- ventilation was 127 minutes, Standard Error of Mean (SEM) 34; the corresponding value for hypoventilation was 50 minutes (SEM 21). The obtained results confirm the applicability

of FuzzyKBWean to represent medical knowledge, thus rendering the weaning process transparent and comprehensible. Periods of deviation from the target are shorter with FuzzyKBWean.
Due to the system is an open loop system, and therefore manual settings of the ventilator cannot be very precise, the utilisation is poor. Only a closed-loop application, i.e. a direct connection between the system and the ventilator, would allow smooth adaptation continuously.
To increase the usability of an open-loop system a more intuitive user interface has been developed.
In order for physicians to be able to make weaning decisions at the bedside, they need to be able to easily retrieve, digest, manipulate, and utilize information relevant to the decision making process. An interface approach that visualizes the actual patient status in the current weaning variation of time is shown in Fig. 6.

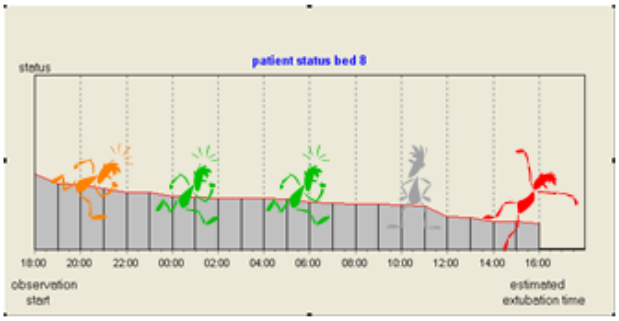


Figure 6: Progressive weaning and patient actual status

The goal is to find out an intuitive user interface that is as simple as possible and even so gives the physician a good perception where the patient is currently positioned in the weaning variation of time.

4. CONCLUSIONS

When CDSS or DSS in general where initially developed, each knowledge base and inference mechanism required programming before the knowledge base content could be written. As the field evolved, researchers found that it was possible to separate the inference mechanism from the domain specific knowledge and databases. This key design feature became responsible for the commercial success of decision support systems. Producing standard inference mechanism and knowledge bases made it possible to unplug one knowledge base and then connect a different one.
In medicine it is the uncertainty found in the process of diagnosis of disease that has most frequently been the focus of applications of fuzzy set theory. Two fields of fuzzy applications were developed since the nineteen seventies: intelligent patient monitoring systems and computer assisted diagnostic systems. Both developments of Zadeh's rule of max-min composition, namely fuzzy relations and fuzzy control, have been applied in these areas. As mentioned above, computer-assisted systems using fuzzy methods will be better able to manage the complex control tasks of physicians than common tools. Most control applications in the hospital setting have to be performed within critical deadlines.
Fuzzy Logic in medicine is still a largely untapped area that holds great promise for increasing the efficiency and reliability of health care delivery. The principles behind fuzzy logic are straightforward and its implementation in software is relatively easy.
Based on the literature, current computer-based clinical CDSS or Fuzzy-CDS systems (FCDSS) are limited in application. Roughly seventy known proprietary medical CDSS exists. Only ten out of seventy CDSSs geared towards routinely use. There is no information available about a real daily average usage of these systems.
A well-designed CDSS should have the potential to assist physicians who can and do use it as often as possible in the daily routine work. In some situations physicians learns from using a CDSS about criteria, facts or process issues that need to be considered in a specific decision situation. CDSSs encourage and promote "rationality" in decision making. CDSSs are intended to support not replace physicians, so the users need to consciously interact with a CDSS to use it effectively.
A big issue is that the expectation needs to be created that the physicians are the ultimate authority and that the physicians can anytime "over rule" or choose to ignore analyses and recommendations of the CDSS.
The greatest anticipated benefit of a CDSS lies in the constituency and uniformity in applying decision criteria of a given situation. Physicians have difficulty making decisions because they cannot exhaustively consider every factor relevant to the decision, due to either limited memory or limited information.
Anticipated limitations of CDSSs are that an optimal physician's treatment requires that physicians be able to have the following information, in real time, if possible:
What is happening right now? What will happen in the future? What do I need to create the future I want? To answer these questions effectively, physicians requires data that are factual, factual inferential (why type questions) and predictive (what if questions). To date, the best support that a CDSS has been able to provide is data that answer factual and maybe some forms of predictive questions [26].
Physicians have no shortage of data available to them. Thus, physicians have found that currently available CDSSs are not able to meet their more complex information needs. As mentioned above one big argument of the rare utilization at this time is that most of the CDSSs have not progressed beyond the prototype stage.
There are no standards or universally accepted evaluation or validation methodologies to ensure that the system's knowledge base is complete and correct.
Further questions about CDSSs are: Does the use of a CDDS improve the quality of decisions produced? And are the economic or other benefits, as for instance patients comfort, attributable to the use of the CDSS?
The absence of a well defined or universal evaluation methodology makes these questions difficult to answer.

To date, an examination of the literature indicates that there is virtually no information available related to the cost or cost effectiveness of CDSSs.

Most of the CDSSs are university-based developments, and still in prototype stage. These costs regarding the initial investment of CDDSs tend to be hidden and therefore difficult to access.

This frightens or hinders the industry's interest in funding and encouraging the development of CDSSs in health care in general [25].

Still, many physicians have a real positive outlook on the potential for these systems, particularly relating to practitioner performance. However, until the use of CDSS is a routine as the use of the blood pressure cuff, it is important to be sensitive to resistance to using these systems.

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Improving Nanoobject Detection in Optical Biosensor Data

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ABSTRACT

The importance of real-time capable mobile biosensors increases in face of rising numbers of global virus epidemics. Such biosensors can be used for on-site diagnosis, e.g. at airports, to prevent further spread of virus-transmitted diseases, by answering the question whether or not a sample contains a certain virus. In-depth laboratory analysis might furthermore demand for measurements of the concentration of virus particles in a sample. The novel PAMONO sensor technique allows for accomplishing both tasks. One of its basic prerequisites is an efficient analysis of the biosensor image data by means of digital image processing and classification. In this study, we present a high performance approach to this analysis: The diagnosis whether a virus occurs in the sample can be carried out in real-time with high accuracy. An estimate of the concentration can be obtained in real-time as well, if that concentration is not too high.

The contribution of this work is an optimization of our processing pipeline used for PAMONO sensor data analysis. The following objectives are optimized: detection-quality, speed and consumption of resources (e.g. energy, memory). Thus our approach respects the constraints imposed by medical applicability, as well as the constraints on resource consumption arising in embedded systems. The parameters to be optimized are descriptive (virus appearance parameters) and hardware-related (design space exploration).

Keywords

Biosensor, GPGPU, PAMONO, Design Space Exploration, Energy Awareness

1 INTRODUCTION

Advances in optical microscopy enable detection of viruses which can then be used for a rapid and distributed epidemic infection control. A novel technique which can achieve the latter is called PAMONO (Plasmon assisted Microscopy of Nano-Size Objects) [8, 10]. It provides the possibility to selectively detect different type of nanoobjects, especially viruses, in case the particles could be immobilized on the sensor surface. Virus types could be distinguished by applying different antigenes or antibodies to the gold layer. PAMONO not only enables an on-site detection of a small amount of viruses but also a detection in real-time which means that the result of a detection in progress can be visualized online while inserting the specimen. The PAMONO sensor unit produces a videostream, which is 1000×500 pixels in size and has a framerate of 30 frames per second. On-site application of mobile biosensors demands to take resource constraints into account, as sensor data analysis has to be carried out in embedded systems. On the other hand real-time analysis demands for high processing power. Thus a GPGPU (General Purpose computing on Graphics Processing Unit) approach was taken.

Despite an enormous amount of GPGPU application papers, in particular, related work in the context of design

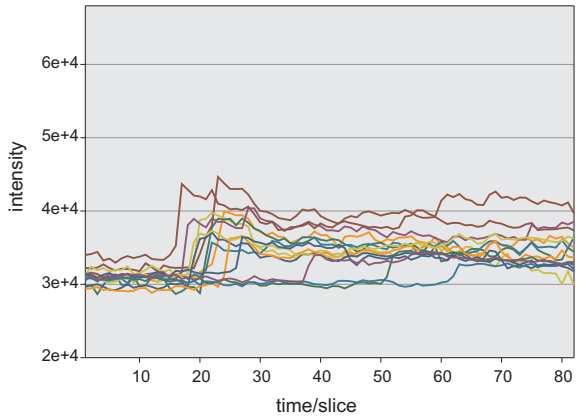


Figure 1: Intensity over time for different pixel positions

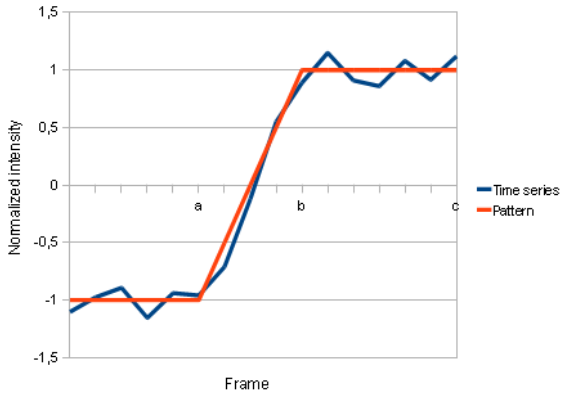


Figure 2: The scaled input time series (blue) is matched to a pattern (red). The pattern is represented by the descriptive parameters a, b and c.

space exploration is important. Especially in the design process in the field of embedded systems a design space exploration can be done at design time to get an optimal system configuration. In this domain, many different approaches [1, 3, 6, 9] exist which provide the capability to automatically explore a design space with objectives such as energy, performance and heat dissipation. The design space exploration in this work takes the detection quality, performance and energy into account.

This work is structured as follows: Section 2 describes a parameterized processing pipeline for the detection of viruses in PAMONO sensor data, followed by a genetic optimization of the descriptive parameters for virus adhesions. Section 3 presents design-time optimization of the consumption of resources by performing a design-space exploration. Finally, sections 4 and 5 provide results and discussion.

2 GPGPU-based Analysis of PAMONO Sensor Data

Our approach is divided into two basic steps. First, the detection of the viruses and second, the optimization of the parameters for an effective detection.

Detection of the Viruses

The detection of the viruses is accomplished by analyzing the video-stream produced by the PAMONO sensor using a graphics processing device. For maximizing the detection quality of the analysis we use a generic approach. The detection process is summarized as follows. First the input data is preprocessed by removing the constant background image and applying a Haar-wavelet noise reduction. The noise reduction process is done in a high parallel manner. For input images of size $M \times N$ pixels the filtering is done in $M \cdot N$ independent threads with $4M \cdot N$ global read/write accesses for each frame.

In the second step, each per pixel time series is matched to a variable pattern, resulting in a pre-classification of all pixels in space as virus candidates. Every virus adhesion to the PAMONO sensor produces a small ($< 6\%$) ascending slope of the intensity in the video-stream at the corresponding pixels. Before and after the adhesion the intensity remains constant. To identify these pixels we use pattern matching. Figure 1 shows some selected time series of virus adhesions.

The pattern (figure 2) is represented by the descriptive parameters a, b and c. The pattern is -1 for the first a values, followed by a linear ascent for the next $b - a$ values and a value of 1 for the last $c - b$. The matching of the pattern to the time series is achieved by scaling the time series to the range of the pattern and then calculating the sum of squared differences (SSD) between these two. If the SSD is below a threshold, the pixel is classified as a virus candidate pixel. The scaled time series is for all types of viruses the same and could be encountered with one pattern. Different types affect the intensity change to some degree, but not the slope of the ascent. The slope can be influenced by how the sensor is functionalized, which could also change the absolute intensity of the ascent.

Each thread on the GPU matches one of the $M \times N$ time series (compare with figure 1).

In the last step the single pixels are combined to polygonal segments, by tracing the borders of the detected pixel areas. The polygons are tracked over time to combine associated polygons. The remaining polygons are then classified as viruses/non-viruses, based on their form factors [4].

All steps, except the tracing of the polygons, are done in time space. Each pixel position is independent from others. This allows the processing of exact one pixel position by each lightweight thread on the GPU without synchronization, which takes the full advantage of the GPU.

The scaling behavior of the algorithms in the steps can be evaluated by increasing the number of cores until the fur-

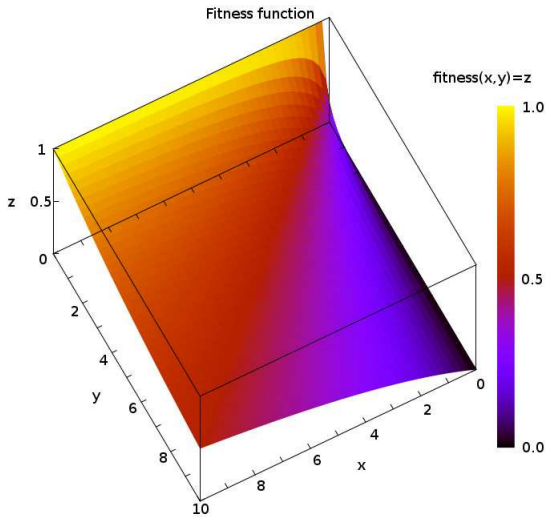


Figure 3: Fitness function with x as the true positive detections, y the sum of false positive and false negative detections and z the resulting fitness value.

ther increase does not lead to a speedup of the pipeline. Especially, in case that a GPGPU application is memory bounded, meaning that it needs a numerous number of main memory transfers, an increasing number of processing cores will not increase the performance when reaching a certain threshold. Furthermore, the performance will not scale with the number of cores if there are too many data dependencies inside the kernels making synchronization necessary. A detail analysis can be found in [7].

Parameter Optimization

Since the optimal values for the parameters of the pattern matching – a, b, c and the threshold – are unknown, an optimization with a genetic algorithm is employed. For an introduction to genetic algorithms see [5]. The chromosome, which is used by the genetic algorithm to generate a population, is built of four genes. Each gene represents one parameter of the optimization. The genes one to three define the size and shape of the pattern and are given by a, b and c as used for defining the pattern. The fourth gene defines a threshold for the SSD between the observed time series and the pattern.

To determine the fitness of a given population, the detected particles are compared to manually annotated data. The true positives (tp), false positives (fp) and false negatives (fn) are computed by automatically matching the detected polygons with manual segmented data. With these values the accuracy, defined as $\frac{tp+tn}{tp+fn+fp+tn}$ [2], is given and selected for the fitness function. As illustrated in figure 3, the fitness function returns a larger value if the true positives outweigh the false classified. The true negatives (tn) are set to zero, because they are not properly defined in this context. A population size of 80 is chosen, the starting population is created with random chromosomes and the fittest individual of each population is propagated to the next generation. If the fitness function reaches the desired accuracy or a specified number of generations is attained, the genetic algorithm returns the best obtained parameters for the pattern matching.

Datasets	Precision	Recall	Accuracy
280 nm	95 %	90 %	86 %
200 nm	87 %	91 %	80 %
VLPs	80 %	86 %	71 %

Table 1: Detection results of different datasets, based on true positives, false positives and false negatives.

3 DESIGN SPACE EXPLORATION

The process of designing a GPGPU-accelerated device like the data analysis system presented, involves a design space exploration (DSE). DSE optimizes the hardware-related parameters of the system with respect to resource restrictions. Especially the objectives *run time* and *energy consumption* are of concern here. The first objective is important in order to realize a system which is capable of visualizing results of the virus detection in real-time while the latter is crucial for mobile devices. The parameters which are evaluated are e.g. the number of required processing units, the amount of memory used and the mapping on the processing cores.

4 RESULTS

The results to be presented in this section comprise the optimization of the detection rate and the design space exploration for different numbers of parallel processing cores.

The experiment set-up was made with a QPhotonics superluminiscent diode QSDM-680-9 and a Kappa DX40-1020FW camera which recorded the images. Different sizes and types of particles are used, amounting to datasets with 280 nm- and 200 nm-sized synthetic particles and virus like particles (VLPs).

The genetic algorithm took about four hours for each dataset with about 22.000 single runs of the pipeline. Due to the parallel GPGPU approach, and caching of the input images, the resulting frame rate exceeds 220 frames per second on a GeForce GTX 480. If the images could be provided faster, the possible throughput of the GPU pipeline is about 2.000 frames per second (images 512×50 pixels, scaling to bigger images is linear).

The results for the improvement of the detection quality are shown in table 1, quantifying precision, recall and accuracy, where the latter serves as the fitness function. The detection quality depends on the particle size.

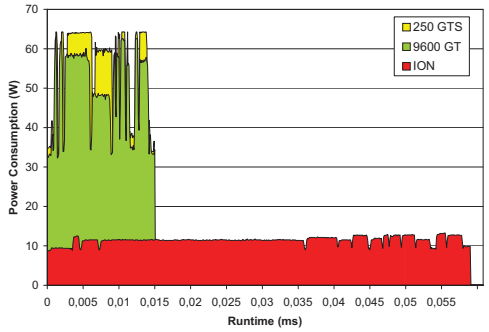


Figure 4: Power Consumption over Application Runtime with Different Processing Cores Number

Three different graphics cards where used for the design space exploration: ION (16 Cores), 9600GT (64 Cores) and 250GTS (128 Cores). As can been seen from figure 4, the runtimes of the image processing and analysis are improving with the number of cores but with a lower factor when scaling from 64 to 128 cores. This indicates that one bottleneck for the speedup is the memory and the second bottleneck is the data dependency of the application. On the other hand, the energy consumption – integral of the power consumption curve over time –, is not improving anymore when switching from 9600GT to 250GTS.

5 DISCUSSION

A method to optimize the descriptive and hardware-related parameters of our processing pipeline for PAMONO sensor data was presented. An automated detection of viruses in such data can be carried out in real-time, using GPGPU computing. The detection can be used to distinguish different types of viruses by applying different coatings to the gold layer. Despite the early stage of development, the detection results are promising in terms of accuracy.

Future research in the analysis of PAMONO sensor data aims at an enhancement of the presented processing pipeline, followed by a multi-objective optimization using machine learning techniques. This enables decomposition of the objective of accuracy into precision and recall, as well as a simultaneous optimization of the objectives speed and consumption of resources. Suitable features beyond time series are to be identified that take into account not only the temporal but also the two spatial dimensions of PAMONO data.

Beyond the descriptive and hardware-related parameters covered in this work, an extended pipeline gives rise to a third class of parameters to be optimized: the computational parameters of the processing pipeline, like e.g. choice of algorithms for preprocessing and classification, thresholds, and the features to be computed for matching. These computational parameters affect all objectives: detection quality, speed and consumption of resources. The next step to be taken is optimizing these computational parameters on a given platform. This encompasses learning the descriptive parameters with respect to the chosen features, i.e. learning the characteristic values those features assume for viruses. The goal of this optimization is improving detection quality (precision and recall) while maintaining the real-time capabilities of the current pipeline and minimizing consumption of resources on the given mobile platform. Achieving these goals means developing the foundation for a mobile PAMONO sensor and analysis device.

Acknowledgment

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Using neighboring domains towards setting the foundations for Enterprise Interoperability science

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ABSTRACT

Collaborative networked environments emerged with the spread of the internet, contributing to overcome past communication barriers, and identifying interoperability as an essential property. Since then, Enterprise Interoperability (EI) has solidified as a well established area of applied research studying the problems, and proposing novel solutions towards interoperability problems. However, in spite of research efforts to date, the proper scientific foundations for EI remain intangible. The paper presents a proposal to analyze neighboring research domains of EI and take insights to support in the settings for the foundations of Enterprise Interoperability science. After an introduction of EI research domain and its motivation and needs to have it developed as a science-base, the authors propose a methodology and action plan to implement it. The proposal presented has been validated by a large community of researchers working in the EI domain, with the support of the European Commission, through the Future Internet and Enterprise Systems (FInES) cluster of research projects, lead by the ENSEMBLE project.

Keywords: Enterprise Interoperability, Science-base, Applied Sciences, Social Sciences, Formal Sciences.

1. INTRODUCTION

Philosopher Karl Popper (1902-1994) said that a statement can only be scientific if it is open to the logical possibility of being found false [1]. This assertion means that scientific statements are evaluated by testing them, and comparing to the world around. Also, a statement is considered non-scientific if it takes no risk of being found false, i.e., when it cannot be tested against observable facts or events [2,3]. An implication of this definition is that one can never be completely sure that any scientific theory is true. This way, accepted scientific theory is only valid since it has not yet been contradicted by evidence, though the future may bring a contradiction. Popper saw the growth of scientific knowledge as a process of conjecture and refutation, and if further observation is inconsistent with the theory, it should then be considered refuted and a new theory or conjecture found [1]. In contrast, if the original explanation is non-scientific, it will never be refuted and there will never be any need to change beliefs.

The concept of science is, therefore, related with observable knowledge, described in the form of testable laws and theories [2,3]. Nevertheless, there is a plurality of sciences that differ very much from each other. For example, physics is universally accepted as a well-defined science, but there are others that are not so, such as history or linguistics. Consequently, the definition of science is difficult and ambiguous [4].

It can be agreed that formalisms like logic and mathematics are an integrant part of every science, i.e., they are essential for physics, less important for chemistry and biology, and their significance continues to decrease towards the more social and humanistic sciences spectrum. Thus, in terms of content, scientific domains exists in an ecosystem of neighboring domains, and must recognize its relationship with these neighbors and with formal definitions of science bases already established for them. Normally, this relationship includes:

1) Boundaries between application fields, which may be fuzzy in the sense that there are some fields which despite being common to more than one scientific domain, could be addressed from the perspective of either domain.
2) Shared methodologies, techniques and tools which may be applicable to problems in more than one domain. Recognition of such sharing provides the opportunity for domains to advance by absorbing methodological and technical advances from related disciplines.
3) Conflicts in approach may also exist, and present possible barriers to interdisciplinary research or application. Formal documentation of such conflict areas will reduce risk of failure in projects arising out of the application of incompatible approaches.

Modern sciences introduce a paradigm shift since, unlike the traditional philosophy of science, they usually do not apply to a single domain, being interdisciplinary and eclectic. Modern sciences enlarged the neighboring ecosystem searching their methods and raising research questions in broad areas, crossing borders and engineering different scientific fields. For example, the modern computer science embraces formalisms and algorithms created to support particular desired behavior using concepts from physics, chemistry, and biology [4,5]. Thus, being also a multi-disciplinary domain by nature, the establishment of enterprise interoperability (EI) scientific base should be developed comprising concepts and theories from related neighboring sciences and scientific domains [6].

This paper explores EI neighboring domains, presenting in section 2, an overview of EI domain, as well as its motivations and needs towards having it defined as a science-based domain. On section 3 the authors propose a methodology to define an action plan for the science-base definition based on experience from neighboring scientific domains. On section 4, a reference taxonomy for the neighboring domains identification is presented, and their relationship with some of the several EI layers is analyzed. Finally, on section 5, the authors conclude on the findings and depict some of the future steps towards the development of the EI science base (EISB).

2. ENTERPRISE INTEROPERABILITY (EI)

Interoperability is defined by the IEEE Standard Computer Dictionary as the ability that two or more systems have to exchange information and use it accurately [7]. Apart from being a technical issue, interoperability challenges also appear in enterprises at organizational and semantic levels, underscoring the need for patterns and solutions that support the seamless cooperation among ICT systems, information and knowledge, organizational structures, and people [8,9]. As information systems in enterprises and organizations evolve and become more complex, the need for interoperable operation, automated data interchange, and coordinated behavior of large-scale infrastructures is gaining increasing importance [10]. Moreover, with the advent of globalization, today an enterprise's competitiveness is to a large extent determined by its ability to seamlessly interoperate with others [11-13]. The advantage of one enterprise over another stems from the way it manages its process of innovation and reduces costs. Therefore, EI has become an important area of research to ensure the competitiveness and growth of European enterprises.

Research has significantly advanced the field of EI in a number of areas over the past few years. Nowadays, it is a well-established applied research area, studying the problems related with the lack of interoperability in the organizations, and proposing novel methods and frameworks to contribute with innovative solutions for EI problems. One of the principal tools that have emerged for addressing interoperability challenges are the various standards that seek to govern the development of information systems and their operation [14]. However, such standards are usually linked with specific market sectors, application areas, or technology trends, and thus have a limited time span, a static nature, and quite often different interpretations amongst technology vendors and users [15,16]. Whereas in the past it was said that EI was unachievable until seamless interaction could take place at the technical, semantic, and organizational layers of interoperability and at all levels of the enterprise [17], today this vision is extended, foreseeing that EI will be fully achieved only when the benefits brought by the new technology paradigms are harvested, including those of the Future Internet[1], e.g., Internet of Things, Internet of Services. Thus, it is very likely that the Future Internet will give rise to new opportunities for creativity and innovation, enable new forms of participation, and further catalyze the formation of networked enterprises and communities that span the world, thereby ushering in a new generation of enterprise systems requiring a reappraisal of interoperability between those systems [18].

Raising a science base for EI

Pragmatically, in spite of the research developed so far, nowadays it was not yet established the scientific foundations for EI. This is a deficit recognized by the EI research community, disabling the generalization and complete reuse of the methods and tools that have been developed both with commercial and collaborative research purposes, namely within the multiple European supported projects (see Table 1). The need to develop an EISB was first documented in the Enterprise Interoperability Research Roadmap [19], specifying it as one of four main grand research challenges to be addressed by researchers and international experts in the domain. This document has been revisited in 2010 [20], and still recognizes that, in spite of the research developed to date, the scientific foundations for EI have not been properly formalized. This is identified as a barrier to the generalization and full use of the methods and tools that have been developed so far, threatening its sustainability [6,21].

Table 1 – Reference projects in the EI domain

Project Acronym	Principal Technical Targets/Results
IDEAS [22]	• State of the art and user requirements in the areas of: architecture & platforms, enterprise modeling and ontology; • Vision and strategic roadmap in the domain of enterprise application & software interoperability
InterOP [23]	• Common Enterprise Modeling Framework for distributed environments • Ontology-based Integration of Enterprise Modeling and Architecture & Platforms • New architectures and platforms for Interoperability
ATHENA [24]	• ATHENA Interoperability Framework, addressing business, service composition and model driven requirements • Interoperability Impact Analysis Model • Enterprise Interoperability Centre (EIC) services and infrastructure • Collaborative Enterprise Modeling Platform • Ontology-based Semantic Annotation and Reconciliation method/language/tool
ABILITIES [25]	• Intelligent and adaptive UBL active messages (an Application Bus for EAI) • Basic interoperability service
GENESIS [26]	• Genesis e-Business Framework • Middleware software components for SME's financial applications
STASIS [27]	• STASIS Desktop Application • STASIS Analyzer, Viewer, Comparator, Purifier, and Storage plugins
COIN [28]	• COIN generic service platform (GSP) • Services for enterprise, information, knowledge, and business interoperability • Services for collaborative product development, production planning, project management, and human interaction • Enterprise Interoperability Value Proposition • SaaS-U Business Models and Enterprise Collaboration Maturity Model
COMMIUS [29]	• Open source framework for interoperability and collaboration focused on SME's needs • Methods and components for system and process interoperability • Framework for semantic interoperability

To cover this gap, the European Commission DG Information Society and Media initiated a Task Force on Enterprise Interoperability Science Base (EISB), which announced an initial agenda within 2009 [30], and identified that the approach to follow should be similar to those of other neighboring domains, such as the Software Science [11]. In that case and according to Redwine and Riddle [31], software technologies

[1] www.future-internet.eu/

have been developed and propagated from the 1980s, through 6 typical phases:

1) Foundational Principles, to investigate basic ideas and concepts, put an initial structure on the problem, and frame critical research questions.
2) Concept formulation, to circulate ideas informally, develop a research community, converge on a compatible set of ideas, solve specific sub-problems, and refine the problem's structure.
3) Development and extension, to explore preliminary applications of the technology, clarify underlying ideas, and generalize the approach.
4) Internal enhancement and exploration, to extend the approach to other domains, use the technology for real problems, stabilize the technology, develop training materials, and show value in the results
5) External enhancement and exploration, which resembles phase 4 but involves a broader community of people who aren't developers, show substantial evidence of value and applicability, and flesh out the details to provide a complete system solution.
6) Popularization, to develop production-quality, supported versions of the technology, commercialize and market the technology, and expand the user community.

Late in 2010, the EMSEMBLE project was launched to provide an official support on establishing the backbone towards the EISB formulation [32]. Special attention is given on scientific knowledge from distributed enterprise systems, shared data and semantics, evolutive applications, dynamics, and adaptation of networked systems on a global scale. These are all directly related with major requirements for interoperability, such as rapid evolution of technology and applications, plug and play instruments, self monitoring capabilities, benchmarking and evaluation of degrading processing, automatic and on-demand reprocessing, recompiling, and fixing of components and processes [10].

3. APPROACH FOR EISB ACTION PLAN DEFINITION BASED ON NEIGHBORING SCIENTIFIC DOMAINS

An action plan for establishing the scientific foundations of a domain defines a concrete set of activities that need to be collectively undertaken by stakeholders with different backgrounds in a logical time frame in order to eventually lead to the general recognition of its scientific rigorousness. However, before that action plan can be defined, a number of steps need to be overcome. Recognizing them, the authors have drawn a methodology towards the definition of the action plan for the EISB formulation (Figure 1). It is based on 7 steps.

The first is the problem identification, and as explained before has been recognized some years ago in Enterprise Interoperability Research Roadmap [19] (section 2). The second is related to the analysis of processes followed by other newly born sciences. A very successful example is the one of Software science, as described in the previous section, but others also exist (e.g. web science). After this, follows core contribution of this paper, with the identification and structuring of the neighboring domains which enable "learning" and "extensibility" steps (more details in section 4). In the "learning" step, those neighbors are analyzed in terms contributions with formal methods for EI problems and solutions description, whereas the "extensibility" step evaluates the interdisciplinary nature of EI, by recognizing evidences of interoperability in the neighboring scientific domains. Finally, having concluded both of them, "conceptualization" can begin formalizing the definitions of contents and structure of the EISB framework which will be instantiated through the more detailed and EI focused action plan that leads to emergence of a new science. Due to space constraints, these two steps are not presented in this paper.

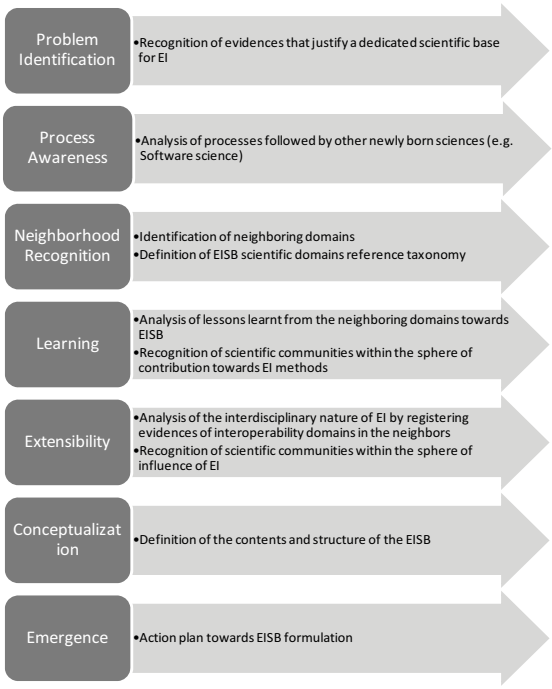


Figure 1 – Methodology towards the definition of the action plan for the EISB formulation

Neighborhood recognition

Social sciences, applied sciences and formal sciences are recognized in the general classification of scientific domains. In all of them, characteristics of interoperability are identified, and the authors consider them to be promising contributors for the EISB formulation, thus propose a three-level structure for the EISB scientific domain reference taxonomy (EISB-SDRT). This model is inspired by several classification structures such as: 1) the AMS mathematics subject classification [33]; 2) the ACM computing classification system [34]; 3) the European Science Foundation research areas [35]; and 4) the SCIENCE magazine subject collections [36]. The rationale for the selected scientific sub-domains and proposed taxonomy is related with the identification of evidences of interoperability issues in each of the scientific sub-domains foreseen. For example, EI implies seamless communications within networked enterprise environments, which are complex systems, emerging in many forms and from different application domains, consisting of many facets whose proper understanding requires the contribution from multiple disciplines. All possess strong theoretical background, mostly based on neighboring domains. The scientific foundations

related with the major EI research topics can be worked out based on the proposed EISB-SDRT and then connected with the results of the existing applied research, for instance with the scientific domains of systems complexity, network science, information theory, or web science.

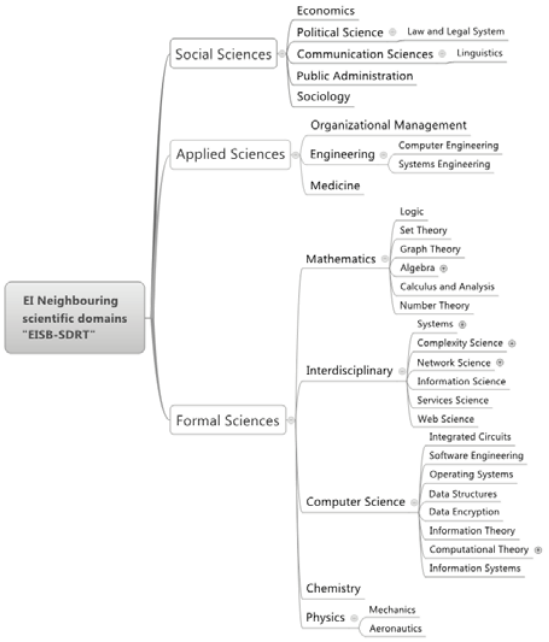


Figure 2 - EISB scientific domain reference taxonomy

Focusing on Social Sciences, those considered of major relevance and highlighted in the EISB-SDRT are within Sociology, Public Administration, Communication Sciences (e.g. Linguistics), Political Sciences (e.g. Law and Legal Systems) and Economics. Concerning Applied Sciences, they were identified of major relevance Medicine, Organizational Management and Engineering, especially those regarding Computer and Systems Engineering. Formal Sciences are considered fundamental for the foundations of EISB. Investigating them and relating them with the EI requirements, it is expected that formalisms for EI can be outlined. Mathematics is the first domain of relevance, particularly on sub-domains of Logic, Set Theory, Graph Theory, Algebra, Calculus and Analysis and Number Theory. Also, Computer Science has main significance in the sub-domains of Software Engineering, Information Systems, Computational Theory, Information Theory, Data Encryption, Data Structures, Operating Systems and Integrated Circuits. Nevertheless, the Interdisciplinary sub-domain has been identified as core for the foundations for EISB, especially on Complexity Science, Systems, Network Science, Information Science, Services Science and Web Science. The sub-domains of Chemistry and Physics, like mechanics and aeronautics, are also considered of relevance for the study presented in the following sections.

This taxonomy is currently available at the ENSEMBLE portal (http://www.fines-cluster.eu/fines/wp/d21/) for deliberation, i.e. the projects is supporting it, and has made it open for experts to contribute. This way, the authors envisage it may grow towards a unified vision of the EI neighbouring scientific domains.

Learning from neighboring domains

This section analyses some scientific domains in the EISB-SDRT, focusing on how they can contribute to the establishment of the EISB. This analysis takes in consideration the work of Charalabidis et al [30], which identified practical applications connected with scientific domains to be used as a reference to formally describe the interoperability problems. Lessons from Social Sciences: Sociology involves systematic methods of empirical research, analysis of data, and the assessment of theories. Unlike the natural world, which can be accepted as it is seen (e.g. a biologist can study the nucleus of a cell because (s)he can observe it with a microscope), society is different, because it is not an object with physical existence that can be directly scrutinized through our senses [37]. Society consists of groupings of humans, and its study looks at the way these groupings behave. When a sociologist studies society (s)he looks at behaviour and the mind, which do not take physical form [38,39]. Insofar as they exist between individuals and groups in a social context interoperability issues are similar. This includes (seamless) communication between individuals and groups, independent of the culture, and verbal or gestural languages. Instances of how these phenomena have been addressed by the science of sociology can be used as referential examples in the context of EI. Nevertheless, the technological feature of the interoperability problem also has an impact on the sociological dimension, and on the social sciences in general, as the sharing of data has been very limited. According to Hughes et al. [40], the reasons for this limited sharing reside in strong concerns about privacy and the lack of appropriate contextual knowledge. However, the problem of interoperability between software tools commonly used for data annotation and coding by social scientists, is a critical issue, even if the other problems so far identified are resolved.

Lessons from Applied Sciences: Medicine has been contributing to the solutions for some major interoperability problems concerning the human body, such as compatibility between organs in transplants. Friedman and Peters explain that today medicine advances numerous scientific strategies to face incompatibilities in live-donor-organ (e.g. kidney) challenges, and achieve an acceptable organ match [41]. For example, this allows physicians to match a donated organ with a patient needing a transplant, identifying an organ that has lesser likelihood of rejection by the recipient. Nevertheless, at the organisational level new technologies are being introduced in hospitals at an increasing rate, and the ability to have this or that medical device immediately working in tandem with any other is a priority among healthcare providers that is recognised throughout the industry. Concerning patient data, today the major enabler of health care information sharing is the electronic health record (EHR), which contains all of a patient's pertinent health care data in a shareable form, integrating functions similar to that of the bill of materials (BOM) in manufacturing [42]. Still in the domains of medicine, an example of success is the cancer Biomedical Informatics Grid, or caBIG [43], which connects several Cancer Centers, research organisations, and companies. Capabilities compliant with caBIG interoperability specifications enable the collection, analysis, and exchange of a wide range of biomedical information through a well-integrated, standards-based infrastructure coupled with open-source and commercial software applications. These technologies create an integrated electronic system that enables clinical research, genomics, medical images, bio specimens, and patient outcome data to

flow easily but securely between and among authorized individuals, organisations, and institutions. With it, it is possible to identify molecularly sub-grouped patients, collect and view patients' histories individually and in aggregate, and collaborate across organisations to test research hypotheses and evaluate new treatments.

Lessons from Formal Sciences: These are the ones most can offer to EISB in terms of formal methods for EI problems and solutions description. An example from this area can be observed in complex systems, which, as in EI, have many structures and relationships. Understanding their interactions is considered to be a major factor in contributing to the success of interoperability solutions and the performance of the entire enterprise. Implicit in both is the view that enterprises are Complex and Adaptive Systems. Preliminary theories have been advanced in specific scientific disciplines, such as biology and ecology, to explain the importance and evolution of complexity in these "systems" [44,45]. Some researchers have attempted to extrapolate these results to a "general systems theory" that could explain the importance and behaviour of systems in all fields of science [46,47]. However, in the eyes of complexity theorists, all systems are dynamic, "living" entities that are goal-oriented and evolve over time. Complexity science, which is generally considered as a branch of systems science, has been developed to address the emergence, adaptation, evolution, and self-organisation of systems [48].

Contributions from this scientific domain to EISB include: system behaviour and adaptability; the "system" aspects of interoperability, from software component design to organisational structure to the "ICT fabric" that provides communication, collaboration, and coordination facilities; the technology trajectory of interoperability as a complex system.

Extensibility to neighboring domains

By analyzing the EISB-SDRT scientific domains to evaluate where there is evidence of interoperability in the levels of business, knowledge, applications, and semantics [9,17], one can determine whether EI is relevant in the context of each scientific domain. This analysis confirms the inter-relationship(s) that other domains have with EI, namely its interdisciplinary nature. The result of this analysis is depicted in Table 2, where the score 3 indicates strong evidence of interoperability in the domain, and the score 0 indicates its absence. The following main findings are obtained:

- Within the social sciences area, it is knowledge and also semantic-based interoperability that has proved to be more important amongst the domains analyzed. In these areas it is quite important to address people-driven information, such as skills, competences, and data interpretation;
- Within the applied sciences, such as medicine or engineering, in addition to the knowledge level, the EI level of applications and data is revealed to be of utmost importance, due especially to the need to keep methods, tools, and services integrated in a seamless manner;
- In the case of formal sciences, the spectrum of neighboring disciplines is much broader. The results vary, demonstrating that interoperability is an integral part of wider-scoped sciences and less so in more concrete ones, such as mathematics.

Table 2 - EI relevance in the context of neighboring scientific domain

		Enterprise Interoperability levels			
		Business	Knowledge	Applications & Data	Semantics
Economics		3	2	1	1
Political Science	Law and Legal System	2	3	0	2
Communication Sciences	Linguistics	0	2	2	3
Public Administration		2	3	2	1
Sociology		0	3	1	3
Organizational Management		3	2	2	2
Engineering	Computer Engineering	1	2	3	2
	Systems Engineering	2	2	2	1
Medicine		1	3	2	3
Mathematics	Logic	0	0	1	0
	Set Theory	0	0	1	0
	Graph Theory	0	0	1	0
	Algebra	0	0	1	0
	Calculus and Analysis	0	0	1	0
	Number Theory	0	0	1	0
Interdisciplinary	Systems	2	2	2	1
	Complexity Science	1	2	2	1
	Network Science	3	1	2	2
	Information Science	1	3	3	3
	Services Science	2	1	3	2
	Web Science	2	1	3	3
Computer Science	Integrated Circuits	0	1	2	0
	Software Engineering	2	1	3	2
	Operating Systems	1	1	3	1
	Data Structures	0	1	3	2
	Data Encryption	0	0	2	0
	Information Theory	0	0	1	0
	Computational Theory	0	0	1	0
	Information Systems	2	2	3	2
Chemistry		1	3	2	2
Physics	Mechanics	1	2	3	1
	Aeronautics	1	2	3	2

To illustrate and for the sake of space, only the specific example of the Network Science is brought to a deeper analysis. The ability and capability of enterprises to collaborate has been closely linked to the ability and capability of enterprises to interoperate. A key premise is that enterprise interoperability is a crucial enabler for networked organizations. The concept of networks as a representation of objects that are connected by some underlying structure has been applied to numerous problems in applied mathematics, engineering, and computer science. Specifically, network science has been concerned with the impact of structure on behavior. Thus, the way those objects are orchestrated is a target of active study and business interoperability results can be applied. In recent years, new advances in network science have resulted from the increased use of innovative applications, relating performance problems to communications structures including the Internet, the Web, and Grids. Research challenges in this domain include: EI and the adaptability, management, and efficiency of networks, e.g. random networks, scale free networks, small world networks, pervasive networks, social networks, clustered networks; "basic laws" for governing networks, and interoperability of digital networked ecosystems, etc. [49,50]. As the taxonomy, this analysis has been supported by the ENSEMBLE project, and is also currently available for deliberation so that it may grow towards a unified vision among the EI community.

4. CONCLUSIONS

Despite of the importance of enterprise interoperability in the global economy, there is as yet no established scientific base for EI. Due to this fact, situations such as network harmonization breaking with loss of interoperability have a great impact on the enterprise turnover, since nowadays generalization and full re-use of the methods and tools that

have been developed so far is still a great challenge due to the lack of an EISB. Therefore, it is of utmost importance to identify an scientific-base solid enough that embodies lessons learnt from the neighboring domains. The aim is to formalize interoperability problems and solutions, ultimately guaranteeing reusability and repeatability. The study of neighboring scientific domains leads to the conclusion that those most closely relevant to EI include social sciences and applied sciences, as well as formal sciences as represented by mathematics, systems science and computer science. The authors also identified in these domains recognition of four scientific levels of interoperability: business, knowledge, applications & data, and semantics; all of these are relevant to EI. The analysis of the EI extensibility to neighboring scientific domains, focused on proposed EISB-SDRT and analyzed across the 4 EI levels, identifies many important contributions that can be used as referential examples for the development of the foundations of EISB. The level of relevance found is not the same for all scientific sub-domains of EISB-SDRT, depending on the EI level aiming to address, and also on the significance of the scientific domain in the EI. It is, therefore, a complementary study to the one presented in the "learning from neighboring domains" section.

Concerning extensibility, the Applications and Data EI level is the one that somehow provides interoperability concepts/methods/solutions to practically all the neighboring scientific domains foreseen, thus has a clear interdisciplinary relevance. Mathematics, Systems and Computer Science are impacted primarily with the level of models and tools, whilst social and applied sciences find relevant contributions from all levels. However, in terms of lessons learnt, some of the identified formal sciences are providing much more input in terms of formal methods to describe interoperability processes, than receiving, e.g. Complexity. It is also important to note that each of these neighboring sciences contributes to both issues and understanding of interoperability, and to the process of foundation of a science base, which will be the further specified in the last two steps of the presented methodology, i.e. conceptualization and emergence. The results here presented have been validated by a large community of researchers working in the EI domain, with the support of the European Commission, through the Future Internet and Enterprise Systems (FInES) cluster of research projects, lead by the ENSEMBLE project. The results are available at the ENSEMBLE portal (http://www.fines-cluster.eu/fines/wp/d21/) for deliberation, so that more experts can contribute and validate this work, enabling it to grow towards a unified vision of the EI neighbouring scientific domains.

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Future Internet Enterprise Systems: A Semantic Approach for a Community-based Research Roadmap

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ABSTRACT

This paper presents the approach that will be followed by the Research Roadmapping activity within the task force of the Future Internet Enterprise Systems (FInES) Cluster, operating in the European Commission, aimed at producing the new FInES Research Roadmap by 2012. Due to the complexity of this task, in terms of subject domain, objective and team management, and the fact that a research roadmap needs a sound organization of the domain knowledge, a systematic approach based on advanced ICT solutions, especially for knowledge acquisition and collaborative management, has been defined. The key idea is that a complex terminological resource, of interest of a diversified community, cannot be developed and maintained by a restricted group of people. It is a socially-oriented resource and therefore the community as a whole must be able to constantly access such a resource and be active in its construction and maintenance (*folksonomy* approach). For these reasons, this paper firstly describes the organization of the FInES task force and the knowledge flow aimed at guaranteeing the production of a high quality research roadmap. Then it focuses on the organization of the knowledge base and the adopted methodology, which is rooted in the theory of Topic Maps.

Keywords: FInES, Research Roadmap, Enterprise Systems, Knowledge Management, Folksonomy.

1. INTRODUCTION

The production of a Research Roadmap (RR) is a very challenging activity, especially when it concerns a multifaceted domain, such as Future Internet Enterprise Systems.

According to the FInES Research Roadmap 2010 [1]: "*Future Internet Enterprise Systems (FInES) is a relatively recent domain that concerns a field of activity with the aim to improving the manner in which enterprises, by means of Information and Communications Technologies (ICT), may confront the future with confidence and integrity. This research domain, that combines Enterprise Interoperability, Enterprise Collaboration and Digital Ecosystems, is one important element of the overall research field of the Future Internet, and has a specific* ***research focus on ICT adoption and usage by enterprises***."

This paper presents the main lines driving the team work and organization to carry out the new Research Roadmapping activity within the task force (TF) of the FInES Cluster, operating in the European Commission (DG Information Society and Media, Unit D4), that will eventually produce the new FInES Research Roadmap 2012.

This research Roadmapping activity is particularly challenging for the level of complexity to be faced. Such a complexity can be seen in least three different, but tightly interrelated, areas.

The complexity of the ***subject domain***. FInES is positioned at the cross-road of several disciplines that per se represent active areas of advanced research. From management science to economic theories, from computer science to system theory, from networking to service science, from sociology to enterprise organization, just to name a few, we need to consider a plethora of research areas, competences, disciplines. The FInES RR Task Force needs to consider all of them within a unitary vision.

The complexity of the ***objective***. The objective of the FInES RR Task Force is to draw the future research lines for the FInES Cluster, within a plausible trend forecasting for each of the disciplines that contribute to the FInES domain. To achieve this objective, we need to be aware of what is relevant today and, even more challenging, what are the current and future trends, what the emerging solutions, and which solutions among them will be relevant in particular for the future of enterprises.

The complexity of the ***team management***. The FInES RR Task Force (as the other task forces created within the FInES Cluster) is not a typical working team, established within a given organization, with defined hierarchical relationships and dependency rules. Experience teaches us that the commitment of people (and the organizations they belong to) is often discontinuous, if not sporadic. There is a high level of turnover and never (to our knowledge) the initial team configuration remains the same until the end of the working period.

For the above reasons, we decided to base the work of the FInES RR on a systematic approach, supported by advanced ICT solutions. In particular, since a research roadmap is based on a systematic organization of the domain knowledge (i.e., on what exists in the domain and what will probably exist in the future) the first ICT platform we considered is aimed at the knowledge acquisition and management. Furthermore, since the activities will be performed by a team having the outlined characteristics, we need to adopt a web-based approach allowing remote, asynchronous, collaborative knowledge management (CKM). Then, to further empower the team members, we integrate the CKM platform with other platforms, e.g., one aimed at the remote management of documents and

contents (Content Management Systems: CMS), a blog system, and a wiki.

This paper focuses in particular on the organization of the knowledge base and the adopted methodology, which is rooted in the theory of Topic Maps, aimed at supporting the FInES Research Roadmapping activities. Section 2 briefly reports on the FInES Research Roadmap 2010 that represents the starting point for the current effort. Section 3 describes the organizational model of the FInES Task Force. Section 4 reports about the knowledge flow proposed to support the production of the research roadmap. Section 5 is dedicated to the method and tool adopted to define the FInES knowledge base, while Section 6 concludes the paper.

2. THE PREVIOUS EXPERIENCE

The activity concerning the new FInES Research Roadmap follows a similar effort that started in 2009, releasing the first FInES Research Roadmap in June 2010 that represents a significant base of work for the current activity. Furthermore, this is a particularly topical period for roadmapping activities and perspective studies, since a lot of initiatives are flourishing in view of the launch of the next 8th Framework Programme (FP8).

Examples of these initiatives can be seen in relation to Internet of Things [2], to the project Digital Agenda for Europe (DAE) [3], to the project AALIANCE – The European Ambient Assisted Living Innovation Platform [4],

One of the key research roadmap being elaborated in this period is the Future Internet Assembly Research Roadmap. However, for sake of brevity, we will only report on the first above.

2.1 FInES Research Roadmap 2010

The first FInES Research Roadmap has been developed by a team of experts appointed by the EC, within the FInES Cluster (DG InfSo, Unit D4) and started to work with two main objectives. The first was to draw a (plausible) socio-economic framework in which European enterprises will be operating in a decade from its publishing. This part is based on the idea that European societies will be able to evolve in the future with a progressive shift in the system of values, becoming increasingly aware of values different from consumerism and monetary values (e.g., the quality of life of workers and citizens). Such new values represent objectives to be included in the idea of progress and development for Europe and the future enterprises. The second area addressed concerns the future of enterprises. Here, rather than addressing specific enterprise departments, such as organization, production, marketing, etc., the document proposes an approach that focuses on ideal traits of a (hopefully) future enterprise, i.e., 6 main 'quality of being', summarised in the following paradigmatic enterprise profiles:

- **Inventive Enterprise** – referring to enterprises showing the capacity to continuously innovate on different aspects and dimensions.
- **Cloud Enterprise** – referring to enterprises for which the 'traditional boundaries' will fade away, evolving towards open organizations, showing a marked attitude to distribute and interconnect functions, resources, expertise, fully achieving a networked structure.
- **Cognizant Enterprise** – referring to enterprises being able to maximise the knowledge acquired while carrying out its businesses, learning from successes (but also from failures), while being open to discover and acquire knowledge and best practices coming from the rest of the world.
- **Community-oriented Enterprise** – while social networks represent one of the most remarkable achievements of internet, there is still some hesitation in the enterprise worlds to embrace such a paradigm and mutate it from social contexts to improve the value production processes. It is foreseen that in the next decade, enterprises will extensively adopt social media solutions, establishing new working and collaboration paradigms.
- **Green Enterprise** – it is widely accepted that we need to change our attitude towards a more careful interaction with the environment, carefully considering the impact of the production systems on the overall ecological system, up to the so called 'carbon footprint'. We expect that a respectful attitude towards the environment, the planet at large, will be among the top priorities of future enterprises.
- **Glocal Enterprise** – this is a characteristic of future enterprises that is partially based on their 'cloudy' nature, therefore avoiding the necessity of a precise localization (a typical characterization of 20th Century enterprises). But it goes beyond that, accepting to recognise (and interpret) also different cultures, different perspectives, only partially connected to specific geographical locations, (e.g., religion, local traditions). Such characteristic is well represented by the largely known aphorism "Think globally, act locally."

After the sections on the vision and the enterprise 'qualities of being', a third part of FInES Research Roadmap 2010 addresses the topic of the architectures for the Enterprise Systems of the future. In particular, it has been decided that the key issue for future competitive enterprises will be their capacity of pushing forward innovation, in all respects. Therefore, future enterprise systems will be based on architectural paradigms compliant with the idea of innovation as the core mission. Conversely, the typical ERP functionalities (e.g., finance and control, HR management, production planning, etc.) will be consolidated according to shared best practices, largely migrating in service clouds, and progressively undergoing a commoditization process. To cope with continuous innovation FInES architectures will be highly flexible and component-based, with an organization that will reflect the lifecycle of innovation, e.g., conception, implementation, operation, monitoring. Accordingly, there will be four main enterprise platforms:

- **Federated open application platform**, providing the operational services and functions for the value production activities, essentially based on orchestration of services available on the Cloud.
- **Awareness and intelligence platform**, for monitoring the running enterprise applications, and the global context as well, to discover innovation needs and opportunities, but also bottleneck and difficulties to be solved for a continuous improvement.
- **Re-design platform** for innovation. Continuous business innovation requires also a continuous evolution of the future enterprise systems (ES) to maintain their business alignment. This platform supports business experts in formulating their innovation plans and transform them into application system specifications.
- **Innovative FInES implementation recasting platform**. The ESs will be largely reconfigurable and component-based, therefore their implementation and deployment will take place according to a dynamic approach, with a large

use of autonomic and self-configuration capabilities, with an agility and flexibility unthinkable with the software development methods existing today.

Besides the four key platforms just described, there will be another 3 platforms dedicated to a new way of (i) organizing and managing distributed **knowledge** bases, (ii) ensuring a high level of **interoperability** with flexible and transparent mechanisms, (iii) managing a rich base of **computational business components** (**FInER**: Future Internet Enterprise Resource), the 'bricks' of a FInES that will allow a fast and effective crafting of future application systems.

The fourth and last part of the report is focused on the technology, what will be the emerging solutions and what are the key emerging technological solutions. The technological solutions have been organized in three main categories, listed below with a few bullet point to indicate relevant topics for ech of them.

Communication technologies

- Convergent networks
- Ubiquitous Communication
- Mesh-Sensor Networks
- Communication as a Service (CaaS)

Organization technologies

- Collaborative Enterprise Networks
- Participative Business Engineering
- Social Mining Techniques
- Business Modelling and simulation
- Governance, Risk Management, and Compliance (GRC)
- Security, Privacy and Trust

Application Architectures technologies

- Cloud technologies
- Proactive application components
- Interoperability as a Service
- Knowledge Representation and Semantic Modelling
- Federated, Open and Trusted Platforms (FOT)
- Software as a Service
- Automated Service Discovery and Configuration
- Intelligent and smart components (FInER)
- Visualisation and Interaction technologies

3. THE FInES RR TASK FORCE ORGANIZATION

As anticipated, the Task Force for the FInES Research Roadmap 2012 operates within the FInES Cluster with the scientific and organizational support of the Ensemble Project[1]. This document provides a few guidelines on the organization of the Task Force.

The proposed organization is structured with 4 concentric circles:

Editors – this is the inner circle where operate people dedicated to the organization of the work, the collection of contributions, the assembling of the material and the overall layout, until the formatting and release of the report ready for publication.

Advisors – this is a focused group of experts specialized in different topics. In particular, they represent the competences in the four knowledge domains indicated below that need to be covered. The Scientific Advisory Group (SAG) will guarantee the necessary expertise to select and organise the contributions that will be submitted.

Contributors – this group is primarily composed by the representatives of the FInES Projects, but includes also all the people who desire to participate to the elaboration of the RR. Contributors operate, e.g., by sending specific documents, signalling significant publications, events, research centers, etc., that may be worth considering. Contributors will also participate in reviewing the draft report, before it is published. Another important activity concerns the support in the verification and maintenance of the FInES Foksonomy (see below) that will evolve in time.

FInES RTD Community – this is the rest of the people, organizations, stakeholders who are interested in a way or another to the FInES Research Roadmap, to comment the advance draft and receive it in its final form.

The Figure 1 illustrates in a graphical way what has been described in the text.

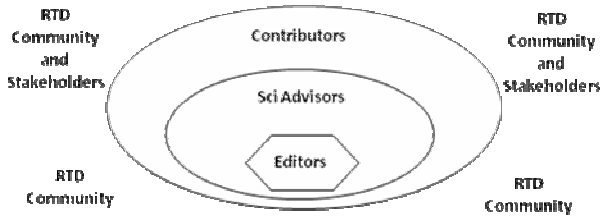


Figure 1: The organizational structure

Initially, the TF needs to agree on a first layout and a high level organization of the report. To this end, the proposal is to consider 4 main domains, represented by conceptual spaces, that represent broad investigation areas. Such domains have their own identity but at the same time are tightly interconnected. They are introduced below, in Section 5.1, with a top-down approach, i.e., from a broad societal view to a focused technological view. This organization of the investigation spaces is a direct derivation of the FInES Research Roadmap 2010 and appears a valid starting point.

4. RR TASK FORCE KNOWLEDGE FLOW

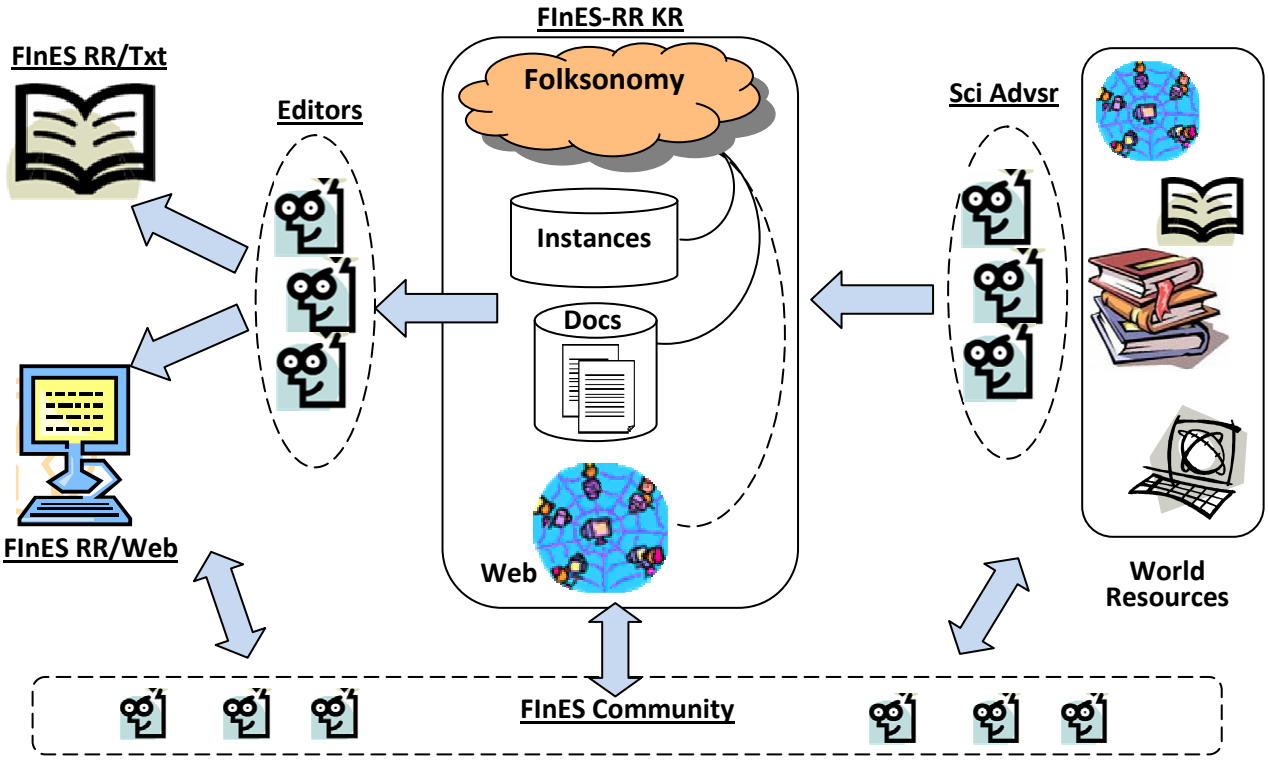
According to the organization model described above, it is useful to draw a picture of the knowledge flow that is required to guarantee the production of a high quality research roadmap. Such a knowledge flow is sketchily reported in Figure 2, along with the positioning of the teams within the TF. What is described is essentially a socio-technical systems, since it is a systems where the technological components and the human components are tightly interconnected and interdependent.

On the left is represented the final outcome of the RR-TF activities, i.e., the FInES Research Roadmap 2012. Please note that we indicate not only the 'traditional' paper based report, but

[1] www.ensemble-csa.eu

also the symbol of a computer terminal to represent the electronic output of the work. The latter is not the simple electronic representation of the same document but it intends to provide a new way of accessing the content of the FInES RR, with ample facilities for querying, browsing, and accessing the RR knowledge along personalized paths.

Here, we briefly describe the method adopted to proceed in defining the knowledge base of FInES, based on a 'folksonomy' approach [5]. A *folksonomy* is a terminological resource, essentially a taxonomy (i.e., a hierarchically organized set of terms), that represents a given domain. In its nature and content, a folksonomy is not very different from a Thesaurus, but the main difference lies in the construction and maintenance approach.



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Figure 2: The FInES RR Knowledge Flow

5. THE FINES FOLKSONOMY

The key idea is that a complex terminological resource, of interest of a large and diversified community, cannot be developed and maintained by a restricted group of people: it is a socially-oriented resource and therefore the community as a whole must be able to constantly access such resources and play an active role of its construction and maintenance. This is the nature of a folksonomy (term stemming from the fusion of the terms *folks* and *taxonomy*). The community-based approach is also a guarantee that the folksonomy will (i) be accepted by the community as a terminological resource that actually represents the domain, (ii) it will constantly evolve with the help of the community to mirror the evolution of the reality, and finally (iii) the completeness and quality of its content will be insured by a social process (i.e., a product of the 'Wisdom of Crowd') that in general outperforms the effort of a restricted group of experts.

The hierarchy of the FInES Folksonomy will exhibits a top level organization based on four main roots. In this section, we start introducing the four knowledge spaces, then we briefly report on a platform to implement the FInES Folksonomy; to this end we selected *Ontopia*[2], a web-based platform for knowledge representation and management based on a method referred to as Topic Maps [6].

5.1 The Four Knowledge Spaces of FInES

As anticipated, The first level of the FInES Folksonomy is organized according to four knowledge spaces conceived as a reorganization of the fabric of the FInES Reserch Roadmap 2010. Such spaces are the following.

1. **Socio-economic Space** – this space represents the larger context in which enterprises operate. It includes topics such as the social responsibility of enterprises, the impact on the environment and their carbon footprint, until the system of values that goes beyond the pure financial dimension.

2. **Enterprise Space** – this is the space where we address the key characteristics of future enterprises, the emerging business and production models, new governance and organization paradigms, new forms of cooperation: all geared towards a continuous innovation paradigm. This

[2] http://www.ontopia.net/

space also includes the investigation on new styles for the relationships with customers, yielding new market forms and logics.

3. **Enterprise Systems, Platforms, and Applications Space** – this space is specifically concerned with FInES, i.e., with the ICT solutions and socio-technical systems aimed at supporting the emerging future enterprises that has been envisaged in the previous space. The issues delineated in this space will be aligned with business needs and rationale identified for the future enterprises.

4. **Enabling Technology Space** – this is the knowledge space that specifically concerns the ICT solutions, in particular Future Internet solutions, knowledge representation, cooperation and interoperability, trust and security advanced services, etc., that will be necessary for the development of FInES. We know that ICT solutions will be evolving according to their own strategies and trajectories, so it is important to understand what ICT enabling solutions will be available 'by default' and what solutions will need to be 'solicited' for the purpose of FInES.

In the representation of the envisaged spaces, it is possible to establish a sort of 'conceptual containment' among them. Starting from the first one that defines the context in which future enterprises will operate and the impact that they will have, then the space of the enterprises, positioned in the previous space but characterized by its own features and needs. The third space is represented by the Future Internet Enterprise Systems, that conceptually are part of an enterprise (even if physically they may be located elsewhere, may be on the clouds), and finally the technological space that produces the solutions, methods, and components that are embedded into the artefacts of the previous level. This conceptual containment is represented in the Figure 3.

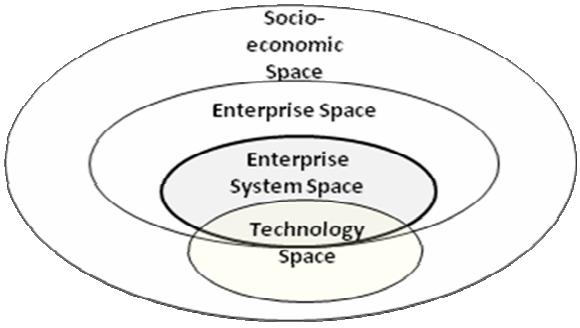


Figure 3: The FInES investigation spaces

Please note that for the technological space there is not a proper containment because technology can be developed also for different purposes than serving enterprises.

5.2 Topic Maps

Topic maps are an international standard (ISO 13250 [7]) for describing knowledge structures and associating them with information resources. As such, they constitute a technology for knowledge management. Topic maps are initially motivated by the problem of merging the indexes of different sets of documentation. For this reason, since the beginning, topic maps were characterized by the basic concepts embodied in indexes, that is Topics, Associations, and Occurrences (the so called TAO of Topic Maps [8]).

A **topic**, in its most generic sense, can be anything, material and immaterial, really existing or not, e.g., a *book*, a *research team*, an *author*. In a topic map, any given topic is an instance of zero or more topic types. This corresponds to the categorization inherent in the use of multiple indexes in a book (index of names, index of works, index of places, etc.). For instance, *La Divina Commedia* is a topic of type *book*, and Dante Alighieri is a topic of type *author*.

A topic may be linked to one or more information resources that are deemed to be relevant to the topic in some way. Such resources are called ***occurrences*** of the topic. An occurrence can be a monograph devoted to a particular subject, for example, or an article about the topic in an encyclopaedia; it can be a picture or video referring to the topic. Such occurrences are generally external to the topic map document itself (although they may also be inside it), and they are "pointed at" using whatever mechanisms the system supports, typically URIs.

Finally, an **association** asserts a relationship between two or more topics; for instance, La Divina Commedia *was written* by Dante Alighieri.

5.3 Ontopia

Ontopia is an open-source suite for building, maintaining and deploying topic maps-based applications. It is a 100% Java and it is released as a web application. Ontopia is composed by the following four components.

- **Ontopia Engine**. The core of Ontopia is the engine, which stores and maintains the data structures representing topic maps.
- **Ontopoly**, which is a topic maps editor which provides a user-friendly web interface. The editing user interface is configurable, and can be set up to present focused views of the knowledge to users, thus reducing the amount of clutter and confusion for them. In addition, Ontopoly is embeddable inside other applications, so that it is possible to add Topic Maps editing capabilities to other applications (such as content management systems).
- **Omnigator** is a web-based Topic Maps browser which can display any topic map. It is not intended as an end-user tool (although some have used it as such), it is rather conceived for a developer support since it can be used to view any part of any topic map. Though Omnigator, a user can also run queries, by using the Tolog query language, validate topic maps, get size statistics, etc.
- **Vizigator** is the tool which provides graphical visualization of the structure of a topic map, which can be very useful for seeing larger patterns in complex data, or simply as a visually attractive and user-friendly alternative way of displaying the topic map.

6. CONCLUSIONS

In this paper, we have presented a few very general ideas and guidelines on the FInES Research Roadmap Task Force activities and organization. This initiative follows the previous one that initiated in 2009 and released the FInES Research Roadmap 2010 a year later. The current activities have therefore the advantage of a solid starting point, but at the same time have the responsibility to proceed with a critical view of the existing version of the RR to understand what is stil valid and what should be updated and improved. For instance, one key problem

is that the different knowledge spaces risk to be well analysed per se, but at the end they remain somehow in isolation, i.e., with a thin relationship one another. On the contrary, it will be very relevant to be able to identify coupling and dependencies across the identified knowledge spaces, drawing also a map of dependency between ICT solutions and enterprise characteristics.

Another key point of this new FInES Research Roadmap 2012 (tagged with the year in which it will be published) is the idea of producing, along with the traditional paper-based report, the FInES Research Roadmap portal. This will be an electronic, web-based knowledge repository with a marked social networking approach, conceived according to the *folksonomy* approach. Here the FInES members will have the possibility to access, browse and navigate the content, as expert users, or will able to access in 'author-mode' to contribute to the improvement and evolution over time of the FInES Research Roadmap.

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Digging Into The Real-Life Enterprise Interoperability Areas Definition And Overview Of The Main Research Areas

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ABSTRACT

Enterprise Interoperability is perceived as a capacity of two or more enterprises, including all the systems within their boundaries and the external systems that they utilize or are affected by, in order to cooperate seamlessly, in an automated manner, in depth of time for a common objective.

The different layers of Interoperability define in high level the necessary stack for interoperable systems, however, their abstraction level hinders researchers and practitioners to really identify problems and provide solutions, as those levels do not only overlap in many cases, but they also hide important low level aspects that deal with technologies and methods that span across all levels. In order to identify a proper structure for Enterprise Interoperability, which can at a second stage be mapped to the four fundamental layers adapted by the European Interoperability Framework, one has to focus on the real object of observation, which is the "Enterprise", and by analysing it in its core components to identify the interoperability needs within them. Starting from those core ingredients of an Enterprise, and by analysing the current technological trends and the background knowledge of the domain the present papers presents the twelve main Scientific Themes of Enterprise Interoperability

Keywords: EI Scientific Areas, Interoperability, Layers, Enterprise 2.0, Science Base

1. INTRODUCTION

Interoperability is defined in the US, NATO and Australia as "the ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together". IEEE defines interoperability as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged". Interoperability means the ability of information and communication technology (ICT) systems and of the business processes they support to exchange data and to enable the sharing of information and knowledge [13]. Through the years, however, interoperability tends to obtain a broader, all-inclusive scope of a repetitive, well organized, and automated at ICT level feature of organizations, as indicated in the definition of the draft EIF 2.0 [29]: "Interoperability is the ability of disparate and diverse organizations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organizations via the business processes they support, by means of the exchange of data between their respective information and communication technology (ICT) systems" and the Enterprise Interoperability Research Roadmap [8] "a field of activity with the aim to improve the manner in which enterprises, by means of Information and Communications Technologies (ICT), interoperate with other enterprises, organisations, or with other business units of the same enterprise, in order to conduct their business».

Today, we propose that Enterprise Interoperability is perceived "as a capacity of two or more enterprises, including all the systems within their boundaries and the external systems that they utilize or are affected by, in order to cooperate seamlessly, in an automated manner, in depth of time for a common objective".

2. DEFINING THE EI SCIENTIF AREAS

Although the continuous efforts that are put in the advancement of this domain, Enterprise Interoperability still lacks a generally accepted definition of a "Science Base", which can describe comparable constructs in a range of scientific domains. However, since domain research has continued for than a decade, there is a significant body of reported research and application, which can contribute to the population of the Science bases, but is classified in broad themes and thus makes it difficult for researchers and practitioners to actually identify their problems and the main technologies behind them.

In order to formulate an inclusive, yet flexible taxonomy for the EI domain, which will facilitate focused and targeted research by scientific communities, the approach adopted bears the following steps:

1. Consideration of the terms "Enterprise" and "Business Transaction" and decomposition of the enterprise concept in its major ingredients (e.g. people, assets, processes, knowledge, etc.).
2. Analysis of the major technologies behind the term "Enterprise 2.0" (like Cloud Computing, Social Networks) and of current technological trends that are related to the Enterprise world (like Internet of Services, Internet of Things, etc.).
3. Identification of the key EI challenges, as documented in the EI Research Roadmaps
4. Definition of a common EI taxonomy glossary in order to ensure common understanding of the key underlying terms. During this step, four different granularity levels for the EI taxonomy have been defined based on the prerequisites they require.

Granularity Levels of EI Scientific Areas

The different layers, as currently proposed in the bibliography, define in high level the necessary stack for interoperable systems, however, their abstraction level hinders researchers and practitioners to really identify problems and provide solutions, as those levels do not only overlap in many cases, but they also hide important low level aspects that deal with technologies and methods that span across all levels. For example, when we talk about data interoperability, semantic interoperability is applied as far as the concepts and their relations are concerned and technical interoperability is also related as far as the syntax and the data exchange is concerned.

In this context, in order to identify a proper structure for Enterprise Interoperability, which can at a second stage be mapped to the four fundamental layers adapted by the European Interoperability Framework (EIF), one has to focus

on the real object of observation, which is the "Enterprise", and by analysing it in its core components to identify the interoperability needs within them.

An Enterprise, as defined in [26] is "…an organization designed to provide goods, services, or both to consumers." The main ingredients of such a system are Infrastructures, Data, Processes, Policies and People. Starting from those core ingredients of an Enterprise, and by analysing the current technological trends and the background knowledge of the domain of Enterprise Interoperability, the first Scientific Areas (SA) are formulated, which are labelled as the fundamental areas and constitute the 1st granularity level of EI, as following:

- SA.1 - Data Interoperability
- SA.2 - Process Interoperability
- SA.3 - Rules Interoperability
- SA.4 - Objects Interoperability
- SA.5 - Software Systems Interoperability
- SA.6 - Cultural Interoperability

Those scientific areas, although being the core components and as such the most important areas of Enterprise Interoperability, are however incapable of solving all interoperability related problems, as enterprises are constantly becoming more complex, with disappearing boundaries, loosely coupled architectures and virtual resources. As such, the issue of interoperability becomes even more complex, as not only new technologies such as social networks or e-ID are constantly being taken up by enterprises, but also as there is a need for constant and flexible collaboration between all enterprise systems in order to correspond in a timely and effective manner to the requests of the global market.

In order to achieve these transformations and the seamless collaboration, new scientific areas of EI have been developed, which derived through the combination of scientific areas that sit in lower granularity levels. In other words, the scientific areas that belong to a higher EI granularity level are regarded as super-sets of areas that belong in a lower level.

Following this approach, the 2nd granularity level, which is populated with scientific areas that derive by the combination of the core scientific areas of the 1st level includes:

- SA.7 - Knowledge Interoperability, which consists of elements coming out of "Data Interoperability", "Process Interoperabilty", "Rules Interoperabilty" and "Cultural Interoperabilty"
- SA.8 - Services Interoperability, which incorporates facts from "Process Interoperability", "Data Interoperability", "Rules Interoperability" and "Software Systems Interoperability"
- SA.9 - Social Networks Interoperability, consisting of elements coming out of "Cultural Interoperability" and "Data Interoperability", and
- SA.10 - eID Interoperability, which is strongly related with "Objects Interoperability", "Software Systems Interoperability" and "Rules Interoperability"

In the same way, the 3rd granularity level of EI includes:

- SA.11 - Cloud Interoperability, which takes elements from "Services Interoperability", "Knowledge Interoperability" and "eID Interoperability" and tries to infuse them with cloud characteristics

Lastly, the 4th granularity level of EI includes:

- SA.12 - Ecosystems Interoperability, which deals with virtual and digital enterprises and is related to "Cloud Interoperability", "Strategy Interoperability" and "Social Networks Interoperability"

It needs to be noted that the proposed scientific areas aim to promote more focused and concrete research attempts towards the goal of establishing interoperable enterprise systems, as they belong to a smaller abstraction level of that of the four fundamental interoperability layers adapted by EIF.

3. ANALYSIS OF THE EI SCIENTIFIC AREAS

Scientific Area 1: Data Interoperability

Data Interoperability is defined as the ability of data (including documents, multimedia content and digital resources) to be universally accessible, reusable and comprehensible by all transaction parties (in a human-to-machine and machine-to-machine basis), by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches [18].

Data interoperability issues have aroused the interest of the research community since the late 1960s when EDI (Electronic Data Interchange) that facilitated the application-to-application exchange of standard business documents between companies, independently of software, hardware, and communication networks, was introduced. With the exponential growth of the Web that opened new opportunities for businesses to transact across all types of boundaries (geographical, national, business category, etc.), early research had focused on providing a lingua franca for B2B e-Commerce, XML, that went beyond HTML to reflect the richness of the data being published [15]. In progress of time e-Business modelling frameworks went through an evolutionary path from monolithic and proprietary standards towards flexible and standardized XML-based stacks covering the requirements from different industries

In order to tackle the data interoperability issues, much progress has been made in terms of developing conceptual and algorithmic frameworks and deploying semi-automatic tools for schema matching and data mapping, promoting semantic reconciliation and mediation techniques, and creating adapters and wrappers. The methods and proofs-of-concept proposed are accompanied by experiments that prove their offerings and the weaknesses, yet such laboratory-oriented approaches need to expand and improve in order to cover real-life situations in enterprise environments.

Scientific Area 2: Process Interoperability

As processes are the core operational elements of enterprises, they are first in line when dealing with interoperability, as the overall interconnection and collaboration of enterprises is based finally on the alignment of their business processes.

In this essence, Interoperability is coupled with the term of business process, as it is self-understanding that the former cannot be achieved without any kind of business process compatibility. Following these claims, Business Process Interoperability is the ability to align business processes of different entities (enterprises), in order to conduct business in a seamless way. In more detail, the realisation of automated and co-operative execution of business transactions requires two or more parties that have compatible business processes, with defined and matching process interfaces, in order for the different parties that take part in the complete transaction to be able to exchange successfully data, avoiding conflicts and loss of data or process control. In this context, process modeling and process reengineering is essential towards interoperable enterprises, as they support the formal representation and the structured reform of them when it comes into cases where two or more entities need to collaborate.

Although during the last decade substantial progress has been made in the field of business process Interoperability, the problem still persists. A report by Gartner back in 2000 claimed, "By 2003, more than 90 per cent of e-businesses will be exploiting process automation technology"[5]. Based on the bloom of research at that time, this assumption seemed quite realistic. However, the research conducted has shown that there are still many obstacles to overcome to be in a position to claim full interoperable processes. As a result, one has witnessed many new developments, either commercial or open source, in areas such as enterprise modelling frameworks, business process modelling, advanced transaction models for business processes, architectures and mechanisms for business process management systems, etc. This progress has however led (to an extent) to further fragmentation of the field, and for quite a time the decisions taken by enterprise on which method/tool to use have more or less defined their degree of Interoperability with other entities, resulting in isolated market silos (e.g. enterprises utilising a specific process modelling and notation language could only interoperate with enterprises that had made the same decision).

Scientific Area 3: Rules Interoperability

Business transactions are generally conducted in a "rule-based" framework, which exists in order to guarantee and safeguard their smooth completion and to resolve any issues that may arise between the different communicating parties. During the automation of enterprise transactions, one has to consider two different kinds of rules that exist and should be treated at the same time for achieving the desired result; Business Rules, and Legal Rules. As a result, rules are considered quite essential for interoperability between systems and their transactions, as they can have either a positive or a negative impact. A negative impact is experienced when rules are not compatible, either due to differentiations in the business models and the business mentality of the transacting entities, or due to different laws and legal frameworks. However, rules can also impact positively enterprise interoperability, as in some cases they can dictate the way a transaction should be carried out (for example banking sector transactions following international standards).

In this context, the term Rules Interoperability describes the ability of entities to align and match their business and legal rules, in order to perform transactions that are both legitimate in each country and do not break the internal operational rules of each other.

Although rules interoperability is closely related with process and data issues, this dimension of transactions has not been extensively studied in the past years. The reason behind this could be a combination of the conditions that are slowly evolving in the global market, which aim to homogenize business rules, regardless of the business sector to which an enterprise belongs, and to establish slowly a common legal framework for all entities to respect (e.g. the common directives issued by the EC that are regarded as the first steps towards the foundation of a new and unified legal environment, or various rules and mechanisms that are proposed by international organizations, such as the World Bank Institution, the International Atomic Energy Agency, etc.).

Scientific Area 4: Objects Interoperability

Objects interoperability refers to the networked interconnection of everyday objects [28]. These objects can embrace aspects besides and beyond software components, consistent with the concept of Internet of Things [11]. Objects can be really seen as orthogonal concepts, each one having its own specific and distinguishing features. In this context, devices or hardware components interoperability can be seen as a particular case of the object interoperability domain.

Objects Interoperability refers to the networked interconnection of everyday objects. Devices or hardware components interoperability can be seen as a particular case of the object interoperability domain. According to the Commission of the European Communities about future network and the Internet regarding object interoperability [9], a number of policy challenges needing consideration can be identified such as Identity Management, Naming and Interoperability and Standardisation. Research literature on objects interoperability is mostly limited to RFID technology. The majority of research work on relevant research subjects, such as Internet of things, factory-of-things and device interoperability are restricted to concepts and position papers. Further work is required towards applicable and validated methods, architectures and tools that will enable object interoperability in a practical manner.

Scientific Area 5: Software Systems Interoperability

Software Systems Interoperability refers to the ability of an enterprise system or a product to work with other enterprise systems or products without special effort from the stakeholders [17] This can be achieved with a large number of alternative IT architectures stakeholders [4], and solutions stakeholders [2], including custom, in-house development of APIs, message-oriented middleware and message brokers, service-oriented architecture implementations, or comprehensive stand-alone B2B software gateways.

Interoperability among software systems has been one of the main goals in the software engineering research in the last two decades stakeholders [24]. One of the most challenging problems has been that of architectural mismatch stakeholders [27]. In general, it is therefore almost impossible to combine components designed for different systems into a working solution. Most approaches for making interoperable software systems overcome this fundamental problem by defining a coherent component model that standardizes the notion of an adapter to be used as a mediator stakeholder [22]. Besides standardizing the properties of the software components to be used, an interoperable software model usually defines a technical infrastructure. With a view to overcoming these problems, recently in service-oriented engineering and its technical foundation, SOAP-style web services, have been employed to extend the component based software engineering approach in order to make completely independently designed software systems work together. However, forming complete business solutions out of service based systems still requires a lot of implementation efforts: data and process mediation problems have to be addressed before services from different systems can be combined.

There is a variety of research literature, standards and frameworks that address Software Systems Interoperability, including methods and tools for component-based software engineering. Nevertheless the value of the majority of these findings and tools is rapidly decreased over time since the underlying software and application technologies are often deprecated. Major challenges lie ahead in the scientific area of Software Systems Interoperability in view of new technological and computer science's advances that indicate the need of a ubiquitous approach that guarantees a high degree of maintainability against the rapid software technology evolution.

Scientific Area 6: Cultural Interoperability

With the world evolving into a unified marketplace, the business context in terms of culture, language and various regional particularities proves to be a great challenge regarding the communication between organisations as well as between their underlying ICT systems [12]. Global trading represents a good example of a domain in which cross-cultural information systems between enterprises are really required. Experts in the global trading domain are under a growing pressure to exchange actual and correct information on very local and unique regions. Different regions in the world share many business processes and data although each region still is unique in terms of different processes, data and business rules due to religion, cultural and social customs [21]. This makes it, on the one hand, difficult to generalize B2B solutions and present them centrally, but on the other hand it is also clear that knowledge about aspects of each situation can be shared. Interoperability between organizations, people and enterprises systems that have different languages and different cultural aspects such as Politics, Religion, regional Art, Traditions and Social Customs defines the concept of Cultural Interoperability [6]. As such, Cultural Interoperability is the degree to which knowledge and information is anchored to a unified model of meaning across cultures. Enterprise systems that take into consideration Cultural Interoperability aspects can be used by transnational groups in different languages and cultures with the same domain of interest in a cost-effective and efficient manner. Cultural interoperability mechanisms are based on the assumption that both high-level and low-level layers of Enterprise reflect culture and that the linguistic encoding of knowledge and information is therefore culturally biased. These interoperability mechanisms and considerations address the ability of enterprises to understand and co-manage context from any source and of any kind, therefore realizing the cooperation between enterprises with major cultural differences.

Scientific Area 7: Knowledge Interoperability

Business Knowledge Interoperability defines the ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilize it, and to further extend them through cooperation. As a result, Knowledge Interoperability does not only describe only knowledge repositories which may come in the form of reports, articles, patents, reviews, inventions, etc.

Other very important issues, which are included under this term, include Ontology Matching Approaches and Data to Knowledge mappings. Today, with the evolution of the Semantic Web, ontology matching has taken a critical place for helping heterogeneous resources to interoperate. The Semantic introduces a new environment where both humans and software agents can unambiguously determine the meaning of resources and make better use of them. As quoted by Tim Bernes-Lee [3] the Semantic Web is "a web of data that can be processed directly and indirectly by machines."

In parallel, Business Knowledge Interoperability also includes human resources, which are the creators and the carriers of knowledge within the boundaries of an enterprise, and which can be either individuals or teams that carry expertise and knowledge in specific domains. In this context, the aforementioned term also includes the ability of business units of enterprises to be extracted from the company they originally belong to, and to be seamlessly integrated in a new business environment (company) for collaboration, a situation which is closely related with Ecosystems Interoperability and with the creation and set up of Virtual Enterprises, which consist of business units from different enterprises that come together.

As bibliography reveals, the main effort of the research community when tackling the issue of Business Knowledge Interoperability lies in the area of Semantics for constructing common dictionaries that will support and ease out the operations of sharing and spreading knowledge amongst various entities. However, Knowledge Interoperability is not solely about semantics, as it includes other facets as well, ranging from business units alignment to context aware systems. Methodologies, standards, tools and not to mention large-scale experiments and case studies on those aspects are absent and need to be researched as well, as sharing knowledge is not only concentrated in the exchange of documents and tangible assets but also relies heavily on human individuals, operating on their own or as part of business units.

Scientific Area 8: Services Interoperability

Services interoperability refers to the ability of an enterprise to dynamically register, aggregate and consume composite services of an external source, such as a business partner or an internet-based service provider, in seamless manner [20].

The major significance of service interoperability was evident when during the last decade the business world warmly embraced the concepts of Service-oriented Architecture (SOA) and Web Services in their everyday operations. Service-oriented architecture (SOA) is a flexible set of design principles used during the phases of systems development and integration in computing [7].

Throughout the foundation of the Internet of Services, the conception of service interoperability has characterized the formation of a number of innovative concepts such as Service Engineering, service level agreements (SLAs) and Mash-ups. Penetration of the Internet of Services, Service Engineering, SLAs and the Enterprise mash-ups is just beginning to proliferate and there are many pending research issues to be resolved. While these technologies are not mature enough and working drafts of the next specifications are in the works, designers and developers have to interpret the meaning in parts of the current specifications. Interpretation allows interoperability problems to seep into service composition, discovery and as well as in the definition of request/response mechanisms. Furthermore future interoperability challenges involve increasing the flexibility and ease of implementation of tangible and intangible services on specific business domains, the architecture of an integrated framework between existing service-front ends and back-end platforms, the enhancement of "as-a-service" models in enterprises as a result of global-wise and distributed activities of the enterprises and their supply chain enhancing the movement towards internet of services and lastly the ability to quickly and effectively assess partner capability, creative thinking about incentive systems to motivate appropriate behaviour, fail soft mechanisms to protect against potential disruptions and clear specification of outputs.

Scientific Area 9: Social Networks Interoperability

Social networks are a major evolution coming out of Web 2.0 and in the last years they have attracted the interest of enterprises, not only for promotional and advertising reasons, but also for operational purposes. Not long ago, enterprises have realised that the power of social networks can also positively or negatively impact their business operations. The impact of them are also underlined in JRC-IPTS report [14], which amongst others states that Social Computing is now mainstream and companies and policymakers cannot afford to

overlook, has the potential to reshape work, health and learning and is a driver for growth and employment.

Keeping aside the dimension of reputation management in social media, enterprises steadily understand the value behind social networks integration to their operation and try to exploit the advantages offered by these networks in terms of collaboration between themselves and also between their own employees. As [1] states "Social networks provide means for enterprises to capture and expose many informal connections between their stakeholders."

Social Networks Interoperability can be defined as the ability of enterprises to seamlessly interconnect and utilise social networks for collaboration purposes, by aligning their internal structure to the fundamental aspects of the social networks. This ability should concentrate into two different operations. Firstly, enterprises should be able to manage and interconnect all their social media accounts, and secondly enterprises need to redefine their services, operation and internal structure in order to integrate social network characteristics to their daily operation. In those terms, interoperability for the enterprise should follow a research into a two layer approach, focusing both of the underlying technologies of the social web but also on the social web as a coherent "platform". Until recently, most scientific attempts focus on the proposal of methodologies for infusing the characteristics of the Social web to the enterprises. However, these methodologies focus on very specific topics and there is a huge lack regarding the proposal of standards and frameworks, which would enable the seamless integration of such features in the operational functionality of businesses. An obvious reason behind the lack of scientific resources dealing with social networks interoperability is the fact that this area is quite young and immature, and innovation activities are preceding research on fundamental aspects.

Scientific Area 10: Electronic Identity Interoperability

An electronic or digital identity is a means for people to prove electronically that they are who they say they are and thus gain legitimate access to services. Electronic identity interoperability defines the ability of different eID systems within or across the boundaries of an enterprise to collaborate in order to automatically authenticate and authorise entities and to pass on security roles and permissions to the corresponding eID holders, regardless the system that they originate from. eID interoperability can provide the advantages such as reducing costs for businesses and administration activities by simplifying procedures and optimizing resources, improving security of eID systems, improving the quality of services making the public sector's and businesses' process more open and transparent, and facilitate transactions between enterprises and public bodies and also harmonizing data and security architecture for a complete international interoperability.[19].

Today, the technologies deployed for identity management are manifold and coined by long-term development and integration. Therefore, the systems are heterogeneous and meaningful for different security aspects such as identity repositories, directories, authentication mechanisms and tools, authorisation and access control [23]. There is a lack of IT compliance for integrated, process supportive identity management and at the moment, the mapping of external identity certifications with internal ICT specific identifiers still needs to be researched, as several problems are still unsolved. As a result, Current eID solutions are not interoperable, as the development of identity management systems is still not coordinated and comprehensive.

Scientific Area 11: Cloud Interoperability

Cloud Computing holds the potential to provide small and large enterprises with a flexible model for delivering added-value solutions by composing best of breed internal and external services which combine diverse data sources deployed across multiple cloud infrastructure providers and possibly reconfigured while running, or with limited interruption, to respond to changes in usage patterns or resource availability.

Today, numerous vendors have introduced paradigms and services based on non-compatible underlying technologies, making the cloud landscape diverse, heterogeneous and vendor-locked [25]. In this context, interoperability which is definitely a challenge for on-premise applications is magnified in the cloud. Cloud Interoperability refers t the ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud dependant. The scope of interoperability refers both to the links amongst different clouds and the connection between a cloud and an organization's local systems [10] in order to realize the seamless fluid data across clouds and between cloud and local applications.

Although standardization appears to be a worthwhile track and many efforts are under way to standardize clouds' important technical aspects, resolving the cloud interoperability problem is still far from reality. Most approaches emphasize on cloud deployment issues, with interoperability not having appeared yet on the pressing agenda of major industry cloud vendors and researchers. There are some positions, definitions and visions on the benefits from addressing cloud interoperability, yet experimentation efforts and proof-of-concept implementations are rather limited.

Scientific Area 12: Ecosystems Interoperability

Globalisation is becoming a fact of our age, and markets evolve from domestic environments to global and cross-border dimension. As a result, sustainability and survival of enterprises (especially of SMEs) is asking for business transactions and collaboration that follow a similar expansion, not only over geographical domains, but also over core business domains. Businesses are constantly concentrating into domain specific environments, called digital ecosystems in accordance to biological ecosystems. The term "business ecosystem" describes a community of enterprises, which all work together towards their main goal which is no other than covering their needs and working together and in a complementary way for the production of added value services and products.

As stated in [16] there are three types of ecosystems; Digital ecosystems, Business ecosystems, and Innovation ecosystems. Ecosystems Interoperability focuses on the ability of different business sectors to interconnect and to achieve a close and automated collaboration, which will benefit not only the dominant companies of an ecosystem, but the whole population of it. As such, Ecosystems Interoperability is defined as the ability of instant and seamless collaboration between different ecosystems and independent entities, entities within the ecosystems and as the ability of different independent entities to formulate virtual structures for specific purposes.

Being a quite young and immature scientific area, the research that has been performed during the last years has not produced milestone results and as most identified references depict, most efforts have been made in the direction of proposing concepts and simplistic methodologies for constructing such ecosystems, based on standards that are "borrowed" from neighbouring and

underlying scientific areas, such as business process interoperability, data interoperability, etc.

4. CONCLUSIONS

Investigation of the scientific themes within interoperability research yields an immense body of research and knowledge relevant to both enterprise interoperability and science base foundation, even where the research is not directly focused on enterprise application.

This body of knowledge has been reviewed in depth and linked to the identified scientific areas through detailed study of the relevant literature, review of EU FP6 and FP7 projects related to the domain, review of major community events, and of the relevant initiatives. This resulted to the formation of a first level taxonomy of 12 scientific areas, which form the base of knowledge available towards the foundation of the Science Base for Enterprise Interoperability.

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Towards an Interoperability Science: Cultivating the Scientific Foundations for Enterprise Interoperability

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ABSTRACT

Enterprise Interoperability (EI) has been recognized as a well-acknowledged application domain in which substantial progress has been made through EU- and national funded research. However, the lack of scientific foundations seems to hinder unlocking its real value and full potential to all its stakeholders. Taking into consideration the fundamentals in establishing a science, the multi-stage incremental evolution of neighbouring scientific domains is studied following a life cycle that can be described in comparison with the human development as: Infancy, Childhood, Adolescence, Young Adulthood, and Maturity. In the context of EI, the present paper investigates the pathway towards establishing a science base. Beginning with the Foundational Principles and the Core Concepts Formulation, the science base evolves through the Development and Extension, & Internal Enhancement and Exploration phases, and concludes to the External Enhancement and Exploration, & Popularization phase.

Keywords: Enterprise Interoperability, Science Base, Neighbouring Sciences, Scientific Foundations.

1. INTRODUCTION

Science is primarily an activity of extending perception into new contexts and into new forms, and as a means of obtaining what may be called reliable knowledge [1]. The history of science has shown that "such puzzling concepts as force, energy, etc., are man-made and were evolved in an understandable sequence in response to acutely felt and very real problems". They were not handed down by some celestial textbook writer to whom they were immediately self-evident [2]. It is well acknowledged that an underlying scientific discipline typically evolves along several decades in incremental stages before being established as a science. Over the 20th century, though, links between science and technology have though grown increasingly strong with many technological domains claiming their position in the scientific status quo.

In this context, establishing an Enterprise Interoperability Science Base (EISB) has been a long-sought challenge that was originally documented back in 2006 in the 4th version of the EI Research Roadmap (as mentioned in [3]). According to the European Commission, such a Science Base comprises a new set of concepts, theories and principles derived from established and emerging sciences, with a view to long-term problem solving as opposed to short-term solution provisioning. The overall objective in establishing an EISB is to formulate and structure the knowledge gained through pragmatic research in the domain over the last decades and more in order to avoid repeating research and missing opportunities for application.

This paper aims to outline a concrete set of activities that need to be collectively undertaken by stakeholders with different backgrounds in a logical time frame in order to eventually lead to the general recognition of its scientific rigorousness. In order to develop such a meticulous and concise Action Plan, the following steps have been followed:

- *Step I: Study which are the key ingredients of a science and a science base*. The fundamentals of the philosophy of sciences and epistemology provide the core principles, commonalities and structure of sciences at a conceptual level that provide significant input on the perspective under which the EISB action plan should be developed.
- *Step II: Absorb lessons learnt from the neighbouring scientific domains paradigm*. A rational selection of scientific disciplines which can be characterized as neighbouring to EI is performed taking into account specific criteria. In each discipline, the stages of development are analyzed in order to gain insight into the process of cultivating a fertile ground for a new scientific base.
- *Step III: Adapt to the context of the Enterprise Interoperability Science Base*. Since the action plan is applied to EI, specific needs and requirements emerging from the state of the art shall be taken into account in order to ensure its appropriateness.
- *Step IV: Formulate the EISB Action Plan*. A generic, yet focused action plan for EISB is defined based on the valuable outcomes of the previous steps.
- *Step V: Deliberate on the EISB Action Plan*. A public consultation with key experts and scientists currently takes place with the help of online mechanisms and face-to-face validation workshops.
- *Step VI: Redefine the EISB Action Plan*. Whenever necessary, appropriate corrective actions addressing the experts' valuable feedback on the action plan will be taken.

Particular care has been taken in order to ensure that the design of the prospective EISB is inclusive and neutral, not biased toward or against any existing discipline or approach.

The present paper is structured as follows: Upon studying the fundamentals in creating a science as depicted in the history of science and epistemology in Section 2, the action plan of related scientific disciplines is analyzed and designates the perspectives and lessons learnt from their paradigm in Section 3. In Section 4, the Enterprise Interoperability Science Base Action Plan is presented in detail giving way to Section 5 that concludes this paper.

2. FUNDAMENTALS IN SCIENCE

A theory or discipline which purports to be scientific needs to present the following characteristics (adapted by [4]):

1. It has been more progressive than alternative theories over a long period of time, and faces many unsolved problems, and
2. The community of practitioners makes great attempts to develop the theory towards solutions of the problems,

shows concern for attempts to evaluate the theory in relation to others, and is considering confirmations and disconfirmations.

Science aims at finding models that will account for as many observations as possible within a coherent framework. In learning a paradigm, a scientist acquires theory, methods and standards together, usually in an inextricable mixture [5]. Knowledge in science is gained by a gradual synthesis of information from different experiments, by various researchers, across different domains of science; it is more like a climb than a leap [6]. Understanding a discipline demands observation, model building, and experimentation [7]. The process is rather slow, but each study advances our knowledge.

Chronologically, Kuhn [5] distinguishes between three phases during a scientific discipline creation:

- *Pre-paradigm phase*, in which there is no consensus on any particular theory, though the research being carried out can be considered scientific in nature. This phase is characterized by several incompatible and incomplete theories.
- *Normal science*, begins when the actors in the pre-paradigm community eventually gravitate to one of these conceptual frameworks and ultimately to a widespread consensus on the appropriate choice of methods, terminology and on the kinds of experiment that are likely to contribute to increased insights. In this phase, puzzles are solved within the context of the dominant paradigm. As long as there is consensus within the discipline, normal science continues. Over time, progress in normal science may reveal anomalies, facts that are difficult to explain within the context of the existing paradigm. While usually these anomalies are resolved, in some cases they may accumulate to the point where normal science becomes difficult and where weaknesses in the old paradigm are revealed.
- *Revolutionary science*, in which the underlying assumptions of the field are re-examined and a new paradigm is established since the significant efforts of normal science within a paradigm have already failed.

A key emerging conclusion from this section is that an Enterprise Interoperability science is in its Pre-paradigm phase, according to Kuhn, due to its several incompatible and incomplete application theories which are accompanied with the growing recognition that many aspects of interoperability cannot be completely understood from current disciplinary perspectives in the information society.

3. NEIGHBOURING SCIENTIFIC DISCIPLINES PARADIGM

From the analysis of section 2, the research topics detailed by Jardim-Goncalves et al. in [8], are evidence of Kuhn's pre-paradigm phase and their recognition as of scientific nature is a first step for the establishment of EI as a normal science. In short, they can be grouped in the following categories:

- *Intelligent reconfiguration of components, for interoperability maintenance of evolutive networked systems*, where Learning and adaptability of systems' behavior, Automatized categorization of ontological structures, and Transient analysis are among the areas of reference.
- *Conformance testing and Interoperability checking for complex systems interoperability assessment*, since enterprise networks need mechanisms for continuous evaluation of its interoperability status.
- And *Harmonization of ontological structures* to support the establishment of an interoperability status flexible to application dynamics and enabling adaptability of users semantical specifications.

However, concerning the interdependencies among scientific disciplines, also EI is not alone and needs to be analyzed together with a selection of established and emerging sciences on neighboring scientific domains. These can inspire the development of a scientific base for Enterprise Interoperability and are selected based on the following criterion: "Scientific disciplines whose research activities target new sets of concepts, theories, methods, techniques and practices for solving interoperability related problems in their own context, and that can somehow contribute to answering the formulated EI open research questions on a scientific basis".

To develop the action plan for the development of the EISB, the authors studied the action plans that today resulted in established science based domains. The next sections describe the action plans of 2 scientific areas selected from those identified as closest to EI.

Action Plan: Computer Science

The computing field has grown enormously since its inception in the 1930s. It began with the marriage of mathematical logic and digital electronics. It has matured into a complex of fields gathered under the large umbrella called computing, informatics, and sometimes information technology (IT). According to Denning [9], the advance of the computer science field fitted in four stages of development mirroring the human development phases:

1. **Infancy:** Algorithms devised by Pascal, Leibniz, and Gauss were used extensively to create tables of trigonometric, logarithmic, and exponential functions. During this stage the first calculating machines where build, which culminated with an all-digital computer ("Z4"). This way, computer science took digital electronic computer and married it with three historical lines: mathematical logic, engineering, and science. Digital electronic brought the infrastructure, mathematical logic brought notations for algorithms, universal machines, and mapping from logic formulas to physical switching circuits, while engineering brought know-how for mechanical calculation and much expertise in electronics and electro-mechanical systems. Finally, science brought a wealth of applications and methods for predicting the behavior of physical systems from their computational models.
2. **Childhood:** The first computer building projects succeeded and stimulated interest in the new technology. Over the next years, the computing industry invented many technologies in programming languages, computer architecture, storage systems, time sharing, virtual memory, remote access, database, graphics, and robotics. In parallel, the academic world started creating courses in computers and computation.
3. **Adolescence:** This third period was a time of great technological advances in computing, with the computer chip and the Internet, which grew very slowly at first, reaching about 200 nodes by 1980. Then it started to take off, reaching about 200,000 nodes by 1990. The Internet and the personal computer advanced together, accelerating each other's progress.
4. **Young adulthood:** In this last period, the "IT profession" initiative was launched, thus recognizing that the field had evolved from a discipline to a profession. The initiative

responded to the growing interest in the industry for professional standards (especially in safety critical systems).

Action Plan: Software Engineering/Science

Software Engineering is a recognized sub-domain of computer science. It has emerged as the principled understanding of the large-scale structures of software systems [10]. From its roots in qualitative descriptions of empirically observed useful system organizations, software engineering has matured to encompass a broad set of notations, tools, and analysis techniques that provide guidance for complex software design and development. In general, and according to Redwine and Riddle [11], software technologies have been developed and propagated along 15-20 years, through the following 6 typical phases:

1. **Basic Research:** where basic ideas and concepts were investigated, thus putting an initial structure on the problem, and frame critical research questions.
2. **Concept Formulation:** where ideas were circulated informally, and a research community was developed, converging on a compatible set of ideas, solving specific sub-problems, and refining the problem's structure.
3. **Development and Extension:** where preliminary applications of the technology were explored, clarifying underlying ideas, and generalizing the approach.
4. **Internal enhancement and exploration:** where the approach was extended to other domains, using the technology for real problems, stabilizing it, as well as developing training materials.
5. **External enhancement and exploration:** which was similar to the previous stage but involving a broader community of people besides developers.
6. **Popularization:** to develop production-quality, supported versions of the technology, commercialize and market the technology, and expand the user community.

As a conclusion, history has been demonstrating that the development of a scientific domain follows a multi-stage life cycle, which can be described in comparison with the human development, as in computer science. These stages comprehend the major phases of the science development that can be matched almost directly the procedures followed in other disciplines (see Table 1), e.g. software engineering/science.

Table 1: Scientific domains development stages compared with human development

Human Development Lifecycle	Scientific Domains Development
Infancy	Foundational Principles
Childhood	Concept formulation
Adolescence	Development and extension
Young Adulthood	Internal/external enhancement and exploration
Maturity	Popularization

4. ENTERPRISE INTEROPERABILITY SCIENCE BASE ACTION PLAN

An Action Plan for establishing the scientific foundations of a domain defines a concrete set of activities that need to be collectively undertaken by stakeholders with different backgrounds in a logical time frame in order to eventually lead to the general recognition of its scientific rigorousness. Such an action plan shall identify the necessary activities, bundle them into action lines and prioritize them with a twofold purpose:

- To identify and coordinate the actions that are feasible to be implemented.
- To outline the necessary activities which require appropriate action by external observers and stakeholders.

In particular, the Action Plan of the Enterprise Interoperability Science Base aims at meeting the following objectives:

- To dive into the basic principles, the commonalities and the lessons learnt from the history of sciences and epistemology.
- To appropriately select and study the stages of development of various neighbouring scientific disciplines.
- To reach consensus on a broad set of actions that will eventually lead to the creation of a reusable Science Base for Enterprise Interoperability.
- To propose the stages of development, the so-called EISB waves, for the Enterprise Interoperability Science Base.
- To decide on the actions that can be undertaken by all stakeholders in order to contribute to the EISB development.
- To outline the milestones and the key outcomes which are associated with each activity.

In order to pave the way towards structuring the EISB (Enterprise Interoperability Science Base) and eventually taking up some of the initial steps of the EISB building process by conducting focused research in specific areas, the long-envisioned EISB will evolve in three (3) different but logically connected "waves" of activities [12]:

- **EISB Wave 1 – Basic Elements**, with regard to the "Infancy" and "Childhood" stages.
- **EISB Wave 2 – Hypothesis and Experimentation**, which corresponds to the "Adolescence" and "Young Adulthood" stages.
- **EISB Wave 3 – Empowerment**, matching to the "Maturity" stage.

EISB Wave 1 – Basic Elements

The EISB first wave aims at providing the ability to identify and describe problems and solutions in the field of EI, and establishing the research community, towards a sound convergence on the concepts in use. It sorts out the fundamental aspects of the Interoperability scientific foundations towards the formation of inclusive and solid definitions of the main issues of the domain, while it deals with the identification and description of open scientific problems. In more detail, this wave includes the following actions:

- **Foundational principles**: investigation of basic ideas and concepts, initial formal methods to describe problems and solutions, patterns identification, critical research questions. Formal approaches in this area include a collection of methods stemming from mathematical formulation, such as First Order Logic, Category Theory, Pattern Theory. Another set of formalization attempts includes management and information technology systemic approaches, such as Model Driven Architecture (MDA), Business Process Management (BPM) or even Service Oriented Architecture (SOA) elements. It has to be noted that specific methodologies are probably needed for each interoperability facet, that generates the need for diversified formal methods for technical, semantic, organisational, legal and policy issues.
- **Concept formulation**: circulation of solution ideas, development of a research community, convergence on a compatible set of ideas, solutions on specific sub-

problems, refinement of fundamental problems structure. This step will now have to work extensively on the definition of solution ideas for various interoperability problems, as they are defined in the previous step, while also developing and stimulating the research community – possibly through the use of on-line, Web 2.0 or similar infrastructures.

In this context, the present wave will firstly define the overall taxonomy of the EI domain and at a second stage will identify the major issues per research area. The formalisation of those problems and abstraction of their description will empower the ability of researchers to similarly identify and describe and resolve other related problems (belonging to higher granularity levels), with the identification, analysis and abstraction of the solution space and its included methods.

In parallel, this wave will aim to formulate the research community which will undertake each one of the identified issues, and will distribute the accomplished results to a wider audience for attracting the interest of the major stakeholders of the domain and of other external experts and stakeholders, belonging to neighbouring domains.

In particular, the specific objectives of Wave 1 are:

- To consolidate the EISB structure and terminology
- To identify evidences of interoperability in neighbouring domains
- To set up the theoretical foundations of enterprise interoperability
- To define the enterprise interoperability problems and solutions space
- To curate existing approaches to key problems
- To synthesize the EI community
- To consolidate and validate the fundamental elements
- To monitor progress of the EISB establishment and further plan the waves

The following table outlines the concrete actions bundled into Action Lines that need to be undertaken in order to meet the objectives of the EISB Wave 1.

Table 2: EISB Wave 1 Actions Outline

AL1.1 - EISB structure and terminology
Definition of a common terminology for EISB
Reaching consensus on the EISB terminology
Taxonomy construction and desk based research for initial contents
Evaluation of the EISB initial taxonomy by experts
Detail documentation of the underlying research sub-areas and finalisation of the taxonomy
Wiki population / utilization for constant documentation and sustainability of findings
AL1.2 – EISB relations to other disciplines
Elaboration of the neighbouring domains taxonomy (EISB-SRDT) in relation to the EISB structure
Identification of shared content and solutions with other disciplines
Recognition of common communities whose research spans EI and other discipline(s)
AL1.3 – EISB theoretical foundations
Collection of formal methods for problems and solutions definition
Definition of a problem and solution description framework
Reaching consensus on the problem and solution description framework
AL1.4 – EISB problem and solution space
Collection of major problems/issues per domain through discussions and desk based review
Collection of major solutions per domain through discussions and desk based review
Open call for the identification of key problem definitions and solutions
Consultation and evaluation of identified solutions
AL1.5 – EISB community building
Construction of 12 scientific community groups, focused in specific scientific areas
Creation and publication of specific journals targeting at specific scientific areas under EI
Initiation of special issues in high-ranked journals on a variety of aspects around the EISB
Introduction and establishment of conferences bringing together EI and neighbouring domains researchers
AL1.6 – Validation of results
Online validation
Face-to-face workshops for validating the Wave 1 Elements
Continuous updates of the Wave 1 Elements in a wiki
AL1.7 – Evaluation of EISB progress
Update on the EISB action plan towards Wave 2

EISB Wave 2 – Hypothesis and Experimentation

The EISB second wave builds upon the initial EISB foundations defined in Wave 1, i.e. the identification and description of EI scientific problems and EI foundation principles, with a view to stabilizing research products, methods and tools in a reusable, extendable and sustainable manner as well to constructing application scenarios that will prepare for the popularization of EI in the third wave. Impact assessment and simulation, together with the development of a training curriculum, is a requirement for the accomplishment of this stage. Furthermore, targeting a broader community, this wave focuses on identifying hypothesis and nurtures discussions and experiments in order to reach consensus on the challenges or to improve the basic elements defined in the first Wave.

The second EISB Wave purposes can be summarized as following:

- **Development and extension**: exploration of preliminary applications of the technological and scientific principles, populations of formal descriptions and generalization of the various approaches. This step will have to bring in extensive experimental applications, where several of the developed approaches can now be instantiated, thus formulating a more complete set of complete scenarios, including limitations in specific contexts. This exploration is most likely to bring a differentiated set of practices, followed in result-oriented approaches and real-life projects, to further enhance the available, populated exemplary patterns. It is also likely that such population approaches will soon result in the definition and maintenance of one or more, syndicated, Knowledge Bases with interoperability research methods and their results, in various contexts and domains.
- **Internal enhancement and exploration**: extension of the approaches to vertical domains, application of the technology in real problems, stabilization of technological means, initial assessment of impact, development of

training curricula and material. This step constitutes a further, full width exploration of various interoperability problem solving methods and tools, now in real-life situations of specific industrial sectors. Specific approaches are bound to appear for sectors like manufacturing, process industry, health, government, small and medium enterprises, supply chain integration, telecommunications and so on. Also, the well-known issue of interoperability impact assessment is to be tackled in this step, most probably in a sector-specific way. The availability of formal methods, solution tools, real-life application examples and impact assessment will also form the core for the interoperability training curriculum, to be brought in a more systematic framework.

In particular, the specific objectives of Wave 2 are:

- To formalize the hypothesis for enterprise interoperability
- To bridge the enterprise interoperability problems and solutions space
- To assess the impact of the EI solution space
- To enable real-life experiments on problem-solution paths
- To generalize models and tools
- To enrich the solution space with result-oriented practices
- To lay the groundwork for a young generation of researchers that will advance research in enterprise interoperability
- To consolidate and validate the fundamental elements
- To monitor progress of the EISB establishment and further plan the waves

The following table outlines the concrete actions bundled into Action Lines that need to be undertaken in order to meet the objectives of the EISB Wave 2.

Table 3: EISB Wave 2 Actions Outline

AL2.1 – EISB hypothesis
Define the core EISB hypothesis that will be elaborated on the actions related to problem / solution space
AL2.2 – EISB problem and solution space
Matching known solutions (from EI or scientific domains) to identified problems for sorting out solved issues
Consultation and evaluation of identified issues
AL2.3 – Impact Assessment
Collection of methods for EI impact assessment
Formulation of the EISB Assessment Framework
AL2.4 – Test Solutions
Selection of specific cases
Study of the needs and requirements of the specific cases
Testing of selected hypothesis for the specific cases
Experimentation on problem-solution paths for the specific cases
Calibration and stabilization of the tested solutions
Availability of data coming from the specific cases for experimentation in other approaches
AL2.5 – Generalise Solutions
Large-scale experimentations of specific problem-solution paths in various contexts and industries
Creation of an open case repository for large experimentations
Generalization of methods and tools
Identification of practices, followed in result-oriented approaches and real-life projects
AL2.6 – Extension of the EISB
Porting of identified practices to the solution space
Continuous updates of the Wave 2 Elements in a wiki
AL2.7 - Training Curricula Initiation
Gather and sort out existing training material
Orchestration of existing training material into curricula
AL2.8 – Validation of overall results
Online validation
Face-to-face workshops for validating the Wave 2 Elements
AL2.9 – Evaluation of EISB progress
Update on the EISB action plan towards Wave 3

EISB Wave 3 – Empowerement

The EISB third wave aims at empowering the scientific foundations for Enterprise Interoperability through proper liaisons with the scientific, research and stakeholders communities, highlighting the quality of the industrial solutions and the substantiation of value. It focuses on the External Enhancement, Exploration and Popularisation of the EI as a science base. In particular, the third EISB wave includes:

- **External enhancement and exploration**: communication towards a broader community, substantiation of value and applicability, detailing towards complete system solutions, embodiment within training programmes. This is a rather progressed step, "announcing" the findings to a broader scientific community, while also continuing on the embodiment of the scientific approaches to university and vocational training programmes. Substantiation of applicability refers to convincing, detailed, sector-specific solution examples that are to be available. An important element will also be related to the completeness of the approach, realising end-to-end interoperability solutions, covering technical, semantic, organizational and enterprise issues in a sustainable way.
- **Popularization**: standardisation and methodologies for production quality, systematic assistance in commercialisation and marketing of scientific offerings. This last stream of activities is aimed at bringing an overall enhanced quality to the interoperability scientific offerings, elevating them, if possible, to industrial-strength level. If this level is reached, commercialisation of the various offerings will be made possible, for methods, tools and services to be provided towards administrations or enterprises of various sizes.

In particular, the specific objectives of Wave 3 are:

- To inspire a new generation of scientists that will advance research on enterprise interoperability
- To communicate results towards a broader community
- To create EI business plans
- To commercialize the EI solutions
- To define EI standards
- To design the EI cookbook
- To identify research priorities and provide a set of concrete future research recommendations

The following table outlines the concrete actions bundled into Action Lines that need to be undertaken in order to meet the objectives of the EISB Wave 3.

Table 4: EISB Wave 3 Actions Outline

AL3.1 – Scientific Community Empowerment
Development of a systematic framework for training
Design of postgraduate programmes dedicated to EI
Constant update and maintenance of the EISB

Cultivate closer links with neighbouring scientific disciplines through common initiatives
AL3.2 – Broader Community Empowerment
Conduction of focused training sessions for industry/SME personnel
Identify and collaborate with key stakeholders from industry and SMEs
Organization of focused face-to-face workshops
Organization of focused online workshops
Disseminate results to all stakeholders through Web2.0 channels
AL3.3 – EI solutions take-up
Creation of feasibility and sustainability studies for product opportunities
Cost and value analysis of solution paths
Detail results towards complete system solutions
Generate marketing plans for the EISB
Identify market opportunities and develop business plans
Populate convincing solution scenarios
AL3.4 – EI Standardization
Identification of Existing Standards and Mapping them with results
Specification of EI targeted standards
Mapping solutions to EI standards
AL3.5 – EI Documentation
Identify and study the structure of cookbooks in neighbouring scientific disciplines
Define the EI cookbook with the most common problem / solution paths
Deliberation and enhancement of the EI cookbook
AL3.6 – Research priorities and recommendations
Study of current research trends, challenges and of major interoperability issues
Ranking of research issues and prioritisation
Issuing recommendations for researchers, industry and SMEs

5. CONCLUSIONS

History has generally proved that when different scientific disciplines and perspectives come together, the outcome cannot be predicted. One discipline can become dominant and absorb parts of the others, or the overlapping pieces can break away and form a new field. But if the new field never becomes more than the sum of its parts, it can fade away over time. From time to time, though, a new and important discipline emerges as a synthetic combination.

In the last decade, Enterprise Interoperability has been recognized as a well-acknowledged application domain in which substantial progress has been made through EU- and national funded research. However, the lack of scientific foundations seems to hinder unlocking its real value and full potential to all its stakeholders: from industry and SMEs to researchers. Taking into account that new scientific knowledge may lead to new applications, that new technological advances may lead to new scientific discoveries, and that potential applications actually motivate new scientific investigations, Enterprise Interoperability has the credentials to gradually evolve to a rigorous scientific discipline. Time will, of course, eventually prove its actual positioning and real perspective in relation to its neighbouring scientific disciplines.

In its quest for recognition, the key challenges that Enterprise Interoperability will have to face include, without being restricted to: substantiation of value, strong engagement and support by industry, sustainable research in the domain through appropriate curricula, and coordination of efforts undertaken by many stakeholders and neighbouring disciplines.

As a first step in its scientific establishment, a Science Base for Enterprise Interoperability making explicit the knowledge and skills, which industry and academia have empirically observed, is now being initiated. Following up on the present action plan, three EISB Waves of evolution have been recognized.

Future work along the EISB includes the initiation of selected actions for the Wave 1.

6. ACKNOWLEDGEMENTS

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Towards the definition of a Science Base for Enterprise Interoperability: A European Perspective

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ABSTRACT

Research on Enterprise Interoperability (EI) has evolved to meet real pragmatic needs to support the ever more collaborative nature of, for example, enterprise supply chains, and virtual enterprises. Research outputs have therefore focused on generating solutions to current problems, rather than to developing a body of knowledge which is structured for ease of re-use.
In Europe there is move to define just such a structure: an Enterprise Interoperability Science Base (EISB). We explore here the current state of this ongoing research, reviewing the understanding gained so far, and looking to the likely future outcomes. However this is clearly not just a European research domain. The main purpose of presenting the European perspective is to stimulate interaction with researchers in all regions who have an interest in the domain.
We therefore address three issues. We review the development of neighbouring sciences, identifying science base structures, and methodologies for their development. The definition and objectives of a science base are analysed, leading to an outline structure for an EISB to include formalised problem and solution spaces as well as structured EI domain knowledge. Twelve Scientific Themes of EI are identified and the current state of research in each is briefly discussed.
Keywords: Enterprise Interoperability; Science base..

1. INTRODUCTION

The need for definition of an Enterprise Interoperability Science Base (EISB)was first documented in the Enterprise Interoperability Research Roadmap version 4 [1] published in 2006 by the European Commission. Here the definition of an EISB was specified as one of 4 main Grand Challenges to be addressed by researchers in the domain. This challenge was recognised by the Enterprise Interoperability Cluster promoted by the European Commission, and in 2008 the Cluster formed a small task force to work on the EISB. This reported back to Cluster meetings through 2008 and 2009, and compiled much of the source material which is summarised in the chapters below. This work was published in [2] in 2010.
During 2009 the European Commission sponsored an "Enterprise Interoperability Science Base Meeting" to which members of the Future Internet Enterprise Systems (FInES) Cluster (previously the Enterprise Interoperability Cluster mentioned above) as well as international scientific experts were invited. This discussed the possible purpose and structure of the EISB, and led to the EC call for a Coordinating and Support Action under Framework Programme 7 in October 2009. The ENSEMBLE project was proposed and subsequently funded as a result of this call.

Any scientific domain exists in an ecosystem of neighbouring scientific domains, and must therefore recognise its relationship with these domains and with formal definitions of science bases already established for these domains. This relationship will include at least:

1. Boundaries between application fields, which may be fuzzy in the sense that there are some applications which could be addressed from the perspective of either domain. Formally, it may be appropriate to define membership functions to applications to recognise and resolve this overlap.
2. Shared methodologies, techniques and tools which may be applicable to problems in more than one domain. Recognition of such sharing provides opportunity for domains to advance by absorbing methodological and technical advances from related disciplines.
3. Conflicts in approach may also exist, and present possible barriers to interdisciplinary research or application. Formal documentation of such conflict areas will reduce risk of failure in projects arising out of the application of incompatible approaches.

For this reason we review below the definitions and structures of science bases in neighbouring sciences reveals that there is no common structure or content to such science bases. However a methodology emerges which might be applied in defining a science base, based on application of generally accepted scientific principles. Specifically we examine the lessons to be learned from not only applied sciences, where perhaps enterprise interoperability science may be based, but also social sciences, in recognition that enterprises are also social organisations and their interactions are societal in nature. Lessons from formal sciences are also relevant to support the formalisation and structuring of the EISB. There are clear interoperability issues identified in each of these three domains.
There is no generally accepted definition of a "Science Base", which can describe comparable constructs in a range of scientific domains. We therefore propose below a definition of the scope, purpose and content of an EISB. This definition will guide initial research on the EISB, but the authors would be unsurprised to see development of the definition during the course of that research. This seems both inevitable and desirable in the absence of any pre-existing definition of the term.
Finally we review the established Scientific Areas in the Enterprise Interoperability domain identifying 12 major Scientific Themes of Enterprise Interoperability (see below). Since domain research has continued for than a decade, there is a significant body of reported research and application, which contributes to the EISB. This is a first review of this content and will in future support the classification of methodologies, techniques and tools within the EISB.

2. NEIGHBOURING SCIENCES

The concept of science is generally related with observable knowledge, described in the form of testable laws and theories [3], [4]. Nevertheless, there is a plurality of sciences that differ very much from each other. Physics is accepted as a well defined science, but there are others that are not universally accepted, e.g., history and linguistics. Therefore, the definition of science is difficult and ambiguous, but it can be agreed that formalisms like logic and mathematics are an integral part of every science, i.e., they are essential for physics, less important for chemistry and biology, and their significance continues to decrease towards the more social and humanistic sciences [5].

Modern sciences introduce a paradigm shift since, unlike the traditional philosophy of science, they usually do not apply to a single domain, being interdisciplinary and eclectic. Modern sciences search for their methods and raise research questions in broad areas, crossing borders and engineering different scientific fields. For example, the modern computer science embraces formalisms and algorithms created to support particular desired behaviour using concepts from physics, chemistry, biology [5], [6]. Thus, being also a multi-disciplinary domain by nature, the establishment of an EISB should be developed comprising concepts and theories from related neighbouring sciences and scientific domains [2].

Based on the previous work from Charalabidis et al. [2], an initial analysis of the sciences that could contribute to EI is depicted in Figure 1. Due to its characteristics where interoperability issues can be identified, the general classification of scientific domains recognizes the social sciences, the applied sciences and the formal sciences [10] as promising contributors for the EISB formulation, and categorise the work developed so far within four levels of scientific elements of interoperability (semantics, models, tools, orchestration) [2]:

- At the level of semantics, the mathematical domains of logic, set theory, graph theory and information theory seem to have practical applications for describing interoperability problems in a formal way. A mention to patterns has also to be made in this area, both in the form of design patterns [2] and also in the more mathematical form of general pattern theory.
- At the level of models and tools, one should look for existing knowledge in the neighboring domains of systems theory, systems engineering, computer algorithms or operational research. Service science [7] should also not be overlooked in the needed definitions of models and tools for interoperability, at this level. Systemic simulation approaches, such as the System Dynamics approach [8].
- At the orchestration level, where more generic formulations are needed, the social sciences provide a sound scientific corpus, in the face of economics, legal science or even public administration and management.

In addition to the above directions towards the EISB formulation, some literature draws special attention on approaches and propositions for a formal framework to describe interoperability such as the category theory application to semantic interoperability [9], combined category theory and calculus approaches [10], or knowledge discovery metamodel application to interoperability of legacy systems [11].

For the higher levels of interoperability, that is the organisational and enterprise interoperability facets, the scientific domains of systems complexity, network science and information science seem to have a high degree of relevance and applicability [12]. As well, relevance for the establishment of the scientific foundations has been identified with domains such as distributed systems, evolving applications, dynamics and adaptation of networked organizations on a global scale.

All these domains possess strong theoretical background, based on domains tagged as "neighbours" of EI, and serve as an input to the work presented on section 2.3 "EI Neighbouring scientific domains reference taxonomy".

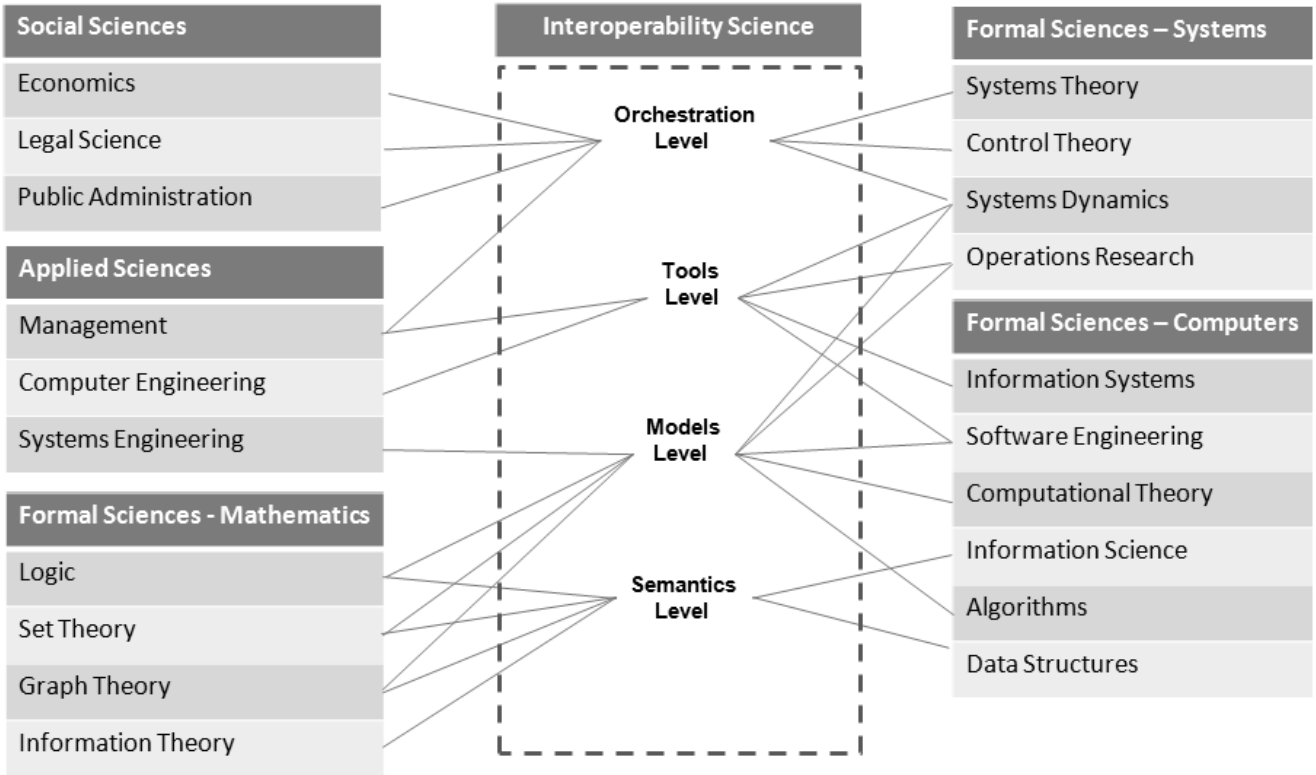


Figure 1: Interoperability Science and Neighbouring Domains

3. DEFINITION AND CONTENT OF A SCIENCE BASE FOR ENTERPRISE INTEROPERABILITY

There is no view of the definition of a science base common to all, or even a related set of, scientific domains, although good examples exist, including for example that for software engineering science [13]. We therefore submit that the definition of a science base is to a degree dependent on the nature of the domain and the purpose for which it is designed and maintained, and indeed the definition for a particular domain will evolve as the needs of the domain evolve with its maturity.

Scope and Content

The content of a science base for an applied science may therefore consist of the following categories of knowledge:

- Formalisation of the Problem space: a taxonomy of the range of application and theoretical problems addressed by the domain, organised so as to be used to characterise real applications and to link these to elements of the solution space.
- Formalisation of the Solution space: the converse of the problem space, this provides a taxonomy of knowledge available for the solution of domain application problems. In turn this links to methodologies and tools in the domain knowledge base.

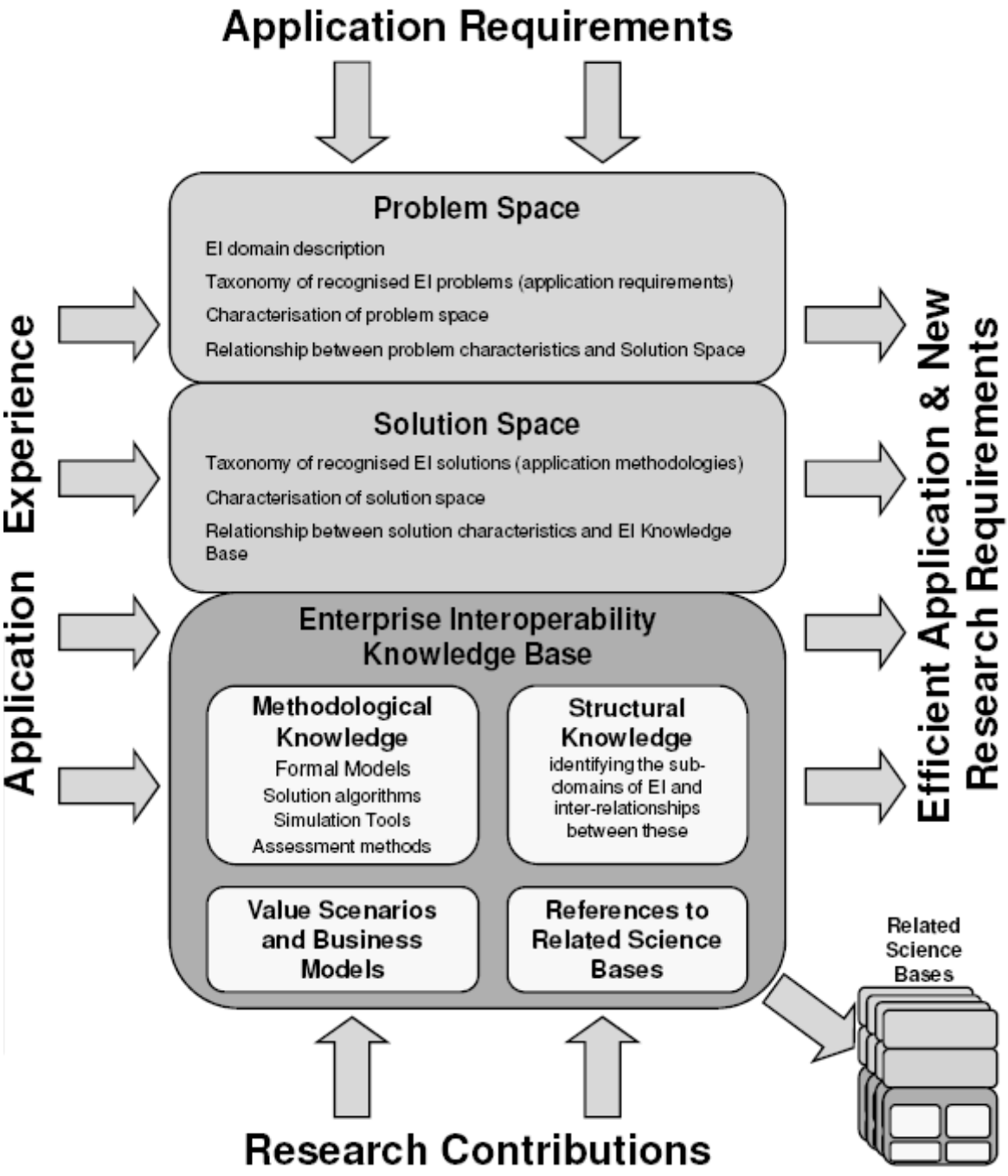


Figure 2: A view of EISB content

- Domain Knowledge Base: the domain knowledge base contains both structuring and methodological knowledge. The former defines the structure of the domain as perceived by its participant stakeholders:
  - a taxonomy of topics within the domain knowledge;
  - the scientific principles which provide the foundation of knowledge in the domain, and of both future research and application;
  - relationships between these topics, the problem space and the solution space;
  - relationships between domain knowledge and knowledge embedded in related scientific domains.

This is further illustrated in Figure 2.

4. SCIENTIFIC THEMES OF ENTERPRISE INTEROPERABILITY

Review of the state of the art (SoTA) of EI related research suggests analysis of published results along 3 dimensions:

- An Enterprise Interoperability Dimension that indicates the interoperability aspect it concerns.
- A Science Base Dimension that classifies the type of the approach, i.e. is it a method developed or a proof-of-concept or a survey?
- A SoTA Dimension capturing the type publication (eg. journal publication, conference proceedings, etc.).

These are illustrated in Figure 3.

Literature on EI research can also be categorised under a set of 12 main Scientific Themes:

1. Process Interoperability
2. Rules Interoperability
3. Ecosystems Interoperability
4. Knowledge Interoperability
5. Data Interoperability
6. Cultural Interoperability
7. Services Interoperability
8. Social Networks Interoperability
9. Cloud Interoperability
10. Electronic Identity Interoperability
11. Objects Interoperability
12. Enterprise Software Interoperability

Study of the state of the art of research on interoperability in general identifies distinct layering of political, organisational, semantic and technical interoperability, and EI is represented in all of these layers. The 12 Scientific Themes can be mapped on to the interoperability layers as shown in Figure 4.

It is significant to note the scale of research activity across these Scientific Themes. Figure 5 shows, in addition to the number of research publications identified, number of research projects relevant to the domain, the number of related events (conferences, workshops, etc.) and the number of initiatives (working groups, clusters, independent entities, standards bodies, etc.) which are current or recent. It is important to note the research project figure is for European activity only. This is not to suggest in any way that activity is limited to Europe: indeed it certainly is not, but the scope of this paper is to report the European perspective. The clear conclusion is that this is a highly active domain, and that efforts to formalise a science base, thus providing a theoretical base for future research as well as the links between the application problem space and the scientific solution space that are essential foundations for an applied science.

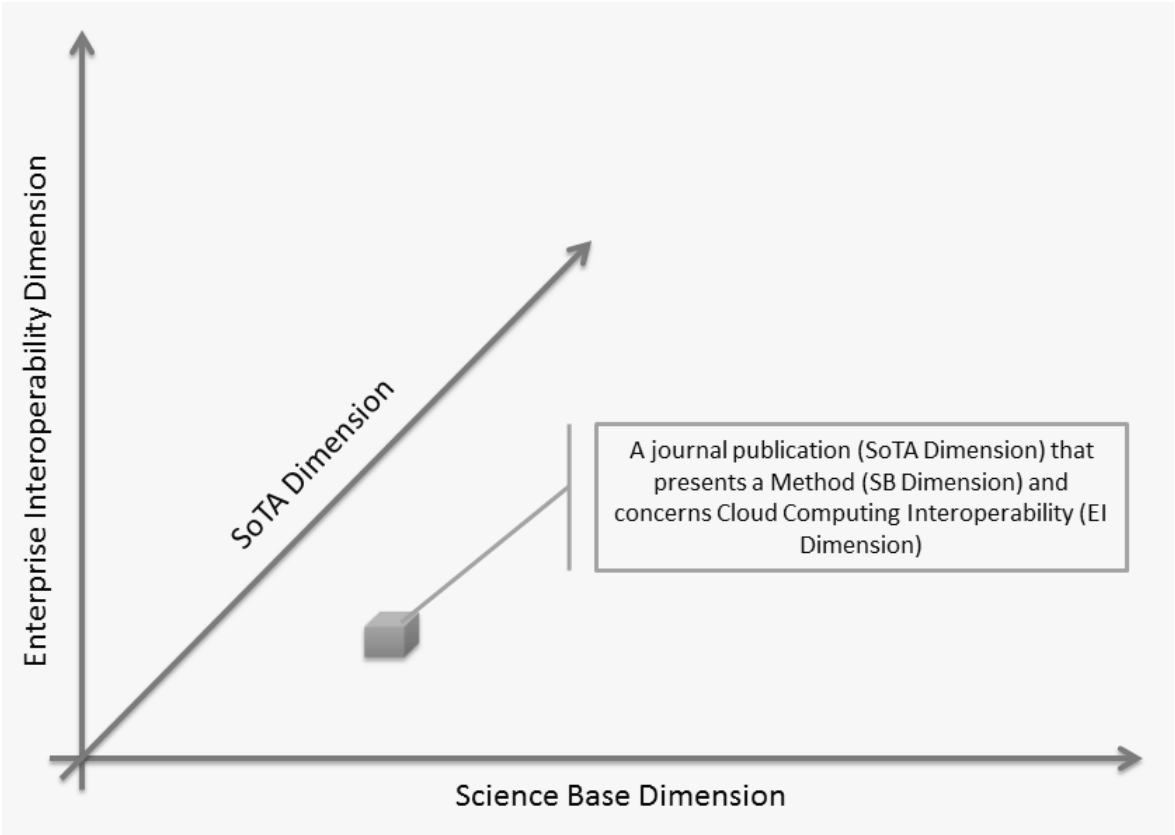


Figure 3: State of the Art Analysis Dimensions

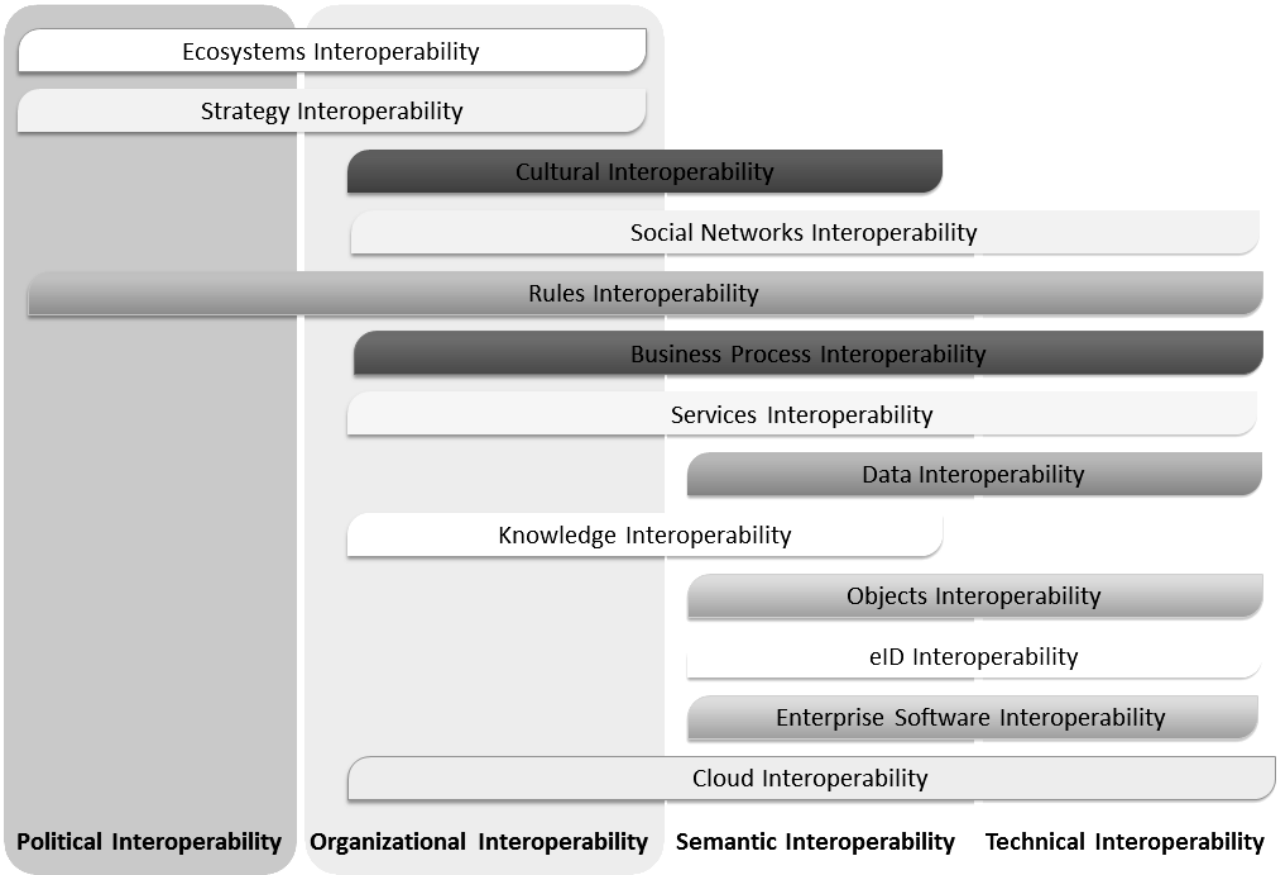


Figure 4: EI Scientific Areas Mapping to Interoperability Layers

5. CONCLUSION

The Enterprise Interoperability domain has clear links with a number of neighbouring scientific domains. Through drawing on these relationships, and identifying the unique contributions of EI research, it has been possible to draft a structure for an EISB which recognises the pragmatic, problem-solving purposes of EI as an applied science, whilst providing structure and content to domain knowledge. This latter must make domain knowledge accessible for application, as well as defining the underlying principle, axioms and theorems that are the foundation of EI.

However it is clear that the definition of an Enterprise Interoperability Science Base is not a parochial, European, interest. Initiatives are in place to develop a worldwide dialogue on the domain, of which this workshop is a part.

Total research contributions reviewed	544
European research projects relevant to EI	34
Relevant events worldwide	66
Relevant initiatives	13

Figure 5: Statistics indicative of level of EI research activity

6. ACKNOWLEDGEMENT

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Increase collaboration through a new software: the case of the MRO process in Avio S.p.A.

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ABSTRACT

The increasing competitiveness in the global market has lead aerospace company to re-formulate their business model looking to enlarge their core business and increase their competitiveness. Companies have, thus, to improve their processes and guarantee high standard of reliability and efficacy. The Maintenance, Repair and Overhaul (MRO) is an important process for the aerospace sector and requires high level of specialization and management of modules and components to satisfy customers needs and to work in accordance with the international policy and law. The actual study is based on an action research realized by Università del Salento and Avio S.p.A. to improve the company MRO process applying the Business Process Management Methodology and developing a new software. Changes in competitive scenario has lead Avio to improve and support its MRO process and in accordance with Università del Salento have applied BPM to reach higher performance. The realized software integrate different standards in a new framework to support MRO process in aerospace companies. It is based on a J2EE platform, integrates Intalio EE and uses a BPEL engine. The libraries and the front-end tools are open sources. Steps and results are described in the paper.

Keywords:
Maintenance Repair Overhaul (MRO), Business Process Management, Business Process Modeling Notation (BPMN), Tracking system, Workflow engine, BPEL, Six Sigma.

1. INTRODUCTION

The nowadays increasing competitiveness has introduced, the necessity to focus the attention on performance of the enterprise and costs reduction. To lead the company to improve their performance reducing the related costs, organizational and operational aspects of companies are analyzed and re-designed. This appears a relevant need and a common practice in high technological industry such as aerospace.
The aerospace product development involves many actors with the aim to better manage the product complexity and to share costs and risks that avoid a single company to realize a whole product (i.e. a whole aircraft but also module such as the engine). The aerospace products and related modules are complex one [1] since are composed by many sub-parts, customized, with a long product life and high cost of development [1]. Their complexity is also visible in the maintenance repair and overhaul (MRO) activities since requires high level of specialization and the management of many modules and components together with the need to satisfy the customer and to work in accordance with the international policy and law.
Maintenance, repair and overhaul (MRO) is a key process in the lifecycle of an aircraft and of its engine. It is necessary to maintain the systems in a safe and functional condition, so that they can fulfill the operational role that they were designed for. The maintenance process includes regular inspections during the life of an aircraft. The inspection schedule of an airplane varies from checks before each flight to a complete disassembly for a detailed inspection requiring a well organized system that brings together manpower, spare parts and equipment for each maintenance type.

Starting from an action research study [2] the paper wants to describe the technological solution developed to support the MRO process inside an Italian aerospace company: Avio S.p.A. The action research has been done by a team composed by members of Avio and Università del Salento.

Avio is leader in the development of subsystems and components, mainly turbines and gearboxes, for military and civil air-engines. The acquired technological competences in the sector make the company an accredited and reliable partner for the major OEMs (Original Equipment Manufacturing), such as General Electric, Honeywell, Pratt & Whitney and Rolls-Royce. The company participates with "design responsibility" to the main national and European programs, as the EJ200 for European Eurofighter-Typhoon, and represents an excellence in the propulsive systems with solid and liquid propellant, realizing the 16% of Ariane 5 European launcher.

Avio is very carefully to continuously improve their process also through ad-hoc internal company project such as Cartesio, leading the adoption and application of Six Sigma methods.

In addition to the activities of sub-systems and components realization, Avio works also in the MRO sector for military engine. This activity is done in the plant of Brindisi in the South of Italy and it has been the focus of our study.

In the last years, the core business of Avio in the MRO sector is changed from a "single customer" (i.e. the Italian army) to "many customers" (i.e. 30 customers) distributed around the world and characterized by own policy in the management of the revision activities and of the related agreements. This situation has matured the need to introduce and apply a software application able to track all the MRO activities and to manage all the related objects such as time, issues and planning activities.

As a process the MRO has been analyzed with the use of the BPM methodology that has lead insights and requirements for the software development. The aim of the paper is to describe the followed steps and the software framework that combine different standards in an new and appropriate structure for MRO in the aerospace sector.

The paper is structured in three further sections. Section two introduces some background definition useful to understand the main concepts related to our study. Section three contains the results of our study and describes phases and solutions applied. Section four concludes the paper and treats the main implication of the obtained results.

2. BACKGROUND

The activities performed in a company can be grouped in processes that allow to order the work activities in the time and space and to specify input and output and the related links. A business process is, in fact, a set of activities performed to obtain an output for a specific customer internal or external to the company [3]. It takes one or many types of input to create the output [4].

A business process is composed by different objectives characterizing its work: the resources, the goals, the constraints, the actors/organizational units and the activities. Resources are the set of input used to perform the activities and reach an output, they can be material and immaterial resources. The goals is the aim for which the process exist and it can be express in terms of desired output. The constraints are condition of different nature that limits and guide the execution of a process (e.g. budget, time). The actors or organizational units are who execute and participate to a process and usually they are the owner of one or more activities. Finally, the activities are the sub-parts of a process and all the set of activities allow to reach an output.

Based on the process classification of Porter [5], processes can be primary and support ones. Primary processes contribute to the core business of a company and create relevant value (e.g. inbound logistics, operations, outbound logistics, marketing and sales and service). Support processes are instead related to the core processes and support their execution and management (e.g. procurement, human resources management, technology and firm infrastructure). Processes are shared between primary and support ones based on the type of company and its core business (i.e. a process can be of support for one company and primary of another one). A further classification of process done by Davenport (3) distinguishes between operational and management processes. Examples of operational processes are product development, customer acquisition, production, integrated logistics, invoice management and after sales. Examples of management processes are performance measurement, information management, human resources management, planning , asset management. The Maintenance Repair and Overhaul process is for Avio S.p.A. a primary and operational processes directly correlated with the company core business and on the creation of value for its customers.

Processes need to be managed in order to meet the required performance but often process fail for errors in the design or execution that lead to inadequate performance [4]. To manage company processes, the business process management (BPM) is one of the most appropriated and used methodology. BPM is a methodology "supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information." [6]

The BPM aims to allow to the individuals to control the process and quickly respond to the internal and external changes [7].

It requires the development of the BPM life- cycle [6][7] through 5 phases:

- *Discovery*. It means to understand how the process works with tools (e.g. interviews, as-is process modeling) that allow to explore the process. Metrics are also used to evaluate the process performance and to discovery gaps that need to be eliminated.
- *Design*. It aims to create the to-be workflow of the analyzed process. The to-be is modeled specifying resources, constraints and participants to the process. IT solutions useful to improve and monitor the process are proposed and developed.
- *Execution*. In this phase, the new process is run-up following the guidelines emerged by the design phase in terms of resources, constraints and participants and ad-hoc IT solutions.
- *Monitoring*. It aims to evaluate the performance of the to-be process and a set of metrics are applied to evaluate the performance of the improved process.
- *Optimization*. It aims to solve the weakness emerged from the monitoring phases through a set of actions that could lead the re-start of the lifecycle.

To enable the application of the BPM, IT systems play a fundamental role since permit to support and control the processes [7]. Business process management systems (BPMS) are "a class of software that allows organizations to devise process centric information technology solutions" [8]. Those solutions need to integrate people, systems and data related to a process impacting on the organizational capabilities [8].

BPMSs are developed or improved in the Design phase of the BPM lifecycle and are based on the to-be modeling of the analyzed process. They have the advantage to be developed reflecting the process owner needs and it is very closer to its way of work and needed resources. The business process owner are, thus, directly involved in the design of a new BPMS [8]. In fact, during the performed action research Università del Salento have worked with Avio to realize a software that reflect the work activities and needs of the process owners in order to reach the best results from the whole system.
Therefore, BPMS allows to guide the execution of a process looking to its workflow and activities and to the resources involved.
Furthermore, the application of BPM in a company can come together with other methodologies of process improvements such as Six Sigma. For Hammer [4], Six Sigma is an avatar of BPM since both of them are based on statistical process controls [9][10]. The integration between Six Sigma and BPM it is usually a successfully initiatives that enable to combine the potential of both methodologies to manage and optimize processes [11]. Six Sigma aims to understand the process variance and to reduce errors in order to increase the reliability of the process and satisfy key objectives. Six Sigma requires to gather data and to make controls that are used for different analysis. This aspect is the most important contribution for BPM since it wants to understand the most critical process and solve critical aspects [11]. Therefore, through the combination of the two methodologies, a wide set of analysis are executed on the most critical process for a company. Based on the experience of Avio in Six Sigma application, this integration is also visible and treated in our study.

3. RESULTS: BPM IN THE MRO PROCESS

This paragraph describes each steps of the used approach and the mapping between Six Sigma and BPM methodologies.
The principle at the base of MRO project recognizes that BPM and Six Sigma approaches run as parallel initiatives to realize a competitive advantage. The SS methodology, already used in Avio, is more focused on which processes are the top priority for the business and which problems are the most critical to solve. On the other hand BPM is more effective about task control, activities automation and data gathering. Common points are about analysis of current processes and quality improvement of themselves.
So an integrated methodology has taken advantages from both approaches.
Figure 1 summarizes the mapping between DMAIC[1] cycle used for Six Sigma methodology and BPM.

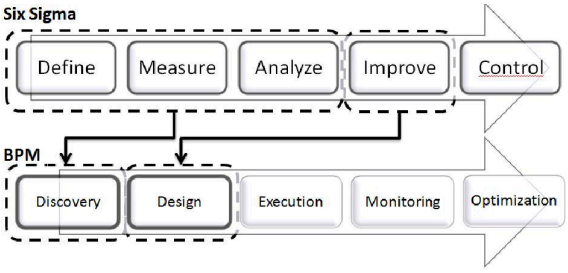


Figure 1: Six Sigma and BPM application in process redesign

[1] DMAIC: Define, Measure, Analyze, Improve, Control

Discovery
The first step in the analysis of existing procedures is the information-gathering, developed through a sequence of interview, aimed to derive key competences for the success of the project. *Tacit knowledge* is very important, more than standard procedures, and on it a great amount of time has been spent, it belongs to the core of sustainable competitive advantage [12].
Acquired knowledge has enabled modelling of existing process and has provided the guidelines to define Key Performance Indicators (KPI).
Used KPIs are cross-sectional in both process and Enterprise's functional areas. All these indicators have been defined for evaluation process's performances, compliance with Enterprise's policy, suitability of the system to satisfy operational requirements, quality of communication between various actors of the process, availability and usability of information required for execution of process. Analysis of results, coming from various measurements, underlines weakness and strength of the process and detects phases and tasks upon which focus the efforts.
These three phases of Six Sigma approach find their natural location in the first phases of process improvement, i.e. AS-IS analysis (Figure 1).
This derives from the definition itself of the first three steps that belong to Six Sigma methodology. In fact they concern about identify the process/product to improve, definition of current performance level and key elements that influence it. Like so the Discovery phase of BPM methodology traces out the same targets.

Design
After preliminary study of AS-IS, Design phase has been started for improvement of MRO process.
Changes have been made to the flow of the process, to the course of some main tasks, to their time sequence and to the nature itself of some activities; a change of information flow has been required in order to improve performance indicators and process's quality, in the perspective to re-engineer all the workflow according to the "Design" step of BPM methodology, like so the "Improve" phase of Six Sigma.
The new MRO process , with all its changes, has been modelled according to BPM philosophy.
Business Process Modeling Notation (BPMN) is the process modelling notation chosen for formally description of MRO process; BPMN is a graphical language widely used in both open-source and proprietary workflow engine software. Design phase is structured in two consecutive steps.
At the beginning, when workflow engine for running process was not yet chosen, a first release of process's model has been developed, without task for interaction tightly coupled with to support information system, then the selected system for the execution of the process is Intalio BPMS EE 6.x. Selection *iter* between various available systems and benchmarking are not discussion topics.
Workflow engine selection opens the way to model all functional facets and tasks for inter-system communication.
Because of the complexity of the process and the hard work to carry out, development and release of system have been partitioned in three sequential phases, with the intent to introduce change gradually, test *in itinere* its effectiveness and optimize development management. The three phases are identified and classified as: receive and storage, overhaul, shipping.

Figure 2 underlines operational *iter* followed in development and release. First thing "receive and storage" phase has been developed and released, and then two parallel activities has been executed: development and release of second phase (overhaul) and execution, monitoring and improvement of first phase.
Similarly, after release of phase two, third phase (shipping item) has been developed and, at the same time, execution,

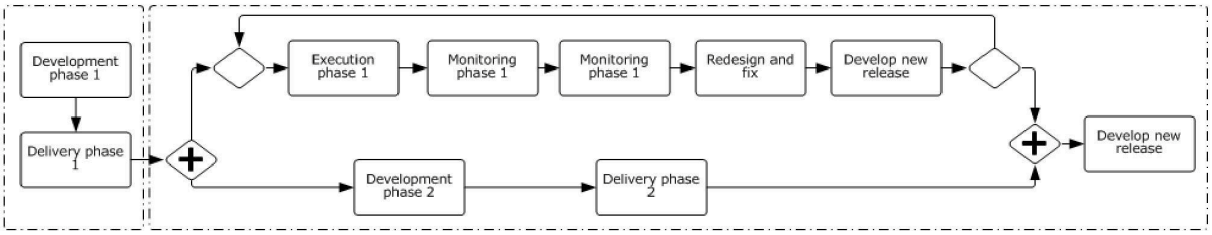


Figure 2: Development process

monitoring and improvement of both first and second phases have been carried out.
This approach enabled to put on trial the system directly in the operational environment and to modify and improve a very complex system before its final release.

Execution
After the model has been designed, the execution phase started. Process's steps were very complex to manage as a whole and subdivision described in previous paragraph was very useful, because it reduces the complexity of the system.
Without the help of a workflow engine this step should be very difficult to perform, but Business Process Management System (BPMS) allows an easy automation of process execution. BPMS enabled a controlled execution of MRO process, driving all involved actors in their tasks, reducing decision-making in human interaction and improving communication and exchange of information.
Another important aspect in execution phase is the "Push mode approach" used drive users. In fact there are two parallel ways in our system for notify user his own task:

- worklists displayed after login (pull);
- email system which notify directly by a personal message as soon as the task can be performed (push).

Execution phase started with an initial training time provided to each involved division. The work-shadowing introduced all users not only to use the system but also to take part in the change in progress into the Enterprise.

Monitoring
Process changes musts be correctly implemented and this need can be ensured by a close monitoring phase. In our project monitoring has been performed in each step (receive and store, overhaul, shipping item) and then, in the final release.
This subdivision has enabled monitoring on a great number of sub-tasks, Enterprise division and involved users and, at the same time, has focused attention without lose the way in the width of the system.
Actually monitoring phase is running yet on the completed system, after release of last phase (shipping item). While in development phase monitoring has been used for test effectiveness of the system, in final release it provides information about process efficiency and performances, system and divisions of the Enterprise. It is a long term task integrated in both process and system and has already provided several information to optimize a great number of tasks in the designed process.
Thanks to monitoring, MRO system performed all the following points:

- Management of task and information upgraded in pull/push mode;
- Case management;
- Centralized workstop management;
- Quick centralized visualization of all items, before and after maintain and repair operations;
- Periodic controls management;
- Dashboard;
- Planning management;
- Operational time management.

Optimization
After the software was developed and released, optimization phase starts with the aim to improve the system and add other tools:

- Administrator's advanced functions;
- Business intelligence dashboard;
- Improved interaction with other systems.

While advanced function are mandatory, dashboard and improvement of communication with other system has been explicitly required.
Dashboard, wanted by top management, is necessary to easily measure process's performance; integration with pre-existing systems has been required by officers of many different departments, in order to reduce the need of communication between various departments. It has been realized including the management of information and functionalities that, at the beginning, were not pertinent to the project and were separately managed.

Software Architecture
Process tracking system has been realized through the integration between workflow engine and Java customized web-based application. The first one controls process advancing, according to BPM schema, using a BPEL-based philosophy. It manages the automated steps of the process performed by web services.
The second one provides both the entire support for user's actions (i.e. for all not-automated step of the process) and automated batch processes for data acquisition. Interaction between these two distinct modules has been performed by web services.
According to the need to integrate tracking system into the Information System of the Enterprise, the interaction between new and existing modules has been carried out without a direct access to information and data, but using web services based communication and a common repository.
New developed modules are :

- Intalio Process Manager (release 6.x) – workflow engine for execution of business process modeled in BPMN and stored in BPEL;
- Web Application J2EE – Web front-end and batch process;
- REALM – J2EE compliant service for definition of roles and hierarchy;
- Application DB – database for web-application data;
- Intalio DB – database for workflow engine data.

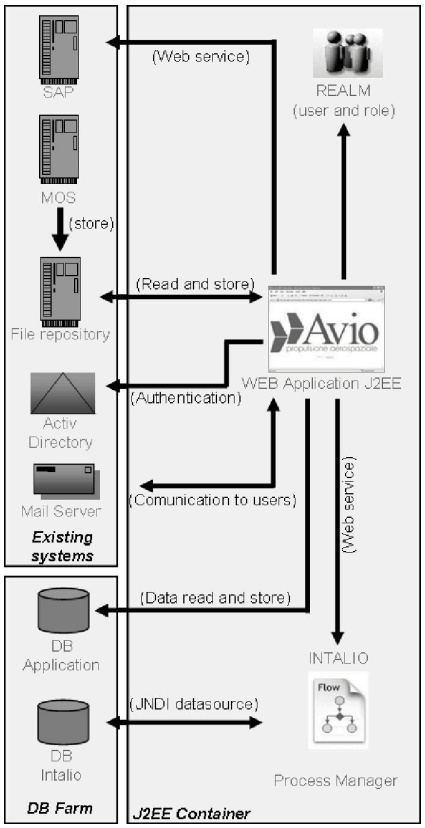


Figure 3: System overall description

All Java components (complying with J2EE 1.4 standard) operate on the same container (Tomcat 5.5) running on open source Linux platform; front-end access can be provided through IE6.0 or later; DB management is assigned to already existing server farm.

Already existing modules which interact with web application and workflow engine are:

- Active Directory – provides the authentication of users;
- Mail Server – used for communicate with all users involved in process, at any level;
- MOS – tracking system for low level detail, it contains all information in a specific part of the process. Communication between MOS and web application requires files repository because of the great amount of exchanged data and because of the data mining required operation.
- SAP – high level business management system.

4. CONCLUSIONS

In the described results, we have modelled the MRO process and developed and executed a Workflow Engine for this process within an aerospace company. To support the process management and the software development we have combined the BPM methodology with the Six Sigma approach.
The first task, analysis according to BPM approach, was very critical for knowledge–gathering, indeed standard procedures are not completely enough for enterprise processes' modelling because of not standardized procedures at bottom and middle level in the organization.
Final process's modelling (Design phase) was realized after choice of Workflow Engine, in respect of guidelines of Intalio Design and Engine. Development was divided in three phases for gradually apply, test and improve the system. After the first release, the execution of system enabled receiving of user's feedback for improvement of the system. So the steps 'execution', 'monitoring' and 'optimization' of BPM approach was realized for each singular phases. After final release, execution, monitoring and optimization concerned the complete system, without the early subdivision in three different sequential phase.
The proposed architecture can be applied also by others company in the aerospace sectors with the same issues and needs of Avio and the described BPM lifecycle phases can be used as reference from same or related studies that aim to improve company process applying BPM methodology.
The Workflow Engine is currently used inside the Avio plant of Brindisi by 100 employees and satisfies with success the following goals:

- Track more than 17 engines models and versions;
- Manage overhaul activities on articles of more than 30 customers;
- Identifies and solves bottlenecks;
- Turns bottom level's tacit knowledge into standardized and traceable procedure;
- Simplifies the monitoring phase through a real time dashboard;
- Improves the information flow between different divisions;
- Optimizes the workforce management;
- Optimizes the planning;
- Reduces the overhaul time.

Therefore, through the MRO tracking system is possible to identify process issues, to fast resolve them and to generally improve the time required for necessary activities.
This system has been the first company action towards a set of changes and improvements in organizational processes. Others actions are planned as also new functionalities for the workflow engine that will be carried out by the team of Avio and Università del Salento.

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Collaborative Integration of Classic Applications in Virtual Reality Environments

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ABSTRACT

When working collaboratively with others, it is often difficult to bring existing applications into the collaboration process. In this paper, an approach is shown how to enable different applications to work collaboratively. It enables a user to do three things: First, the ability to work collaboratively with the application of choice, selecting those applications that fit the need of the scenario best, and the user is comfortable to employ. Second, the user can work in the environment he chooses, even if the application is not specifically designed for this environment like Virtual Reality Environments or mobile devices. Third, the technology presented makes it possible to mesh applications to gain new functionalities not found in the original applications by connecting those applications and making them interoperable. Taking a Virtual Reality Environment and a standard office application, the use and fitness of this approach is shown. It should be specifically noted that the work underlying this paper is not specifically on multimodal usage of Virtual Environments, although it is used that way here, but rather showing a concept of meshing application capabilities to implement "Meta-Applications" that offer functionality beyond their original design.

Keywords: Collaborative Engineering, Collaborative Work, Virtual Reality, Scientific Visualisation

1 INTRODUCTION

Traditional collaborative work that is state-of-the-art today focusses on screen sharing and video conferencing. Although this method works, as it is simple and does not imply a lot of demand on the systems used, it is awkward and uncomfortable. Modern collaboration demands more than just screen sharing. Especially in research and development the data is much more interesting than just the visual representation that you can capture using screen sharing alone.

The design of a new prototype in R&D often requires the consideration of a multitude of parameters that influence the final product. The product design impacts on the process in manufacturing and on the physical properties and vice versa, costs have to be calculated and reduced as much as possible and physical prototypes have to be somehow correlated to the initial virtual design. This often requires a multitude of data and views on that data, each usually bringing along its own application for display.

Thus, a design process involves several documents that contain different data that is somehow interrelated. An Excel sheet could contain the specifications for a virtual prototype that is visualised in a Virtual Environment, and a simple text file may specify the log and parameters for a simulation run whose results are displayed on top of the displayed prototype. Also, different views using the same application are often required to assess a development. This does not just include different viewpoints to a data set, but also different representations and different aspects. Sometimes, different tasks require different media for display or kinds of interaction, like making it necessary to relocate a discussion from a meeting table to a Virtual Environment for a closer discussion of an issue that has arisen.

Especially in aforementioned Virtual Reality Environments – but also on emerging every-day technologies like multi-touch screens – it is difficult to work with "classic" applications, as the interaction paradigms there are quite different from those used on the desktop. Here, the traditional screen sharing approach definitively fails, as it is impossible to translate the unique input restraints in those environments directly to the shared screen, thus limiting the collaboration to the same kind of the original device.

In this paper, an approach is introduced to make applications accessible in a collaboration, even beyond the boundaries of a single application. This technology will be used to access data from Microsoft Excel in the collaborative Virtual Reality Environment OpenCOVER for COVISE. COVISE is a modular and collaborative post-processing, simulation and visualisation framework enabling the analysis of complex data sets in engineering and science [1]. OpenCOVER, the COvise Virtual Environment Renderer first described in [2], supports Virtual Environments ranging from workbenches over Power Walls, curved screens up to full domes or CAVEs and head mounted displays. Using OpenCOVER, users can analyse their datasets intuitively in a fully immersive environment through state of the art visualisation techniques, including Volume Rendering and fast sphere rendering. Physical prototypes or experiments can be included into the analysis process through Augmented Reality techniques. OpenCOVER features an extensible plug-in framework that allows to add further functionality to the environment. OpenCOVER already supports collaboration at every level. Users can connect from different locations, analyse data sets, include audio and video conferencing in their session, mark and document collaboratively features of the data set, and other. Using COVISE and OpenCOVER, it is even possible to join a collaboration just using a plain web browser without any specialised plug-ins, enabling collaboration from everywhere [3].

2 Related Work

It is generally accepted that applications especially created with collaborative use in mind are less functional and used than the single user applications that are commonly used by the end users (e.g. [4] [5]).

A few methods exist that enable different users to share their applications with each other. There are the rare kind of applications especially designed for sharing. They incorporate concepts for collaborative work and inherent sharing. The advantage of that approach is that, as the sharing is done at the application level, it is usually much more sophisticated, efficient and powerful compared to all other approaches. Drawbacks here are that the shared application is usually developed primarily as a research vehicle for sharing concepts and often lacks the functionality typically found in state-of-the-art single user applications [5]. This is still true, though recent efforts of e.g. Microsoft [6] and others show that the once single user applications start to be extended to further support collaboration, integrating more and more into collaboration enabling Groupware systems. When looking at application design, collaboration features form usually a very small part of a complete application [7]. Thus the common collaboration research applications are doomed to fail comparing to state of the art applications. Collaboration design is nevertheless important, but it seems more straightforward – if the original software creator refuses to add internal collaboration facilities – not to replicate the application just for adding collaborative features, but rather to extend the existing application for collaborative functionality.

Different methods of transparent application sharing have been deployed. The first efforts undertaken were focused on image based sharing of the application. Here, the desktop screen or parts thereof is captured and transmitted to the partners in the session. This is currently the most accepted form of application sharing, used in various state-of-the-art commercial collaboration software like WebEx [8], TeamViewer [9], and others. The reason behind the wide adoptance is the ease to share arbitrary applications, nowadays usually without a dedicated application framework but through the web browser with appropriate standard plug-ins. The main drawback is generally a comparatively high bandwidth needed while sharing the application and that the application shared is not really collaborative, but rather just one user can work with a single application instance at a time, the others are viewers only. This limits the usability and flexibility of this approach, leading to other ways of transparently sharing an application.

In research, more semantic approaches are common nowadays. Those approaches use transparent sharing that enables to share applications without them explicitly knowing that they are being shared. In contrast to the screen sharing approach, they usually only capture raw input events like key presses or mouse clicks rather than pixel data and transform those into more abstract events using knowledge about the application. The clicks and inputs are then replayed in all the participants' locally running applications and thus keep the application state consistent on all connected hosts. Systems using this approach are described e.g. in [5] and [4]. The main advantage of this approach is that it is feasible for all current applications. But it requires the applications to be visually equivalent to capture the right button at the right coordinates. If one user reconfigures his user interface, this method may fail completely. It is also usually limited to a single operating system type as it accesses low level operating system features not found on other systems. Furthermore, only the surface of collaboration is touched this way. Capturing the application state and the content currently processed in the application cannot be included in the synchronisation process, although it is typically the most important part in the collaborative work.

A more sophisticated system will try to access the internals of an application and use the loaded documents and application states to improve the collaborative experience [7]. Almost all state-of-the-art commercial applications, especially on Microsoft Windows, nowadays support some kind of API a programmer can connect to and issue commands to the application or retrieve information about the document loaded or the state the application is in. This kind of API makes it often very easy to implement a collaborative layer, quickly enabling an application to be used in a collaborative way. In the last decade, several such solutions emerged that did not simply broadcast screen contents and capture keyboard input, but rather analyse the input events and the application semantically and replicate the events and synchronise the application contents on remote machines. This approach is surprisingly successful, as several examples show, extending off-the-shelf software like Word [7], Visual Studio [10], or Maya [11]. Xia e.al. [7] for example use Operational Transformation to map events from an application to simple insert and delete operations on a linear object space. As those operations are quite simple, it is also relatively easy to assert the consistency of the two documents when edits change cursor positions in the document. Thus, no direct data is exchanged, but the events occurring in one application are analysed, packaged into an abstract, simpler representation and replayed in the target application. This is currently done between the same applications though, forfeiting much of the power of this approach, but this is maybe owned to the linear operational space and the simple operations.

3 Objectives

Many sophisticated applications are available that offer a plethora of functionality. Usually, this functionality is limited to a certain environment – usually the desktop – and is available to a single user only. Users should be enabled to choose the application and the environment they desire and collaborate freely with others nonetheless, even if the other partners prefer other applications or environments. Thus participants should be enabled to work in Virtual Environment if desired or at their local desktop, or on mobile devices. It is also desirable to switch between those environments and let others participate in what they are working on.

In Section 2 several examples for coupling two running instances of an application or two applications of the same type were introduced. But while enabling collaboration between different partners, a goal is also to bring together different applications to offer

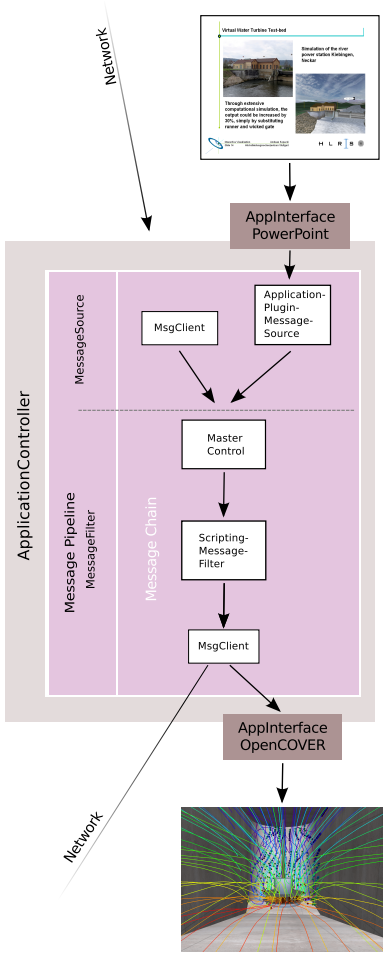


Figure 1: The message pipeline of the Application Controller

a unique functionality not available out of the box, harnessing the power of a specialised application and connecting it to offer an advanced functionality via a common interface. This separates this approach from others available that allow the collaborative, real-time working on documents like Microsoft Office Live, Google Docs and is even more powerful than the simple screen sharing approach used by WebEx or TeamViewer.

Both, the sharing and coupling of those applications, should be done transparently without the need of explicitly informing the application that it is used in a way thus. Also, the set-up of the functionality should be both flexible and easy to learn, using state-of-the-art technologies available on most platforms.

4 Design

The implementation of the collaborative and inter-application capabilities is designed around a central component – the Application Controller – that is running on every participants' computer. It can be used for starting and stopping the applications as well as – more important – to steer the application and distribute and transform events originating from the controlled applications to other participating applications.

Application Controller

For transparently sharing applications, a component is needed that captures application events, analyses their contents, transforms them appropriately and distributes them to all applications interested in this kind of event. Thus, an Application Controller was developed that is capable of taking control of an application and steer it with a small subset of commands. Using the Application Controller it is also possible to save the application state of the controlled application to storage and to resume the operation later on with the same application state as before.

The Application Controller is a small networked service application that is running at every host participating in a session. Every application that is integrated into a session will require a specialised application interface for communicating with the Application Controller. These interfaces are realised as plug-ins, linking them at run-time directly to the Application Controller. The application interface is responsible for translating the commands originating from other applications to mechanisms native to the application, like COM, CORBA, WebServices, signals, and others. It also gathers the feedback and events from the application and sends them back to the Application Controller. Thus the network of the Application Controllers creates a hub that connects all applications in a session, relieving them of the necessity to directly communicate with a common protocol.

The Application Controller itself is listening at a SOAP interface [12], waiting for commands to execute or sending messages to other running instances. Applications are instantiated using this interface and taken control of by the Application Controller. It creates the new application instance by loading the appropriate application plug-in and starting the application process. A communication link is established to the native API of the application.

The capabilities – i.e. the commands an application accepts – are published using a simple XML document. This descriptive document also contains other information about the application like what documents it is able to process, if it can load directly from a certain source (e.g. via the http protocol), and more. Clients to the Application Controller can use this information to create generic user interfaces to steer every application supported by the application controller out of the box. All Application Controllers are connected via a network bus for collaboration beyond host boundaries.

Messages

Generally, the design is based on a message passing, message transformation and state preservation mechanism. Messages are usually coming in from the network or generated by the applications with the help of their application plug-ins connecting them to the Application Controller. Thus, whenever e.g. a PowerPoint slide set is loaded, an event is generated in PowerPoint that is captured by the Application Controller plug-in for PowerPoint.

It generates a message, indicating that a file was loaded. This message is sent to all other components that are subscribed to these events. In Fig. 1 the message is transformed and passed on to a Virtual Reality Environment, loading a data set corresponding to the slide displayed in PowerPoint. Messages are realised as strings encoding the message body. Arbitrary strings can be sent in the message body, but per convention, an XML format is used for easy parsing and structuring of the message content. But of course, other formats can also be used that are understood by the message destination, like JSON for ECMA-Scripts or Base64 encoded binary data for other destinations. Choosing a string representation has several advantages, like human-readability, non-endianess, same bit representation, and ease of use, but of course limits the amount of data sent between applications. While it still may be feasible to distribute a text document, the overhead for large data like in numeric simulations is just too much and has to be done using different communication channels.

Message Filters

Applications could react directly to those events, but that would be quite inflexible, only allowing a pre-defined behaviour that also would be hard to switch off if not desired. Thus, a more flexible approach is used. All messages are sent down a message pipeline that consists of several filters that process the message on its way to the receivers. Filters can be arranged sequentially in the pipeline, as well as in parallel, allowing the aggregation of results from several independent filters. This aggregation allows the flexible combination of functionality, for example to prevent Master/Slave control from having an impact on network communications. The filters are able to modify messages, add new messages, replace the message with one or more, or discard the message entirely. As messages sent from and to applications are basically strings containing information possibly interesting for others, it is very simple to parse and react on them even from different frameworks like scripting languages or other runtime environments using their own byte-code like Microsoft CLR or Oracle JVM. Messages also contain some extra fields providing information like who generated the messages and a topic describing a message group. Other applications or message filters can subscribe to a topic or subscribe to all topics and filter messages themselves for topics of interest.

Message filters are realised as plug-ins and dynamically loaded by the Application Controller. Message filters can have arbitrary functionality, but are usually used to modify or block messages or send them to other Application Controllers or components partaking in a collaboration. Filters exist for communication, transformation, master/slave floor control, collecting user data, and others. Currently, the most used filters in the Application Controller framework are a network component sending all messages to a message bus for other Application Controllers to react on them, thus enabling collaboration between different users or allow application meshing between applications running on different hosts, and a scripted transformation filter that reacts on events using a scripting language. The advantage of a scripting language for filtering is its flexibility and fitness for quick rapid prototyping cycles. For scripting, QtScript was chosen. QtScript is a subset



Figure 2: Using Excel data in a Virtual Environment

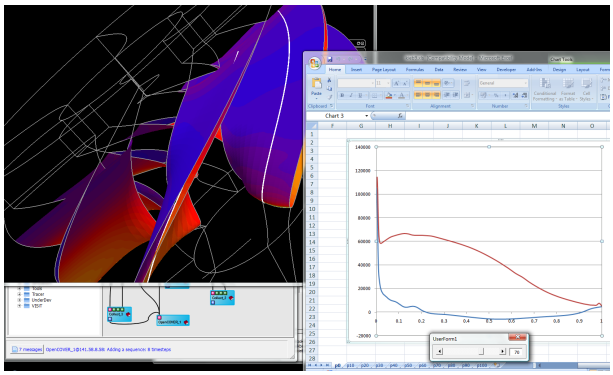


Figure 3: Using the same set-up as in Fig. 2 collaboratively at the desktop

of the ECMA standard that is also the base for more common languages like JavaScript and should be easy enough to learn by anyone who is already familiar with languages like C++, C# or Java. Scripts can also access all Application Controller functionality by calling its native methods. Thus, scripts can send arbitrary commands to application plug-ins to retrieve further data to be processed.

A script can be easily loaded by directly distributing it amongst the Application Controllers issuing a command or by passing a file name to all Application Controllers to load the script from. This creates what we call a workspace, connecting different applications together, enabling meshed functionality and collaborative features.

5 Application of the Concept

The concept of collaboratively using off the shelf applications in different environments was used in several scenarios ranging from contextual support to complete workspaces for meeting support. To exemplify this technique, a small evaluation scenario was chosen for this paper to demonstrate the possibilities of collaboratively using applications and meshing two ap-

plications within a Virtual Reality environment. It consists of a small real life problem in turbo machinery development. Here, while designing turbines for water power stations, the performance data is usually assessed using two tools: A 3D visualisation of the turbine with various parameters mapped on the turbine blades in the Virtual Reality Environment OpenCOVER and a two-dimensional curve of the pressure profile in Microsoft Excel. Those two views are difficult to merge: The pressure profiles are selected using a percentage of the boundaries of the turbine that is not easily mapped to the real turbine in 3D.

Thus it is difficult to correlate these views that reside in two different applications. Therefore, a method was needed that was able to show the location of the pressure profile in the Virtual Reality Environment to make it possible to establish this correlation. Admittedly, it is possible to somehow display those curves by exporting them from Excel and writing a reader module for the Virtual Reality Environment for visualisation. But it is obviously more desirable to have the data within its original application and share it with others in a transparent way – and to do this using the applications as they are without adding direct functionality. If changes are made, they can be directly applied to the Excel table and will be immediately visible in the Virtual Environment for further analysis without any explicit conversion steps. Using the Application Controller, this also allows to collaboratively share and discuss the data from within several environments.

The applications were connected using the Application Controller and a small script reacting on changes within Excel and sending the data to the Virtual Reality Environment. In the set-up described here, three computers are involved. One head node driving the cluster for the Virtual Environment running OpenCOVER in Linux (Fig. 2), one Windows Workstation running Microsoft Excel and a TightVNC server [13], and one Notebook of a remote partner running a desktop version of OpenCOVER and another instance of Excel (Fig. 3). When the script for the workspace is loaded, it automatically loads the Excel file corresponding to the turbine currently displayed in the Virtual Reality Environment. It also causes OpenCOVER to connect to the workstation running Excel using VNC, displaying Excel directly within the Virtual Environment and allowing a limited interaction with Excel and the data loaded. On the remote notebook, both, Excel and OpenCOVER are started, the appropriate data loaded and displayed. Both users – the one in the Virtual Environment and the other one at the remote notebook – can now analyse and discuss the data, select different pressure profiles via a slider in Excel and compare the pressure profiles to the three-dimensional visualisation of the turbine blade.

When the slider is moved, the chart displaying the pressure profile changes and an event is sent to all participants. The event arrives at the script that consecutively queries Excel for the location of the pressure profile on the blade. The coordinates are stored within the Excel sheet and thus can be accessed by the Application Controller script. The coordinates are transformed to the correct format and sent to OpenCOVER that can use the x-/y-/z-coordinates to display a poly-line on top of the turbine. The user in the Virtual Environment can now compare the pressure profile with the data mapped on the 3D visualisation with ease. The other user sitting at his desktop can also compare the same results concurrently.

A small evaluation was done with engineers doing turbine assessment in their daily work. They were impressed by the ease they could now compare the pressure profiles and the three-dimensional visualisation. All used both views for assessment while working in the virtual environment. None of the users neglected one view in favour of the other. This shows that meshing applications allows for a wider range of functionality than that available from a single application that is unable to cover everything, but is usually focused at one field it excels. Using the internal API of an application while meshing them gives a lot more possibilities in combining views, data and control. The shown example is very basic in its nature, but shows that just using the off-the-shelf applications it is possible to get results that were not able to be achieved before.

6 Conclusions

In this paper, a technique was demonstrated that not only allows to make applications collaborative in a way transparent for them, but also allows to mesh those applications to add functionality to other applications in use. It was not necessary to change those applications for the functionality implemented. In the given example, we chose an Virtual Environment application and a standard Office application for showing the application meshing concept. The approach is not directly targeted or limited to this example though, but rather a generic coupling method of two or more distinct applications. The coupling is done by generic or specialised filters that transform application events into new behaviours and commands. The flexible approach chosen using a directed message filtering graph allows to combine different filter functionality with ease.

This example is still not "feature complete" of what you may have in mind what can be achieved by coupling of data sources and applications. Of course, when adding further functionality to the applications in question, a more seamless interaction concept is possible. E.g. the Virtual Reality Environment OpenCOVER could be extended by a plug-in that better visualises the location of the pressure profile and even maps the profile directly onto the turbine blade. Also, the slider to steer the Excel table could be integrated as an interaction concept into the virtual environment rather than using the original Excel slider. This would have required a dedicated component in one of the applications, a thing that to do was avoided in this paper to show the possibilities of the method without extending the original application and with relatively minimal effort in scenario programming.

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The Importance of Effective Risk Management System in the Slovak Enterprises

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ABSTRACT

The aim of this paper is to call attention to the importance of the effective risk management system in the Slovak enterprises, especially at present, when the consequences of the world economic crisis still persist and the enterprises have to face many external factors bringing the risks.

Keywords: enterprise**,** performance, risk, crisis**,** enterprise risk management.

1. ECONOMIC CRISIS AND SLOVAK ENTERPRISES

The economic crisis, directly or indirectly, affects the activities of a majority of the Slovak enterprises also at present. The crisis gave us a lecture on risk management importance in key moments and in all business activities. Drawing on the gained experience the managers aware that if they want their firm to be prosperous and survive their present management way has to be changed. This reality is supported also by the results of the survey realized by the Slovak agency TNS SK with title "Economic crisis and it consequences in 2009". In this survey participated 211 respondents presented by middle and top managers and IT specialists from the Slovak enterprises. The survey confirms that almost 50 % of the Slovak companies really perceive the influence of the economic crisis through their customers or directly through their own acting. But what is more important, almost 59,2 % of addressed companies presented that the economic crisis will affect or already has been affecting their internal decision making and forced them to reduce the costs. 32, 7 % of the companies have concentrated on increasing the productivity and effectiveness and 25, 1 % of the companies decided to restrict their growth plans. 18% of the companies reduced activities that are not part of their core business. Only 16% of the companies declared that the economic crisis does not have any impacts on their decision making. The costs reduction is realized especially in companies with number of employees over 50 and companies from public sector and manufacturing. Increasing the productivity and effectiveness, more than in other fields, declared especially firms from manufacturing and services [1]. The costs reductions and increasing the effectiveness and productivity in the company are not sufficient for successful crisis overcoming. In the enterprises the pressure on short time thinking is still increasing what results in their drowning in the whirl of operative hectic and spending the resources needed for long-time enterprise development. The enterprises so waste their forces and do not create new potential for the future. Everything is concentrated only on the short time financial results. But building prosperous enterprise requires concentrating on the future and changing the way of management in long term horizon.

2. RISK MANAGEMENT SYSTEM

Good strategy and in detail elaborated strategic plan encompassing risk management system are the central points of business fruitfulness. In the first place, the company management should assign what objectives are to be achieved through the risk management system. The optimal outcome should include the activities as follows [2]:

- we know all important risks threatening the organization objectives,
- the external factors affecting risks importance are known,
- we are able to identify new risks and opportunities in time,
- for all important risks is defined :
    - personal responsibility for their management,
    - internal control and measures limiting the impacts on the organization (we know also the costs),

- indicators indicating (measuring) fruitfulness of their management (they are regularly evaluated and presented to top management).

But the reality in the conditions of the Slovak enterprises is different:

- risks are watched at random and in separated fields,
- intuitively and unsystematically,
- very informal,
- only reactions,
- without structure and individually,
- no risk management but risk ignoring,
- risks assessment only within actual knowledge and experience,
- attitude that risk management is only tool for their reducing.

The basis of the risk management is to learn the organization to live with the risk. It does not concern only risk management or elimination it but especially to consider it as a part of the organization at all management levels. Thus, the effective risk management is not aimed only at preventing the business mistakes but also to ensure the proper management that is closely connected with a measure of business risk. Nowadays total risk ignorance is very dangerous strategy. However, also the best strategy for increasing the performance of a firm or to avert its failure can lead to nonsuccess if is not realized properly. At present, the risks ownership is more key strategic question than ownership of assets, capacities and abilities. At present the continual changes of the external environment are very difficult to be foreseen or effectively responded. Therefore it is necessary to reassess the objectives and strategy periodically and so bring affects also on the key risks of the company. Accordingly, the changed risk profile of enterprise has often impacts on the strategy change.

3. ENTERPRISE RISK MANAGEMENT

Implementation of the risk management system in the companies is realized in a variety of ways. The Enterprise Risk Management (ERM) brings the principal change of the view on the risk management system in the Slovak enterprises. Just the ERM has great influence on the fulfillment of the enterprise strategy since it manages the risks in close relation with objectives achievement. The further contributions include e.g.:

- higher probability of objectives achievement,
- consolidation of reporting concerning various risks to the level of managing bodies,
- enhancing the understanding of the key risks of the organization and their broad connections,
- identification and share in commercial risks,
- greater concentration of management on key matters of organization,
- less surprising crises,
- greater emphasis on proper partial decisions and proper way,
- higher goodwill to accept changes with regard to achieving the objectives of organization ,
- ability to accept higher risk in term of higher reward,
- more information about risks usable during decision making.

Without top management active participation the risk management cannot be successfully implemented. Each enterprise must clearly set what is to be achieved through implementation of the integrated risk management system and what way its contributions will be evaluated.



Figure 1: Changes in approach to risk management system in enterprise from view of the ERM [3]

For the time being the application of the ERM in the Slovak enterprises is more only on the theoretical level. With the exception of big transnational companies this way of risk management is used only exceptionally. Insufficient awareness of the enterprises about contributions and ways of utilization of the ERM and also the implementation costs and training of the employees are the main problems. The main factors affecting implementation of the risk management system in the Slovak enterprises include especially economic situation and size of the enterprise, lack of material and personal sources. The costs and especially problems connected with restructuring the information and communication technologies present another problem. The level of internal management system and audit are also connected with top management willingness for actively participation in development and implementation of the ERM.

At the beginning of the third millennium, the Slovak enterprises are also dealing with new conception of risk management EWRM (Enterprise-wide risk management) that has not yet found greater application in strategic enterprise management as well as the ERM and these two conceptions are often incorrectly considered as identical. Except big transnational enterprises, these risk management conceptions are used in Slovakia only exceptionally. EWRM conform to the paradigm of management of all key risks from perspective of strategic management. Through this effective tool of strategic management the enterprises continually enhance their obtained experience and extend knowledge in accordance with development towards more complex techniques of integrated risk modeling.



Figure 2: Changes in approach to risk management from view of the EWRM [5]

In connection with the risk management in the Slovak enterprises, the position of manager responsible for risk management in enterprise - Chief Risk Officer (CRO) is absolutely missing except banking and insurance sectors. The problem is that managers of many functional departments and business units can unwittingly suppress or undervalue certain risks in the interest to obtain desired budget. The enterprise organizational structure is often divided on many different units what results in disintegration of information and responsibility. Eventually the risks in specific spheres of business activity are monitored separately, without mutual context (e.g. variations in prices of commodities, credit risks, toll of life, etc.). Each manager endeavors to reduce his risks as much as possible and avert possible negative consequences. This approach has very negative impact on total business results of enterprises because solution of one risk activity often brings the risk somewhere else. The task of the Chief Risk Officer is to cover all risks of the enterprise in the context and manage them. They have to disposal many tools and techniques that work with risks.

Chief Risk Officer is usually responsible for [3]:

- accentuating to inform about risks and risk management in organization,
- presentation of possible approaches to risk management in enterprise and explanation of its advantages,
- assistance in correct and early risk identification,
- creation of uniform system of risk assessment,
- preparation of possible risk strategies (risk minimization),
- guidance for enterprise employees how to manage risks
- preparation and development of enterprise risk management system,
- stability of enterprise business activities in proceeding in changing risk conditions, too,
- etc.

If the principles and practices of risk management are realized outside the earnest attention of enterprise top management neither the best CRO is not able to realize EWRM effectively.

4. RISK MANAGEMENT STANDARDS

Many countries try to help their enterprises in the fight against business risks and their experience could be used also by our business subjects in their effort to hold competitiveness and sustained growth. In the 90s, the number of insolvent companies in the German economy permanently grew and also several well-known companies run into trouble. For the purpose to prevent further deterioration of the situation, the lawmakers provided the enterprises in the KonTraG with certain foundations how to deal with possible risks threatening their existence. KonTraG (1998) is German law on monitoring and transparency in business sector that accentuates risk reporting and monitoring [5]. The central point of this law and discussion about it is included in perfect identification, evaluation and risk reporting. But smaller attention is paid to the consequential treatment with reported risks. The existing recommendations lead especially to "externalization" of the risks and their consequences. They specify that the enterprises have to establish certain system that ensures the risks are uncovered in a way that management has sufficient time to take appropriate action. In accordance with this law the management of enterprise is compulsory to make a clear and complete list of existing risks.

For the Slovak enterprises are available, for their support in risk management, legal rules that have only advisory character and were assumed from other countries. Specifically it is the Slovak standard STN 01 0380 Risk Management (AS/NZS 4360: 1999). This national standard includes Australia/New Zealand Standard AS/NZS 4360: 1999 and is published with the permission of Standards Australia. This standard specifies the particulars of the risk management process but its aim is not to force on the uniformity of the risk management systems. It is general and independent from specific industrial or economic field. The proposal and implementation of the risk management system will be influenced by changing need of the organization, its specific aims, products and services as well as the used processes and specific practices. But just the generality of the standard uselessly put a lot of enterprises off from the need to introduce risk management system on their organization especially if it is not their duty.

5. COMPETIVENESS OF THE SLOVAK REPUBLIC

In the year 2010 position of the Slovak Republic relating to the competiveness evaluation declined in comparison with previous year in 13 positions falling to 60th in ranking 139 countries. This fact results from the Global Competitiveness Report 2010-2011 published by the World Economic Forum [9]. It is historically the worst position of the Slovak Republic from its integrating into this prestigious international comparison. The Global Competitiveness Report evaluates ability of the countries to ensure high level of prosperity for their inhabitants. It monitors functioning of public institutions, analyses economic policies and factors underlying sustainable economic growth in medium term horizon. Quality of managerial education is evaluated very adversely and in the field of labor market the main problem is low flexibility of working legislative (record fall from 15th to 104th during four years). This was caused especially by negative steps of government within the business environment in last year, low ability to reform and eliminate principal barriers to entrepreneurship.

Understandability, applicability and stability of legal enactments are the main problems. Entrepreneurs criticize presentation and frequent changes of government proposals when at first the intended and presented change is later in short time denied and immediately quite new proposal, often diametrically different from original, is presented. Enhancement of unity and exactness in publishing prepared measures so that the entrepreneurs would be able to plan their actual and future activities in regard to planned change in legislation would be contribution.

Here we can see also the space for legislative support of the state in the form of legal rules oriented on risk management system in enterprise what should bring positive effect on keeping and increasing performance and competitiveness of the Slovak enterprises.

Despite many minuses the Slovak economy has also a lot of competitive advantages. The most significant are as follows:

- openness of Slovakia to foreign ownership of enterprises,
- low customs barriers,
- low risk of terrorism,
- low spread of interest rates,
- legislative supporting investments,
- high correlation between wages and labour productivity,
- internet availability,
- low trade barriers,
- healthy bank sector,
- favourable taxation.

6. CONCLUSIONS

The enterprises are interested to avoid the crises because the crises block resources, threaten results and goodwill. Therefore they have in principle two possibilities, either they will start to manage risks or they will have to manage crisis. The later is certain risk identified, the more expensive are the impacts. Early risk recognition is a proper way. But this way is demanding, because on the one hand individual mistakes hinder risk identification, on the other hand the organization is also source of risk. Risk management in enterprise should be understood as an effort to reduce consequences of all risks connected with its activities so that the interests of shareholders and especially clients are not threatened.

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Do I know where I am going? And how do I read the directions along the way?

The knowledge pathway in the context of surrounding information and a toolset for effective growth.

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ABSTRACT

This paper utilizes theory from several previous Science that do not exist in a vacuum. It is surrounded by philosophy, theology (although not always popular to recognise today) and art as a beginning. These diverse areas have undergone parallel developments and as they do so the tools and techniques to investigate and explore these areas have also progressed in parallel. Following the movement of the modern western world this paper starts with a broad comparison using science, branches of mathematics, philosophy and art, with additional comparisons with theology.

Knowledge management - an often abused expression - is more than just data collection, information presentation, or simple pathways beyond this. Rather it involves the efficient juxtaposition of background information and the value adding of presentation to enhance explicit understanding in a dynamic manner.

The paper explains the different approaches to knowledge management inherent in each time phase, using concrete examples, and then suggests possible extrapolation of these linear progressions for future knowledge management as well as possible toolsets necessary for future understanding and expansion of the knowledge set.

This paper also goes one step further than normally considered, by investigating approaches to cognition in the data management areas and human cognition requirements and advantages. As society evolves, the requirements for successful presentation of data evolve, and yet the raw data amounts can also be effectively presented in new and more compressed manners. So the total information presented can actually increase exponentially and may become easier to understand.

Finally explicit modern examples are utilised to demonstrate the effect of the altered approaches through the distinct time periods and a simple juxtaposition of the technological tools available in each period are utilised to enhance the data presentations. The end results are considered and the effect that the technology may have made to the recording and use of the data and it's transmission as data, information or knowledge evaluated, and a suggested model for overall efficiency of knowledge management presented in conclusion.

1. Introduction

In English the word “orient” originally meant, “to face east”. The original meaning is recalled in now older use such as “Orientals” to mean Asians, or even the original full description of P&O, “Pacific and Orient” In fact some early maps started off with east being “up”, rather than the “north” of current standard practice. Others, primarily from Moslem cultures saw

south as up, and some had Jerusalem as the centre of the world, primarily for theological reasons.

But this is not the only change that has occurred with maps, the initial combining of disparate maps into Atlases, and their "more modern" offspring, street directories. In fact we are suggesting that the changes that have occurred in the map world are explicit demonstrations of information packaging in both past, present, and future, and they hold promise to demonstrate how to effectively present information to humans for easy absorption and use.

Homer is often presented as a blind minstrel. Yet centuries later his epic song is still "known," of sorts. While knowledge of the original (which was not actually ever directly recorded, even on paper,) is sketchy, Greek, Latin and English, amongst other versions exist. What Homer does is present, as entertainment, a (questionable) history and allows us to travel with the tale without moving.

Humans have a limited number of inputs, often called senses. The 5 classics are Sight, Feel, Taste, Smell, and Hear. Sometimes "developed" additions are included, such as intuition. Intuition is probably an evolutionary survival adaption allowing the formation of conclusions from an incomplete data set by triggering "memories" with a bypass of signals through the amygdala (Damasio,1994)

2. Oral Travel and it successor, travel books

Most of us are familiar with instructions like "travel down beyond the house with the white picket fence and then turn down the 2nd street on the left." This is the basis of oral travel or instructions, and the precursor to visual maps and travel instructions like maps We mean precursor in two distinct ways, one is prior to actual maps as a scientific guide, and the other is prior to specific maps as the recordings of travelers have been used to develop specific guides and maps.
Homer's stories allowed travel through the recipients imagination, as well as presenting details of a world picture and possible routes to specific places – real or imagined.

Benjamin of Todelo (1907,and notes, say 1890) was a major 12th century traveler who was on the road from around 1159 to 1173 C.E. and so approximately 100 years prior to Marco Polo. He was the first European traveler to write about China although there is some doubt if he actually traveled to China or just reported on the travels of others thee.

Benjamin's work gives us clear demographic detail such as key personalities, community sizes, and skills and economic status of persons and communities he met, as well as secondary reporting of others information (in such a form as to distinguish between original and hearsay information!) (Benjamin of Todelo - notes, say 1890))

Marco Polo spent approximately 24 years traveling to and in Asia and China, and following his return to Venice in 1295, he was captured by Genoan forces and imprisoned. At that time he dictated his story of travels to Rustichello da Pisa, an author of romantic fictions, and Fra Mauro picked up, these details amongst other sources in his significant map of the known world in 1540.

3. Maps

The history of cartography probably is well founded in pre-history as sand/dirt drawings and also cave drawings placing location of objects and places in perspective. (http://www.phil.uni-passau.de/histhw/tutcarto/english/3-0-eng.html, Edney 1998)

Harley and Woodward note "Maps are not natural, self-evident 'statements of geographical fact produced by neutral technologies'. The hand of the mapmaker is guided by a mind located in

a certain time and place and sharing inevitably the prejudices of his or her surroundings." (Harley & Woodward 1987)

Edney goes further and suggests that maps not only "…just show the world. They show our conception of what the world ought to be."(Edney 1998)

Maps are depictions of the earth's surface scaled and un-scaled with or without a defined projection, limited in content to the extent of technology and the knowledge, wish and, or wants of the cartographer or person or the purpose for which the maps were produced.

Maps are used as tools to convey all sorts of information, the list is endless: political, historical, topographic, ethnic, religious, economic and military to name but a few. Today we often think of maps only as tools for navigating from one point on the world's surface to another. If we stop and look at all the maps that we are bombarded with every day we can see that maps are much more than navigational tools. Advertisers, governments, journalists, academics and everyday people, use them for a myriad of reasons. Maps have a great visual power capable of conveying information with incredible authority whether real or illusionary.

"The medieval world map (Mappae Mundi) conveyed little useful information for the traveler, it wished to convey the beauty and clarity of God's world, as described in the psalms "Nach Zahl, Gewicht und Maß hast Du alles geschaffen." For this reason Jerusalem is placed in the centre with the rest of the world divided in the continents Asia, Europe and Africa, showing the settling of the world through Noah's sons; Sem, Japhet and Cham. The map emphasises the reach of God's work by showing that the graves of the apostles can be found in the farthest corners of the World," (Frenz, 2002)

Of course maps up to and into the late 15th century were sometimes, like Homer's records, a record of real and imagined countries and facts. But sometimes the discrepancy between accurate and imagined is not arranged chronologically.

The Fra Mauro map was made around 1450 by the Venetian monk Fra Mauro and his assistant Andrea Bianco, a sailor-cartographer, under a commission by king Afonso V of Portugal. At least significant sections such as Africa and parts of Asia and Japan are recognizable to the modern eye.

Compare this with Vopel's Terrestrial Globe with Armillary Sphere, of 1543, produced in Cologne Germany. It illustrates terrestrial and celestial globes and armillary spheres were important educational tools for illustrating the Ptolemaic, or earth-centered, cosmic system. The series of eleven interlocking and overlapping brass rings or armilla, some of which are movable, that make up the armillary sphere are adjustable for the seasons and illustrate the circles of the sun, moon, known planets, and important stars. (http://www.1worldglobes.com/History/historyofmaps.htm)

Ironically this was the same year that Copernicus's theory of a heliocentric universe was published, a theory that greatly changed the design of armillary spheres.(http://www.1worldglobes.com/History/historyofmaps.htm)

Other forms of information such as perspective and colour were also developing, although with only a few exceptions, maps were not printed in color until the end of the nineteenth century. The "lines" are those that form the image and are normally black or black-brown. (http://www.phil.uni-passau.de/histhw/tutcarto/english/index-hiwi-karto-en.html)

And perspective and projections were developments from a renaissance world coupled with developments in both geometry and philosophy. A popular start date for the renaissance involves the competition in 1401 between Lorenzo Ghiberti and Filippo

Brunelleschi for the contract to make the Florence Baptistery doors won by Ghiberti.

Of note in this art piece is the development of perspective and elements of implied distance, prerequisites for maps that are trying to impart data about distance and relationships on a single page.

4. Atlases and Street Directories

In 1570 the Antwerp cartographer Abraham Ortelius published the Theatrum Orbis Terrarum, often considered the first modern atlas.

The key elements of this first atlas were the publication of diverse location maps in one publication.

The addition of multiple maps allows comparisons and the building up of detail in layers. It is also important to recognize that Ortelius also included a vast southern continent, 'Terra Australis Incognita,' supposedly to counterbalance the known northern hemisphere world. (Notes from the State Library of Victoria, Australia associated with the Theatrum Orbis Terrarum by Abraham Ortel published in 1574
Street Directories were not far away. The earliest reference we have found was to a 1650 publication for the City of Albany, New York, USA, utilizing the research of Prof. Jonathan Pearson, of Union College and including the dates of patents and transfers of city lots. (Munsell, 1871)

In the same year, Henry Robinson produced a directory in London, in this case, a list of names kept in an "office of addresses" available for viewing, presumably on paid subscription. Whilst not a map, it provided detailed background data that in time would become part of the overall street directory. (http://en.wikipedia.org/wiki/Henry_Robinson_(writer))

Over time, although exactly which year and where is questionable, the data was provided graphically – nominally in line drawings using black ink.

5. Layers

In this paper we have made reference to layers several times. Layers are both actual and also conceptual.

Layers allow explicit details to be published having a combined impression and context. We can see geographical information such as streets together with land use information, specialist services, traffic flow and/or direction (such as one way streets or time limited parking zones) and even economic spheres of influence such as "natural shopping zones" for demographic differentiation.

Originally layers were produced using a transparent or semi transparent material such as acetate sheets or tracing paper over a fully opaque back sheet.

Today layers are usually electronic in form, and are seen easily in places such as GPS software or versions such as Google Maps where feature sets can be turned on or off.

It should be noted that layer information can be detailed but often requires context to be easily or fully understandable.

6. The Psychology of cognition

In this paper the term cognition is not used just to mean thinking but rather the process that includes an ontological examination of terms and processes.

Because cognitive science often tries to understand minds in the same way a computer processes inputs through processing and then to

specific outputs we utilize a simplistic but usable model.

The authors also have come into knowledge management from a Engineering and Human Engineering / Ergonomics background and so the when understanding human cognition try and utilize a holistic view drawing on the work of application oriented modeling both within the individual and also within the layered environment between work space and outside world (Leamon, 1980, Wilson and Corlett 1991)

So cognition requires sensors to "read" displays – be they visual, tactile or audible, a processor stage, and an effector stage with potential feedback loops to fine-tune processing and ability to effect specific control.

7. Memory

In humans, different types of memory have different roles. Short term memory is involved with processing and comparison. Miller's (1956) approaches to 7+/-2 numbers is an example of short term memory

Long term memory is sometimes structured into declarative and implicit classes. Declarative memory is that which is recognized and consciously remembered. Implicit memory is used for priming and is also sometimes called procedural memory as actions and activities cause it recall.

Norman (1988) specifically considers human mapping and activities and concludes that where the design of control systems correlate with the human's mental model our ease and accuracy of using equipment is enhanced and made more effective.

8. Concrete – abstract continuum

The more concrete a symbol or instruction is the easier to understand and act on. The more abstract the greater the local processing that must be done by the individual.

Symbols may be concrete or abstract. Language too is worthy of consideration here as if the language and connotations of language are understood, then we may fast track to understanding context and means of tacking in information, and also of acting upon such information.

9. Knowledge Skills Rules

Rasmussen (1983,1989) introduces the ideas of Knowledge, Skills and Rules, and that repetition of acts, activities, or even thinking may make a process evolve from requiring active thought to becoming an automatic activity. This may be demonstrated by rote learning of a route to travel or by rote learning of multiplication tables till they become automatic responses.

The familiarity and use of standard technologies, be they maps or computer programs leads to a repetitive speed and enhanced ability to take in information. It must be highlighted that this is not the same as understanding – the repetition increases speed to do not to understand what is going on as sometimes the data intake is more superficial.

10. "Knowledge tools"

Tools are hereby considered as items that enhance our ability to intake information, ensure it is in context, and then potentially ease our ability to act upon such information. They may also minimize repetition without adding significant knowledge or context, and so automate or partially automate our responses to the information.

The use of modern computer programs to place information in a graphical form, and in context of geographical or major numerical factors, such as traffic patterns and activity, alternative route recommendations, and facilities within reach, as well as means of minimizing the need for instruction books (Norman 1988) and allow "the information in the world" to be understood in correct context, is to be desired.

The use of colour and audible tones in a manner consistent with human facilities (be they physical or cultural,) and the use of controls that match human attributes (eg. size of fingers, response times,) increase the usability of knowledge tools, ensuring interaction with the tool is likely to enhance the total experience.

11. Conclusion

Well designed knowledge tools should enhance the total knowledge experience. They need to build upon human attributes, be they physical, cultural or psychological, and they need to ensure knowledge presented is in a context to enhance absorption and to enhance the utilization of this knowledge.

Whilst these ideas seem simple the lack of application is regularly experienced and the use of older tools can be reviewed in light of modern understandings of human interaction in a broader world.

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A Methodology for Engineering Competencies Definition in the Aerospace Industry

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ABSTRACT

The need to cut off lead times, to increase the products innovation, to respond to changing customer requirements and to integrate new technologies into business process pushes companies to increase the collaboration.
In particular, collaboration, knowledge sharing and information exchange in the Aerospace Value Network, need to a clear definition and identification of competencies of several actors. Main contractors, stakeholders, customers, suppliers, partners, have different expertise and backgrounds and in this collaborative working environment are called to work together in projects, programs and process.
To improve collaboration and support the knowledge sharing, a competencies definition methodology and the related dictionary result useful tools among actors within an extended supply chain. They can use the same terminology and be informed on the competencies available. It becomes easy to specify who knows to do required activities stimulating collaboration and improving communication.
Based on an action research developed in the context of the iDesign Foundation project, the paper outlines a competency definition methodology and it presents examples from the implementation in Alenia Aeronautica company.
A new definition of competency is suggested supporting by a new method to specify the structural relationship between competencies and activities of aeronautical processes.

Keywords: Aerospace industry, Technical activities, Human competencies, Competency management, Competency dictionary.

1. INTRODUCTION

In a value network [1], many actors are called to work together in projects, programs and processes sharing resources, knowledge and expertise.
This interaction requires to several actors with different expertise and backgrounds to discuss about the requirements of products and decide about technologies, innovation, time, budget by which develop the product that best satisfy the potential customers.
The organizational activities aimed to continuous monitoring of resources and their expertise, become fundamental to identify the gaps in the skills and to define the actions to fill them [2] improving the creation of value for the whole network of companies.
In business environments, characterized by extended structural dimensions and by organizational complexity, often it is very difficult to objectively define and identify competencies of people involved in business activities. Also, it is complex to express these competencies with a common language shared by all the companies belonging to the network.
Each competency must be associable and linkable to specific activities performed into a company and to individuals, who are the owners of these competencies. Having a skills portfolio, companies can define a competency development plan consistent with future objectives and strategic positioning of the company.
In fact, the competency management has an important impact on improving the overall quality of the final product, and then on customer satisfaction.
These effects are clearly visible in a very complex enterprise network, like Aerospace Value Network, where the design and manufacture of complex products such as aircraft are based on the integration of specialized management and engineering competencies [3, 4, 5] available in different companies.
In aerospace industry, often the effort of improving the performance of engineering activities is translated into an enhanced knowledge management of people about sophisticated technology, innovative materials and knowledge-intensive processes and into an appropriate allocation of human resources in complex engineering processes, such as the design and manufacturing of aircrafts.
Therefore, competencies sharing between these companies necessitates of a clear definition and identification of competencies within the aeronautical network. However, studies explore the competencies management topic in aerospace industry [6, 7] but none is focalized on the description of a methodology that allows competencies definition in one company and in the whole network.
In this industrial context, the scientific research has the role to define general reference models, to indentify the basic pillars and the future troubles. The research project Innovative Design Foundation (iDF) is being carried out by a partnership among the Center for Business Innovation, a laboratory of University of Salento (Lecce, Italy), and two Italian firm: Avio, an aero-engine company, and Alenia Aeronautica, an airframe one. It aims to define an innovative model of a collaborative New Product Development, NPD, into the aeronautical value network, building a framework able to permit an intra-firm

collaboration, with high levels of standards of security and protection of knowledge assets.

The development of a complete competencies definition methodology and of a system supporting it is one of main objectives of the iDF project. A competencies definition methodology means a set of rules to specify and, thus, define all the available competencies creating a dictionary. The proposed iDF methodology is based on a competencies dictionary that contains and structures all the competencies available in the network in order to homogenize and generalize similar competencies and to define and identify critical competencies into a specific area. The system is actually under development and it will be able to evaluate the competencies set existing into each aeronautical company areas and to measure the impact of different allocation of individual and their competencies in other areas or firms in order to support collaboration and creation of relationships for NPD. This paper aims to describe the developed methodology and the related dictionary focused on a competencies identification process based on technical activities of design and development of complex products such aircrafts that is characterized by many competencies that need to be analyzed.

The paper is structured as follows. In the next section some theoretical definitions and previous studies are briefly reviewed in order to outline the background of the proposed methodology. Section III contains the description of the research approach highlighting the followed phases. In section IV, the paper results are treated: firstly the definition of a competency dictionary methodology is done and secondly there is a practical case study of the methodology application. Finally, section V draws conclusions, limitations, and future research.

2. BACKGROUND

In literature, several definitions of competency are available. The term competency has became popular with the study of McClelland and his collaborators, especially Richard Boyatzis [8, 9]. In its book "The Competent Manager", Boyatzis defines a competency as an intrinsic characteristic of an individual casually related to an effective or high level performance (e.g. motivations, skills, own image, knowledge) in executing one or more defined task [10]. Klein [11] has, instead, provided a definition that looks the competency as a set of observable behaviours or behavioural indicators that can be grouped around a central topic and became a competency.

From the definitions available in literature, it is possible to conclude that competencies are the knowledge, ability and behavior to execute an effective work task. These features are observable and measureable and looking to them is possible to improve and differentiate the results of the related activities [12, 13].

Several studies are focused on the classification of competencies. In competency model of Harzallah [14] the competencies are shared in three categories:

a) *Knowledge*. It concerns to everything that can be learned from educational/formative system, training course and everything which involves cognitive processes (i.e. perception, learning, communication, association and reasoning). It represents the theoretical understanding of something such as a new method or procedure, an updating of them, etc.…
b) *Know-how*. It is related to personal experiences and working conditions. It is learned by doing, by practice, by experience. It is the practical knowledge consisting in "how to get something done".
c) *Behavior*. It is referred to individual characters, talents, human traits, or qualities that 'drive, direct or select' someone to act or react in a certain way under certain circumstances.

Furthermore, an individual has several competencies impacting on the organizational activities and on patterns of organizational evolution and change [15]. An activity needs specific competencies to be executed and to optimize its performance. The application of the same competencies in two different activities can lead to different level of results. In this perspective, competencies are defined in literature as "effective performance within a domain/context at different levels of proficiency" [16]. In addition, the level of specialization in a given competency, based on the qualification, experience and focalization of the actor in executing an activity is also an important aspect. A more specialized competency allows to execute an activity, in which it is required, in a faster and more effective way [15].

Competency management involves several processes that can be categorized in four classes [17]:

- *competency identification*. Starting from an analysis of business processes, business areas, operating procedures, values and corporate culture, and using the definition of competency on the business context, for each business area/process, the competencies of the human resources are identified. These are the skills that must have employees to make (in the short and medium term) the expected performance and business objectives. This phase brings to a competency dictionary creation. In order to be an effective tool, this catalogue of competencies should be regularly updated and adapted to any changing needs of business and corporate strategy.
- *competency assessment*. In this process, a valid method to measure the effective knowledge of human resources that performs a specific activity, is identified. To calculate a competency gap, the real competency level of each employee is compared with the level of competency considered optimal.
- *competency acquisition*. In this phase, a company have to plan and decide about how and when to acquire some competencies. There are different acquisition competency tools that allow several types of analysis.
- *competency utilization*. This process uses information about the competencies produced and transformed by the identification and assessment processes.

The assessments obtained allow to perform analysis such as [6]:

- identifying the gap between the competencies needed by activities and competencies possessed by personnel and corporate entities;
- placing all available resources in the right roles with positive organizational effects;
- identifying critical resources that need training and/or improvement actions to develop their potential;
- assessing the change impact of movements of certain individuals in other companies or areas.

Looking to the literature, it is perhaps missed a definition of competency able to collect all the evidences needed to represent the complexity of high technological sectors such as the aerospace one.

3. RESEARCH DESIGN

Based on an action research, the paper outlines a competency definition methodology and it presents findings from the implementation in Alenia Aeronautica company. An action research [18] has been realized moving from the objectives of the iDF project and from the needs of the members companies.
In Corallo [6] is described a methodology used by Alenia Aeronautica to improve and monitor the own competencies looking to the internal company activities. This methodology needs more customization and theoretical justification that have lead the company to explore a new methodology able to catch all the available competencies and structured them in a sounder way. Furthermore, technological systems are available inside the company to support the employees allocation in the work activities based on their competencies [6] and new technological solution more powerful are actually under development [19].
The aim of the study is to suggest a new competency definition methodology representing the complexity of the aerospace industry that can be diffused in networks of companies in order to share common definitions about the competencies needed to perform an activity favoring the allocation of employees and the scouting among companies. The methodology is, thus, created and used to define a competencies dictionary for the aerospace sector. To develop the methodology four main phases have been followed:

- literature analysis;
- companies exploration;
- methodology definition;
- methodology test.

The literature analysis has investigated competency definitions and methodologies available in scientific papers in order to highlight and compare different scholars and specify existing gap. The second phase has, instead, explored how companies manage their competencies and which methodology they apply. In this phase, the methodology used in the iDF partner companies and in other companies have been explored in order to find best practices and criticalities. The first two phases have been useful to design the "as is" in the competencies field and to guide the development of a new methodology. In the third phase, a new methodology has been proposed to reflect the complexity of the aerospace sector and the network perspective. In the final phase, the methodology has been tested in the Alenia Aeronautica by a set of interviews to company key persons in order to validate the findings.
In the following section, the methodology is described and some practical examples are reported.

4. COMPETECY DICTIONARY

The research activities in the Research Project I-Design Foundation have allowed to develop a methodology for drafting a competency dictionary for aeronautical network.
The competency concept definition is focused on the structural relationship between technical activities of an aeronautical process and its required skills .
Starting from the competency subdivision in *knowledge*, *know-how* and *behavior* ([14]; see section 2), this study leaves out the behavior category. Because for its multifaceted feature it's difficult to define and classify. Only the concept of knowledge and know-how related to a competency have been considered. The introduction of behavior in the competency dictionary methodology will be evaluated in a future extension.

Concepts and proposed methodology
The analysis of Alenia Aeronautica's technical activities and the study of competencies classification (knowledge, know-how, behavior) reported in the literature have been necessary to obtain a competency definition valid in a technical context. This definition provides guidelines for the creation of a competency dictionary.
In order to get the competency/ies necessary to realize/implement a technical activity it is necessary to ask: "*What is it need to know?*", "*What are the main aspects of the tasks you need to know to perform them?*". By analyzing the activities and how they are described, it is possible to identify three main features that characterize them: method, technology and product.
Method represents procedures, company policies, methodological standards, implementing rules and calculation methods. Method's knowledge allows the human resource to operate and carry out activities in accordance with default procedures.
Technology is the tool or technological knowledge used for the activity. It may be broadly defined as everything, both material and immaterial, created by a mental and physical effort to solve real world problems. In this sense, technology can refer to both simple and complex tools/machines and technological knowledge necessary to carry out the activities. The virtual technology as a software falls under this definition of technology [20].
Product refers to the good or service (with all its components and sub-components) that the company produces. For manufacturing activities, it could coincide with the output of an activity. In general, the product is defined on the basis of its physical characteristics (size, shape, etc..) and its complexity (detail or assembly).
Given a task, a human resource has the competency to carry out this task if he knows these three aspects.
In conclusion, the competency to perform a given activity is defined as the knowledge that the human resource must have about the three main features characterizing the activity: method, technology and product.
The activities description will be the starting point of this study: only after understanding in detail their content it is possible to identify the related three competencies features.
To correctly identify the competencies all the activities must be described with the same level of detail.
However, the list of activities considered often presents both macro activities described in a very general way and simple activities described in great detail.
In these cases, to obtain an homogeneous and detailed definition of competencies of each activity, it could take into consideration the output of the activity.
A macro activity produces several outputs while a simple activity produces a single output.
Starting from the analysis of the information about the output, the competencies features about method, technology and product required to perform an activity, can be specified. Usually, an activity generates an output that typically can be a document, a design model, a single product or assembly, etc. The output description contains all the information about the three aspects of competencies that people must have to execute the task. (
Fig. **1**)
Considering a simple activity that produces a single output, the three aspects of competency required by activity can easily be deduced from the analysis of the only output.

Considering a macro activity that produces several output, the list of competencies required is given by the set of competencies needed to get every output.
The output of the activities can also be considered in the competency assessment phase within the competency management model.
Indeed, an objective competency evaluation of human resources is focused on the assessment of the output produced by the resources in their activities.
Therefore, the output is a fundamental element both to identify and to evaluate business competencies.

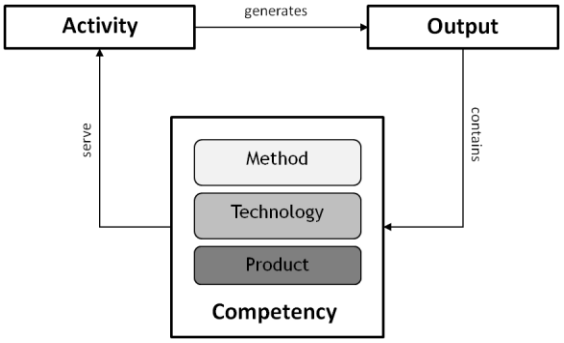


Fig. 1: Competency identification.

Competencies indentified in this phase are used to populate the competency dictionary. This dictionary will be composed by three chapters: the first containing the competencies related to the products made in the activity, the second comprising those related to the methods, practices and procedures adopted and the last including those related to technological tools and technologies that the activity uses.
In this study the term "competency" is intended only as *knowledge*, i.e. the theoretical knowledge about the three features but not as *know-how* or practical knowledge.
The dictionary should be used to understand which competency of a person must be assessed. In the competency assessment phase, only the knowledge aspects that find expression in tasks and become know-how, are evaluated. To allocate its resources on the business activities, a company needs to evaluate what a person can effectively do, that is the "know-how" derived by his experience in present or past programs or projects useful to perform the activities. When the available knowledge is not converted in know-how, improvement initiatives, such as training courses, must be provided to the resources in order to fill the identified gaps.

Practical Examples

The case study presented aims to be an example of the application and, consequently, validation of the methodology illustrated in the paper. It is focused in the Alenia's Interiors Area, specialized in the development of all aircraft's inside arrangement.
The competency dictionary methodology is applied to all the activities of the Interiors Area in order to obtain a complete competency dictionary related to this area.
In this section, it is reported a part of this competency dictionary obtained from the application of the methodology to the technical activity "Drawings and production detail models issue" belonging to Alenia's Interiors Area. This is a generic task which produces different types of outputs, related to different products.

Consequently, a detailed definition of competencies of method, technology and product of this activity, cannot occur without the analysis of its outputs. As an example, two of the several activities outputs are treated ("Design model of Lining of the passengers cabin"; "Design model of aircraft's secondary structure") and some competencies of method, technology and product are identified.
The realization of the output "Design model of Lining of the passengers cabin" requires the competencies listed in figure 2.
In order to carry out the activity "Drawings and production detail models issue" that produces such design models is necessary to know:

- the products Lining;
- the materials forming the product (such as Aluminium);
- the manufacturing technologies (such as folding process) related to the product material;
- the software tools as the CATIA V5 modeling tool and the product lifecycle management (PLM) software, Engineering Team Center;
- some company procedures (Drafting Manual, Practice and Procedure Design, Civil Regulations).

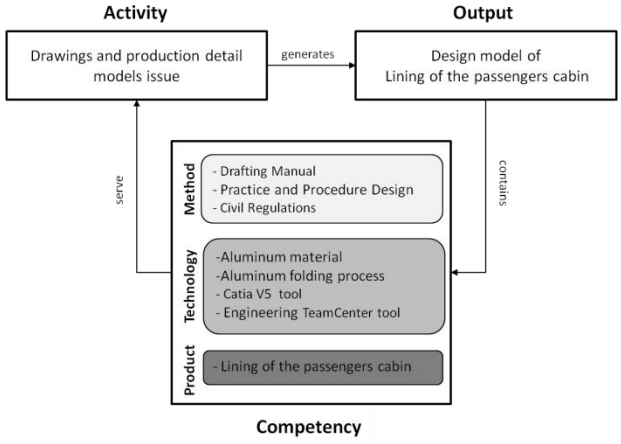


Fig. 2: Competency identification starting from the output "Design model of Lining".

Different competencies will be associated with the same activity for each output it produces. The activity taken in example, "Drawings and production detail models issue", realizes the output "Design model of Lining of the passengers cabin" described before and the output "Design model of aircraft's secondary structure". For this last one, a competency characterized by a specific combination of Method, Technology and Product is required (Fig. 3) and it differs from the previous one described (Fig. 2). In fact, the realization of this output, requires the knowledge of:

- the aircraft's Secondary Structure;
- the materials which form the product (such as Steel);
- the manufacturing technologies (such as forming process) related to the product material;
- the software tools as the CATIA V5 modeling tool and the product lifecycle management (PLM) software, Engineering Team Center;
- some company procedures (Drafting Manual, Practice and Procedure Design, Civil Regulations).

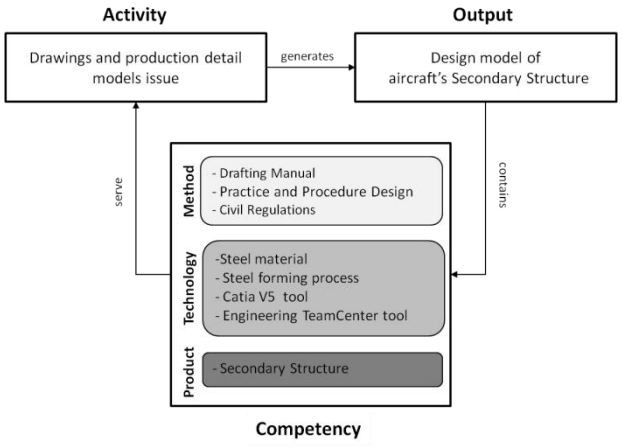


Fig. 3: Competency identification starting from the output "Design model of aircraft's Secondary Structure".

The similarity of the competencies of methods and of technologies (related to the tools) between the previous examples was expected since both competencies are related to different outputs which belong to the same activity. Therefore, among competencies of the same activities there could be some similarities.

Looking to a whole activity it is possible to summarize all the related competencies and thus, to present the activity as a set of competencies. Looking to the analyzed activity "Drawings and production detail models issue", the identified competencies respect to the two outputs, are summarized in the following table.

Activity	**Competency aspect**	**Competency: Knowledge of…**
Drawings and production detail models issue	**Method**	Drafting Manuals
		Practice and Procedure Design
		Civil Regulations
	Technology	Aluminum material
		Steel material
		Aluminum folding process
		Steel forming process
		Catia V5 tool
		Engineering TeamCenter tool
	Product	Lining of the passengers cabin
		Aircraft's Secondary Structure

Tab. 1: Example of Competencies dictionary related to the activity "Issue drawings and models of production detail".

Continuing the analysis of all the different outputs, the complete competencies dictionary associated with this activity can be obtained.

The same method has been applied to all the activities belonging to Alenia's Interiors Area in order to achieve a complete competency dictionary.

5. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Starting from the definition of the "competency" concept reported in literature and by the analysis of competency definition methodology in literature and in the firms practices, a new methodology to define the engineering competencies has been defined and tested on a real process of Alenia Aeronautica using a set of interviews to company key persons. The main goal of this approach is to obtain a competency dictionary common to the actors working into a collaborative environment. The competencies available in each company will be defined with the same criteria and using the same terminology that will support the collaboration, the search and exchange of resources.

A competency related to an activity, it is characterized by three main aspects: method, technology and product. Consequently, the competency dictionary mapping the knowledge required for the activities is divided in three sections, the competencies related to the methods, the competencies related to the technologies and the competencies related to the product. The methodology has been tested on the activities of a specific technical area of Alenia Aeronautica but the study will be enlarged with the implementation of the proposed methodology to the whole enterprise including also other areas and activities (such as logistics activities, manufacturing activities, administrative activities, etc…).

The approach described and validated in this study may be and should be extended also in other companies of the aeronautical sector in order to obtain a common and sharable competency dictionary.

Furthermore, in a future research the methodology could be tested and verified into company of others complex sectors (such as naval, medical, ecc…).

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Optimizing a Competence Management System: An Algebraic Approch

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ABSTRACT

Aerospace industry is particularly interesting for its complexity due to the high technological products and to a deep and wide net of actors located on a worldwide scale that collaborate to realize the final product. Furthermore, aerospace products require specific and adequate engineering competencies.
The use of competencies management system shareable by a whole network of companies can improve the collaboration and the knowledge exchange with a more effective and efficient monitoring, development, and scouting of technical competencies available to perform engineering activities.
However, few studies are specifically focused on the process of competencies management in engineering activities to support the development of aerospace products. Based on the experience in an aerospace company, Alenia Aeronautica, its CMS has been translated, in this work, in a mathematical formalism to well define the multifaceted and disparate concepts concerning the related competencies management methodology. The use of a mathematical approach overcomes the linguistic divergences and understandings and allow to apply its concepts and rules also in other companies and realize an inter-companies CMS. The application of the mathematical model in a company case study clarifies the approach and lead to further improvements.

Keywords: Enterprise Value Network, Aerospace industry, Engineering competencies, Competency management systems, Set theory.

1. INTRODUCTION

The innovation requirement of global markets, the reduction of product life cycles to obtain a rapid delivery, the necessity to minimize the cost, push the advanced manufacturing enterprise to change their traditional organizational and productive model toward new model. Companies to survive in this competitive environment must react to the changes quickly, through new forms of business organization (i.e. extended or virtual enterprises), that promote collaboration, knowledge and expertise sharing and information exchange to produce complex products [1].

To continuously maximize the competitive advantage, competency development is seen as one of the critical strategic factors [2]. To directly sustain the company's competitiveness, the top management identifies corporate core competencies and works to establish them throughout the organization. 'Core competencies transcend any single business event within the organization' [3] and are essential to get a competitive advantage respect the others firms. Behind the organizational core competencies, the single competencies of each human resource are also fundamental to contribute to the company productivity. The human resources and specially their competencies are considered strategic assets to achieving the companies objectives [4]. In fact, individuals competencies focus on knowledge, ability, experience of a human resource to carry out a specific task and they are typically specific to the position inside the organization.
Companies need to know at all times what competencies human resource have and how they can contribute to the overall performance of the organization. Competency management systems (CMS) can be useful to define and manage the set of existing human resource competencies according to the companies' objectives [5; 6; 7].
The problem of managing engineering competencies is a very pressing issue in engineering processes aimed to produce complex products and systems. In these processes, a large number of elements interact dynamically, both the physical aspects and the informations. Each interaction is, in fact, rich and influences all the others elements [8]. Aerospace products are complex ones, they are composed by many parts and demands several and varies engineering competencies related to sophisticated technologies, innovative materials and knowledge-intensive processes.
This study is based on the complex aerospace scenario in which organizations are called to improve the management of heterogeneous competencies located both internally to the company and in their value network [9]. In this context, the continuous monitoring of resources and competency gaps, and the definition of actions aimed to fill them, become fundamental organizational capabilities. However, the management and evaluation of human resources is a complex and complicated process; the need to identify, register, and maintain the required competency data of the human resources have pushed several companies to use information technology (IT) solutions.

An efficient way to implement a complete competency management tool, which have a flexible structure related to the enterprise context, is to explicit a mathematical formalization supporting a valid understanding of competency management.
Several studies have been focused on the use of analytic mathematical model adapted to the theoretical basis concerning the enterprise's core competency evaluation [10] and individual competency management system [11; 12; 13] but no one is based on the representation of the complexity of engineering competencies in aerospace sector.
This work starts from the exploration of the methodology at the base of a competency management software tool, developed inside the Chief Technical Office (CTO) of a leading Italian aerospace company, Alenia Aeronautica, which provides an objective method to support the management and evaluation of engineering competencies. The main and innovate purpose of this paper is to re-design entities and rules of this system using an algebraic approach. The translation of CMS in mathematical terms allows the understanding of the system working and its generalization promoting the adoption of the system also in others companies of the network with the aim to realize an inter-firm CMS.
The paper is organized as follows. Section 2 introduces the background of the study highlighting definition and main issues; Section 3 explains the study phases and methods used; Section 4 contains the results and the algebraic representation is discussed together with an example to a company case. Section 5 concludes the paper and treats limits and future research.

2. BACKGROUND

According to the intent to represent the competency concept needed to perform a specific task, this document uses the term "competency" in preference to "competence". On the one hand, "competency" is frequently used in educational and professional contexts in association with performance ability for specific tasks and roles. The competencies are real and observable behaviors specific to a certain task that a person is able to perform according to a predetermined performance standard. On the other hand, "competence" means the skill (i.e. capacity, knowledge, personality traits, physical characteristics, attitudes, etc.) considered as a possibility of success in performing a task or job performance [14].
In the first case, it assumes a tangible structure that can be assessed and measured, whereas "competence" refers to a theoretical scheme that is difficult to formalize in operational terms.
The human competencies have to be specified considering a strong connection with the tasks performed and thus, the competency diagnosis and the competency gap analysis are related and lead by the normal working tasks [15].
Skills and competency management systems (CMSs) can help organizations to define the right competencies for the right job in respect to requirements within the organization and consequently, to improve the effectiveness of the employees allocation and performance.
IT-supported competency systems can vary from a simple module for competencies planning and management to a complete solutions for human resource management (HRM) that also support payroll, recruitment, and other basic HRM functions. A computer-aided competency management can be a driver of relevant benefits such as experts and talents location and allows increasing the objectivity in the evaluation of human resource [16; 17; 18]. In fact, CMSs are aimed to optimize the identification, development, and scouting of competencies required in business activities in order to identify those processes or tasks that are critical to achieving enterprise objectives, to evaluate the competency gap between people and role and to determinate the main important actions to mitigate the gaps.
Several studies have adopted an analytic mathematical model to structure and to formalize the concept of a competency management methodology.
Analytic Hierarchy Process (AHP) and fuzzy mathematics approach is used to evaluate the enterprise's core competencies [10]. Also a general approach for the analysis and development of individual competency management information systems is available in literature to enable company's competency management at all business control levels (i.e., strategic, tactical, and operational) [11].
In other studies, the analytic mathematical model is adopted to respond to precise aims, i.e. to develop a model for a effective and efficient assignment of employees to workplaces [12] or to evaluate the strategic competency of senior leaders [13].
Previous studies explore the methodology at the base of CMS in aerospace companies [7; 19]. The study of Lewis [7] shows a successful application of a method based on the definition of competencies, resources, processes in an Aerospace Composite Technologies company. The study of Corallo et al. [19] is instead focused on the optimization of the competence management process in the Alenia Aeronautica, the same company object of the current study. No one translates the related concepts in mathematical formalism.

3. RESEARCH DESIGN

The paper wants to translate a competency management methodology of an aerospace company in algebraic terms for leading the related IT system reengineering. The development of a mathematical model helps in acquiring and sharing of a univocal methodology that well defines the multifaceted and disparate concepts concerning the competency management within a company. A mathematical approach provides a precise and punctual representation allowing to overcome linguistic divergences between semantically equivalent concepts.
The study is carried out through an action research based on an inductive approach in which problems and solutions have been deducted from observation of the organizational practices [20; 21; 22]. This action research is carried out by a team of engineers of Alenia Aeronautica and researchers of University of Salento. The main contributions coming from the direct observation of the competency methodology application and of the use of the CMS system inside the aerospace company During the period of observation, the needs to improve the competency management methodology and to re-engineer the CMS with new functionalities and further indicators, have emerged to optimize the decision making process related to actors allocation, scouting and improvement.
A mathematical model has been considered the most adequate choice to represent a competency model that reflects the complexity of an aerospace context. The Alenia Aeronautica approach to competency management is, in fact, rich of concepts and linkages among these and the use of set theory allows to easily represent this complexity providing an immediate and complete view on objects, rules and indexes.
The developed formalism has been applied in some company case to evaluate the validity and one of these cases is described

in the paper to allow a further understanding of the research results.

4. ALGEBRAIC DESIGN OF CMS

Key points definition and mathematical formalization

In previous studies, all the objects constituting the existing model of competency development plan adopted by Alenia have been described [19].

A **person** or **human resource**, *p*, is who operates within the Chief Technical Office (CTO) and this can be an internal or an external employee. In fact, also employees working for the company but enrolled in a different company can be included (e.g. consultant). The set of all *m* human resources is:

$$P = \{p_1, p_2, \dots, p_m\}$$

A **competency area**, *w*, is a set of activities that requires similar knowledge and skills to be performed. The set of all *s* competency areas results:

$$W = \{w_1, w_2, \dots, w_s\}$$

Activities, a, are tasks or jobs performed by a human resource in order to achieve the goals of its competency area. The set of all *n* activities is:

$$A = \{a_1, a_2, \dots, a_n\}$$

In order to better describe the activities executed within the CTO department and to allow a set of useful analysis, it is possible to classify the activities of each area according to their complexity, using two parameters:

a) *technical difficulty*, ***t*** that is a measure of the technical content of the activity. It is a numeric value ranging from 1 ("easy") to 4 ("very complex"), according to the amount and complexity of specialized knowledge required to execute the activity (see y-axis in the Fig. 1);
b) *interaction level*, ***li*** that is the measure of the interaction with internal discipline boards and external boards required for carrying out the activity. It is a numeric value ranging from 1 ("low") to 4 ("very high") according to the density of interactions/relationships needed for the execution (see x-axis in the Fig. 1).

These two dimensions are connected through the complexity matrix shown below.

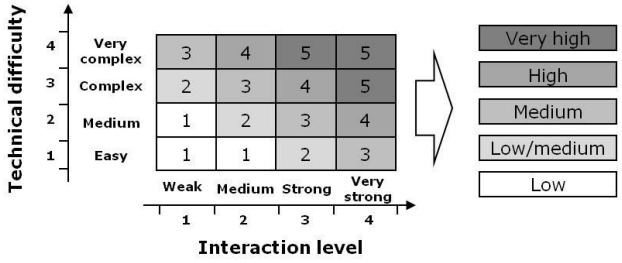


Fig. 1: Complexity matrix.

A **complexity index** ($\tilde{k}_i \; with \; i \in \{1, \dots, n\}$) is a value derived by the combination between the technical difficulty and interaction level for a given activity and varies from 1 ("low") to 5 ("very high"). The use of five greyscales provides an immediate perception of the average level of complexity for an area (Fig.1). This index allows to position the activity in a specific area of "technical complexity".

The set of complexity index of all activities is indicated as the **Vector of complexity** (1xn):

$$K = [\tilde{k}_i] = [\tilde{k}_1 \quad \tilde{k}_2 \dots \quad \tilde{k}_n] \; with \; \tilde{k}_i \in \bar{K} = \{1, 2, 3, 4, 5\}$$

A **competency** ($c_{ki} \; with \; k \in \{1, \dots, m\}$ and $i \in \{1, \dots, n\}$) is the human capability to perform a particular activity. Every person, with reference to an activity, can actually performs it or not and, if not, he/she could be potentially able to do that (values 1, 0, -1).

The set of competency of all people and of all activities is indicated as the **Matrix of competencies** (mxn):

$$C = [c_{ki}] = \begin{bmatrix} c_{11} & c_{12} \dots & c_{1n} \\ c_{21} & c_{22} \dots & c_{2n} \\ \vdots & \ddots & \vdots \\ c_{m1} & c_{m2} \dots & c_{mn} \end{bmatrix} with \; c_{ki} \in \bar{C} = \{-1, 0, 1\} \qquad (1)$$

Given an activity, a **competency level** ($l_{ki} \; with \; k \in \{1, \dots, m\}$ and $i \in \{1, \dots, n\}$) represents the assessment makes by the head of discipline, or leader, expressed by a numerical value from 0 to 4, according to the degree of competency possessed by a particular person, independently if it performs or not the activities.

It follows the **Matrix of competency level** (mxn):

$$L = [l_{ki}] = \begin{bmatrix} l_{11} & l_{12} \dots & l_{1n} \\ l_{21} & l_{22} \dots & l_{2n} \\ \vdots & \ddots & \vdots \\ l_{m1} & l_{m2} \dots & l_{mn} \end{bmatrix} with \; l_{ki} \in \bar{L} = \{0, 1, 2, 3, 4\} \qquad (2)$$

Within a competency area, it is introduced the concept of the **role** (R) as a set of activities. The set of *t* roles[1] is:

$$R = \{R_1, R_2, \dots, R_t\}$$

The activities belong to a role with a certain weight ($v_{ij} \; with \; i \in \{1, \dots, n\}$ and $j \in \{1, \dots, t\}$) that represents the competency level required by the activities of this role.

Within the same competency area, an activity may be related to several different roles. Every human resource belongs to a role and can perform tasks that constitute that role with a competency level.

The **Matrix of weights** (nxt) with which the activities are associated to a role is:

$$V = [v_{ij}] = \begin{bmatrix} v_{11} & v_{12} \dots & v_{1t} \\ v_{21} & v_{22} \dots & v_{2t} \\ \vdots & \ddots & \vdots \\ v_{n1} & v_{n2} \dots & v_{nt} \end{bmatrix} \; with \; v_{ij} \in \bar{V} = \{1, 2, 3, 4\} \qquad (3)$$

For each activity belonging to a given role, the **Advisor Role** is an ideal figure with the appropriate competency level required by the activities of this role. The index associated to this figure is the **competency index of advisor role** ($AdvR_j \; with \; j \in \{1, \dots, t\}$)**.**

This index derives from the following calculation:

$$AdvR_j = \sum_{i=1}^{n} \tilde{k}_i \times v_{ij} \qquad (4)$$

Generally,

$$AdvR = K \times V \qquad (5)$$

[1] It is a set constituted by nonempty subsets disjointed:
$R = \{Ri | i \in \{1, .., t\}\} \; \exists' \; R = \cup \, Ri \;\; e \;\; Ri \cap Rj \neq \emptyset \; per \; i \neq j.$

A **role index** (IR_{kj} $with\ k \in \{1, \dots, m\}$and $j \in \{1, \dots, t\}$) measures the ability of the resources to carry out the activities belonging to a given role in relation to the competency level of the advisor role.
To establish the Role index, it is necessary to calculate $\widetilde{L}$, that is the matrix related to matrix L limited to the competency level of the advisor role[2]

$$\widetilde{L}_{i,b} = \left[\tilde{l}_{i,b}\right] = \left[min\left(l^T{}_{ki}, v_{ij}\right)\right]$$

$$where\ b = m + t, i \in \{1, \dots, n\}, k \in \{1, \dots, m\}\ and\ j \in \{1, \dots, t\} \quad (6)$$

This role index derives from the following calculation:

$$IR_{kj} = \sum_{i=1}^{n} \tilde{k}_i \times \tilde{l}_{ib} \quad (7)$$

In general,

$$IR = K \times \widetilde{L} \quad (8)$$

The last index existing in Alenia's CMS is the **competency level of a person relative to a role** (LR_{kj} $with\ k \in \{1, \dots, m\}$ and $j \in \{1, \dots, t\}$). For each resource, this value is calculated as the ratio between the "Role index" and the "Expertise index of advisor role". In a mathematical representation, results:

$$LR_{kj} = \frac{IR_{kj}}{AdvR_j} \quad (9)$$

Generally[3]:

$$LR = diag(IR) \times \left(diag(AdvR_1 | \dots | AdvR_k)\right)^{-1} \quad (10)$$

This value is important to evaluate competency gaps between persons and roles and to determinate the main important actions to mitigate these gaps, as to provide a training course or make a better resource allocation.
In the follow section, all this concepts and their mathematical formalisms are showed for a specific Alenia's case study.

Mathematical Formalization in a Company Case Study
To validate the mathematical model used to represent all the concepts of Alenia's CMS, it is considered as case study the Aerodynamics competency area (w_1).
People, activities and roles belong to this area (w_1) are estimated. In fact, for simplicity, the methodology is applied considering only two persons (p_1 and p_2) and six activities (a_1, a_2, a_3, a_4, a_5, a_6) related to this area.
Each activity is characterized by its technical difficulty index and its interaction level and by the value of the complexity indexes calculated for each activity (see Tab. 1)

A	Definition	t	li	K
$\mathbf{a_1}$	Design and construction design of models and test equipment	3	1	2
$\mathbf{a_2}$	Instrumentation models (electrical, electronic, pneumatic, etc.).	3	1	2
$\mathbf{a_3}$	Manufacturing equipment and test models, fitting models according to test requirements	3	2	3
$\mathbf{a_4}$	Performance of tests in tunnels business, analysis on the consistency of the results, check the consistency and compliance with specifications and emission of test reports	2	2	2
$\mathbf{a_5}$	Concordat and control models of tunnel construction and testing at external facilities for testing transonic, supersonic, high Reynolds	2	4	4
$\mathbf{a_6}$	Modelling the effects of the propulsion system on the aerodynamic characteristics of the airplane and the definition of such contributions to the aerodynamic database	4	1	3

Tab. 1: Example of lists of activities.

The competency assessment of resources is as follows:
- p_1 isn't able to carry out the activity a_1 (c_{11}=0 e l_{11}=0), a_4 (c_{14}=0 e l_{14}=0) and a_6 (c_{16}=0 e l_{16}=0),
- p_1 carries out the activity a_2 with a *competency level* 2 (c_{12}=1 e l_{12}=2) and a_5 with a *competency level* 3 (c_{15}=1 e l_{15}=3),
- p_1 potentially is able to carry out the activity a_3 with a *competency level* 4 (c_{13}=-1 e l_{13}=4);
- p_2 isn't able to carry out the activity a_2 (c_{22}=0 e l_{22}=0), a_4 (c_{24}=0 e l_{24}=0)
- p_2 carries out the activity a_3 with a *competency level* 3 (c_{23}=1 e l_{23}=3), a_6 with a *competency level* 3 (c_{26}=1 e l_{26}=3) and a_5 with a *competency level* 3 (c_{25}=1 e l_{25}=3).
- p_2 potentially is able to carry out the activity a_1 with a *competency level* 1(c_{21}=-1 e l_{21}=3) .

The following roles are examined:
- R_1, Specialist equipment for building and testing models in wind tunnel;
- R_2, Wind Tunnel Test Engineer.

In the Tab.2 there is the summary of the concepts applied to this case study.

Element	*Formalism*
Set of people	$P = \{p_1, p_2\}$
Set of activities	$A = \{a_1, a_2, a_3, a_4, a_5, a_6\}$
Vector (1x6) of complexity	$K = [2, 2, 3, 2, 4, 3]$
Matrix (2x6) of competences	$C = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} \end{bmatrix} = \begin{bmatrix} 0 & 1 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$
Matrix (2x6) of competence level	$L = \begin{bmatrix} l_{11} & l_{12} & l_{13} & l_{14} & l_{15} & l_{16} \\ l_{21} & l_{22} & l_{23} & l_{24} & l_{25} & l_{26} \end{bmatrix} = \begin{bmatrix} 0 & 2 & 4 & 0 & 3 & 0 \\ 1 & 0 & 3 & 0 & 3 & 3 \end{bmatrix}$
Set of roles	$R = \{R_1, R_2\}$
Matrix of weight (6x2) with the activities are associated to a role	$V = \begin{bmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \\ v_{31} & v_{32} \\ v_{41} & v_{42} \\ v_{51} & v_{52} \\ v_{61} & v_{62} \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 2 & 4 \\ 3 & 1 \\ 1 & 4 \\ 0 & 2 \\ 0 & 1 \end{bmatrix}$

Tab.2: Summary of the concepts for the case study.

Considering all the numerical elements above, it is possible to calculate the *competency index of the advisor role*, as in Eq. (5)

[2] The columns of this matrix, $\widetilde{L}$, are minimum values calculated between the competence level of i-th person for all n activities (columns of L^T) and the weight of j-th role for the same activities (columns of V). The size of $\widetilde{L}$ is $n \times b\ where\ b = m + t$.
[3] The matrix: $diag(AdvR_1 | \dots | AdvR_k)$ is constituted by the repetition of the vector AdvR k-th time as it is the number of people to evaluate.

$$AdvR = K \times V = [2,2,3,2,4,3] \times \begin{bmatrix} 1 & 1 \\ 2 & 4 \\ 3 & 1 \\ 1 & 4 \\ 0 & 2 \\ 0 & 1 \end{bmatrix} = [17 \quad 32]$$

The value "17" is the value of the "Advisor Role 1" and the value "32" of the "Advisor Role 2".

To establish the *Role index*, it is necessary to calculate $\widetilde{L}$, (Eq. (6)):

$$\widetilde{L} = \begin{bmatrix} 0 & 0 & 1 & 1 \\ 2 & 2 & 0 & 0 \\ 3 & 1 & 3 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For further explanation, the values in the second row of the $\widetilde{L}$ matrix are obtained in this way:

- $\tilde{l}_{21} = min(l_{12}, v_{21}) = min(2,2) = 2;$
- $\tilde{l}_{22} = min(l_{12}, v_{22}) = min(2,4) = 2;$
- $\tilde{l}_{23} = min(l_{22}, v_{21}) = min(0,2) = 0;$
- $\tilde{l}_{24} = min(l_{22}, v_{22}) = \min(0,4) = 0.$

In the same way, the value of the others rows are calculated.

Therefore, the *Role index* (Eq. (8)) is equal to:

$$IR = K \times \widetilde{L} = [13 \quad 15 \quad 11 \quad 16]$$

To calculate the *competency level*, equal to the ratio between the *Role index* and the *Expertise index of advisor role*, Eq. (10), it is needed to consider the diagonal matrixes associated to vectors IR and AdvR.

$$LR = diag(IR) \times \left(diag(AdvR_1| \ldots |AdvR_k)\right)^{-1} =$$

$$\begin{bmatrix} 13 & 0 & 0 & 0 \\ 0 & 15 & 0 & 0 \\ 0 & 0 & 11 & 0 \\ 0 & 0 & 0 & 16 \end{bmatrix} \times \begin{bmatrix} 17 & 0 & 0 & 0 \\ 0 & 32 & 0 & 0 \\ 0 & 0 & 17 & 0 \\ 0 & 0 & 0 & 32 \end{bmatrix}^{-1}$$

$$= \begin{bmatrix} 0.76 & 0 & 0 & 0 \\ 0 & 0.47 & 0 & 0 \\ 0 & 0 & 0.65 & 0 \\ 0 & 0 & 0 & 0.5 \end{bmatrix}$$

On the diagonal of this matrix, there are the *competency levels* of each person relative to each role, in detail they are:

- to person p_1 and to role R_1 $LR_{11} \cong 0.76$
- to person p_1 and to role R_2 $LR_{12} = 0.47$
- to person p_2 and to role R_1 $LR_{21} \cong 0.65$
- to person p_2 and to role R_2 $LR_{22} = 0.5$

The presented formulas provide an easy to understand representation of the competency management rules available in Alenia Aeronautica. This mathematical approach can be used to implement a new software since the proposed mathematical formalism can be translated in software language in a fast and clear way. The formulas are also very flexible to any required changes that can be emerged using the developing system.

5. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

The study proposes the translation of the CMS of Alenia Aeronautica aerospace company, in algebraic terms in order to provide a unique meaning and understanding for the entities and rules of the related methodology. A simple set of formulas is proposed to express all the most important rules useful to guide the CMS re-engineering.

The application of the mathematical model in a company case study clarifies the benefits of this approach. Using a common and complete representation of the objects and linkages, the development of software, based on an algebraic design, is easier and has the advantage of a developing time reduction.

This approach allows to provide a design easy to understand and flexible for further improvements. Actually, a competencies dictionary and new assessment parameters, such as the time-work and work-load, are under evaluation. Moreover, the algebraic representation is under-testing of the research team and several applicative case studies are developed in order to test the appropriateness of the proposed formalization and to eliminate emerging errors.

As future researches to obtain a re-engineering of the actual competency management system based on the proposed algebraic representation, new functionalities will be introduced as the evaluation parameters and the algorithms to optimize allocation of the resources.

The implementation will improve the results and the soundness of the mathematical representation.

The used representation can be also applied in other companies through easy adjustments to the formulas.

The mathematical formalism allows the generalization of the methodology and the possibilities to replicate the methodology inside others companies applying a similar CMS and pushing also the creation of a networked CMS version. Future researches will be designed to explore multi-company context in order to highlight the complexity of a multi-domain and propose an extended version of the discussed formalism. Looking to an inter-companies CMS, further indexes will be useful and will be developed trying to include the specific features of the context in order to guide the competencies monitoring and scouting in a network of company.

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Collaboration, Product and Knowledge

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ABSTRACT

Inter-organizational collaboration is no longer entirely a free choice, but is close to a necessity imposed by economic, technical, and knowledge-related concerns. A deep understanding of collaboration will assist in making intelligent decisions on entering, operating, and evaluating collaborative ventures. The nature of the partners—industrial corporations, consultants, academic institutions and others—and the collaborative structure are important, but so too is the nature of the product. We consider its effects in the collaborative domain on knowledge, intellectual property, and catastrophic risk.

Keywords: Collaboration, knowledge management, ICSD, risk management,

1. INTRODUCTION

Inter-organizational collaboration is no longer entirely a free choice, but is close to a necessity imposed by economic, technical, and knowledge-related concerns. A deep understanding of collaboration will assist in making intelligent decisions on entering, operating, and evaluating collaborative ventures. Important factors include the structure of the collaboration [6,23], the nature and experience of the partners [20,24], collaboration-aware handling of policies and risk [10,14,21,22,27], knowledge [3,7,9,12,18], mental models [4], and information flow [13,14,16,17], and the goal of the collaboration, which we consider in this paper.

In [23], we reviewed four modes, three of them collaborative, largely in the context of software development: contractual development using subcontractors and vendors, supply-chain structures, *ad hoc*, short-lived virtual organizations, and long-term collaborations. We argued that software development tends to encourage long-term collaborations, resulting either from long or iterated development cycles for novel applications, maintenance of a long-lived system, or the desire to preserve technical and knowledge-intensive relationships in a setting of increased trust and cultural familiarity [1,19,28]. While we explicitly excluded development of open software in that earlier paper, we should here add federation as another mode, whether a federation of individuals and organizations developing open software, a collection of libraries centralizing cataloging, or a group of franchisees who need to maintain the reputation and consistency of services provided.

As we considered risk and collaboration further, it became apparent that the nature of the product was also significant. As an initial classification, we consider (1) sharing of resources, (2) provision of services, (3) development or manufacture of material artifacts, and (4) creation or modification of intellectual property.

- Resources: In such ventures, partners tend either to be collocated, sharing support services, or more-or-less peers in the same field, sharing production resources. We consider two simple examples—a consortium of Brazilian tool-and-die manufacturers sharing excess plant capacity and staff [29], and a group of small companies or organizations centralizing coordinated business support services.
- Services: We consider three classes of examples: first, franchised or coordinated professional services, such as large tax accounting firms or independent insurance agents and adjusters; second, services meeting daily needs, such as fast-food franchises; and third, a virtual organization—an ad hoc or permanent confederation of concerns—bidding (for example) to host social events or conferences, each providing a different aspect of support.
- Material artifacts: Most collaborative supply-chain operations fit here. We consider the manufacture of automobiles and of electronic devices. (While there is a contractual side here, the relationship often becomes obligate on both sides—there are at most a few suppliers of

a specified part, and at most a few large customers for that part. Thus planning for future production inevitably takes on a significant collaborative dimension.)

- Intellectual property: Notable examples include collaborative software development [2,14,30], development of on-line courses, collaborative works of art or knowledge (although these often involve individuals and not organizations), and collaborative knowledge bases. One further example of interest is collaborative design and engineering of a novel structure [15]—while the building or other structure itself is clearly a material artifact, the difficulties often emerge in or from the design, which is clearly an intellectual product.

Individual collaborative ventures may of course comprise a mix of these characteristics, in both dimensions. A fast-food franchise operation, for example, comprises both a supply-chain operation to provide materials, and a federation to provide service, and its product is both a service and a material good, if not exactly a novel one. Likewise, structure building can be seen throughout as a mix of intellectual property and material artifact.

In the balance of the paper, we consider the relationship between the nature of the product and the collaborative structure, product implications for the role of knowledge and the nature of knowledge objects, and implications for risk—in particular, motivated by current news, legal issues on the one hand, and the consequences of catastrophic failure for one partner on the other.

2. PRODUCT AND KNOWLEDGE

The different classes of product require different types of knowledge object [9,11,12].

Resources: A consortium of Brazilian tool-and-die manufacturers [29] organized in the last decade to share idle capacity, and possibly also portable tools and manpower. Since the partners work in a common domain, and processes were for the most part well-established, the role of knowledge is minimal—at most the specifications of parts made for a largely-shared client base. Likewise, establishing a common venture to share bookkeeping services such as payroll would expose some personnel and perhaps corporate information, but largely information already known to a good approximation by the other partners. Knowledge objects thus comprise primarily specifications and data sets, with minimal surprise, minimal required integration, and minimal interpretation.

Material artifacts: A good example is auto parts. Such ventures tend to fit into supply-chain collaboration. Collaborators typically undertake differing parts or process steps. Relevant knowledge typically involves the physical interfaces (e.g., mechanical) and interactions (e.g., chemical) between components, and process and internal product knowledge must be revealed only insofar as necessary to satisfy specification. While constraints on factors such as safety and precision must be exposed, much of this is again largely shared if approximate knowledge. Knowledge objects are part/component specifications and descriptions plus external constraints. There will tend to be some surprise, a moderate amount of integration and collaborative knowledge [18], and varying but perhaps high amounts of encoding and interpretation needed.

Services: While knowledge for resource-sharing and production of material artifacts is largely product knowledge (plus common domain knowledge), service-oriented ventures inherently also and perhaps primarily need to share the knowledge needed to promote consistency and non-interference. While marketing and product knowledge are important for the fast-food example, sharing of process knowledge is important in the other two cases. For the independent agents, processes are common and shared, and consistency of process is typically what characterizes successful collaborative and franchise professional service ventures. With the catering service venture, on the other hand, processes are heterogeneous, and interactions are more frequent and less predictable, requiring that awareness of other partners' internal processes sufficient to minimize interference. For many such organizations, sharing will also include customer and/or supplier information and management guidelines. We would expect varying levels of surprise, a level of integration depending on the level and form of partner interactions, and moderate-to-high levels of encoding and interpretation.

Intellectual property: There is a spectrum here between loosely coupled components—as in the chapters of a book taking different points of view, or in software components that have little interaction except to share a user- and file-interface—and a single tightly-woven seamless product—such as a building design or a complex computer application. At the high end of the spectrum, the complications are significant—as we have discussed in our other papers. In the software example, partners have to have access to some knowledge of the internal technical and perhaps business processes at other partners, a view (not necessarily complete) of their domain knowledge bases, and some understanding of aspects of the internal structure of their components. The set of knowledge objects is diverse, and needs to encompass business and technical process knowledge, domain knowledge [5], and development knowledge. Knowledge is both a critical input and a critical output of the development process. Some knowledge (both input and output) may emerge from the collaboration, and be joint rather than individual property [18]. The levels of integration and of encoding/interpretation will tend to be very high, and the level of surprise likewise, especially since some knowledge objects will not initially exist, but come into existence only by integrating partner knowledge, or in the process of development and use of the product, and others will be dynamic, changing over the lifetime of the project.

Thus, resource-sharing collaborations tend to have minimal knowledge requirements; service and material artifact ventures have varying demands, generally with high needs for interpretation and encoding; and intellectual property efforts are characterized by diverse, dynamic and heterogeneous knowledge objects, with high levels of integration and dynamism, and a very high need for interpretation.

3. MORE ON KNOWLEDGE OBJECTS

We can distinguish three categories of knowledge objects entailed in the collaborative development of a product:

- Hard-coded: The physical structure of the product and its concomitant artifacts, its input data sets, and its output (if different from the product itself), and interface specifications.

- Soft-coded: Knowledge of processes, practices, and interactions.

- Meta-coded [11]: Views and understandings, related to cultural co-variances and to intellectual property protections.

When we consider the collaborative knowledge base itself, these become, respectively, the data in the knowledge base; its inference rules, forms, queries and reports, and its patterns of use; and the views available to each partner and collectively, and the informal guidelines for interpretation of that information.

In general, a product – whether of resource, service, material artifact, or intellectual property – bears a blend of hard-coded, soft-coded, and meta-coded knowledge in varying shares. Figure 1 provides an initial picture. Collaborative efforts require the sharing of product knowledge between partners, either by making common use of a set of knowledge objects, or by employing interfaces which act as links between knowledge objects [11, 12]. At the same time, there is the tension at each collaborating partner between the benefits of sharing one's own knowledge with others and the risk of giving away competitive advantage.

Balancing this tension is critical to the success of a collaboration. The balance must be envisaged prior to the start of a collaboration, maintained while collaborating, and reflected at the end of a collaborative venture–all of this making it, for each partner, subject to knowledge management: the assessment of and the decision on which knowledge objects to share, and whether to share in whole or in part. In [9,12] we have suggested the knowledge objects approach for knowledge management in collaborative software development. The broader horizon of collaborative engineering, or collaboration in general, leads to an extended definition of knowledge objects, with the distinction of hard-coded, soft-coded, and meta-coded knowledge. It results in different ways of knowledge sharing or protection depending on the category of a knowledge object. And it may even make the case for designing new knowledge objects that are specific for, or adapted to, a given collaborative setting.

Figure 1. Sharing of knowledge in collaboration

Nature of product	Hard-coded	Soft-coded	Meta-coded
Resource Sharing	Moderate	Moderate	Minimal
Service	Moderate	Substantial	(homogeneous) Minimal (heterogeneous) Moderate
Material Artifact	Substantial	Moderate	Moderate
Intellectual Property	Substantial	Substantial	Substantial

4. PRODUCT AND LEGAL RISKS

Every venture of course may encounter a wide spectrum of risk. The discussion here treats only risks that arise because of collaboration, not those to which a single organization providing the same product would be subject to a comparable degree.

Resources: The individual data sets are of course proprietary, and in a case such as the tool-and-die example, there needs to be protection against theft of clients or jobs. But such risks are usually well-understood at the time a venture is begun, and standard safeguards exist. In the presence of goodwill, property issues can often be resolved with minimal trouble.

Services: In cases where the partners are peers supplying a common service, the main goals are consistency and reputation/reliability. Problems are well-understood, and structures exist to try to prevent them or recover from them. There are two refinements. First, if business information from the individual partners needs to be shared, difficulties are introduced as in the previous case. Second, to the extent that the partners are providing different services, as in the catering example, there is a risk that one partner will use the process or business information provided by the other to compete. Nonetheless, the process and business information required to be shared will not usually reveal trade secrets or endanger privacy and security of the partners or third parties.

Material artifacts: Legal concerns focus on scheduling and non-compliance plus those interfaces. Since internal process information typically needs to be revealed only to the extent that it affects safety or other extra-functional requirements, there is generally no need to share process knowledge. Two exceptions exist, though: first, whenever incremental innovations from either side shall be included in the product, at least partial knowledge about business or market strategies gets exchanged; second, when an artifact as a whole (an end product, like a new type of car – or a part, like a new drive control device) is being innovated, also technical and manufacturing processes have to be aligned and therefore revealed to a certain extent. Customer and supplier information, to the extent shared, is also a concern.

Intellectual property: Typically, almost all of the concerns raised above apply. Further, intellectual property, privacy and security issues are inherent in development, not only of software development, but of most production of intellectual property. These issues affect the necessary sharing of internal technical and business processes, knowledge bases, the internal structure of the components, and knowledge produced directly by the product, or indirectly by analysis thereof. These concerns increase with several factors: the complexity of the product, its dynamicity, the level of component interaction, and the involvement of protected information.

In sum, the first three forms of product have moderately well-understood intellectual property risks and protections, while development of intellectual property, particularly software development, introduces a wide variety of risks pertaining to privacy, security, trade secrets, and other concerns.

5. PRODUCT AND CATASTROPHIC RISK

Recent news events, particularly the Japanese earthquake, tsunami and nuclear disaster, but also volcanoes, hurricanes, tornados, wildfires, have exposed serious problems in supply-chain manufacturing. Comparable problems will affect collaborative ventures, and are more substantially affected by the nature of the product and its decomposition into components than by the nature of the collaboration.

Resources: A catastrophic failure to one of the partners, unless it damages a central processing facility, will generally not impede e the collaboration, but at worst reduces the benefit of collaboration, either by limiting the resources available to the other partners, if they are overloaded, or by reducing the work available to the central facility, raising the amortized cost. The immediate impact will typically be small.

Services: In the homogeneous case, one partner's failure, unless accompanied by serious damage to the venture's reputation, will have almost no short-term effect on the other partners, or in some cases even a small positive effect, as that partner's business is allocated among the remaining collaborators. In the heterogeneous case, or when the service is to be provided in a single venue, there may be a delay or loss of capacity until that partner is replaced. But this will not usually introduce substantial delays or losses, unless the partner is essentially irreplaceable, since the collaborative knowledge demands are minimal.

Material artifacts: The Japanese disaster illustrates difficulties with supply-chain ventures, when all facilities making a critical part fail catastrophically. Since modern manufacturing processes typically require specialized facilities, and material artifacts often require bottom-up integration, the lack of such a part imposes a bottleneck, as can currently be seen with the automobile industry or the manufacture of laptops. In the meantime, other partners will have either to curtail operations, or to allow large inventories of parts to accumulate. If it is possible to replace the failing partner, there are still likely to be delays resulting from start-up instrumentation and activities, as well as the need to acquire and understand needed information.

Intellectual property: Failure of a generalist partner (one who is simply "sharing the load") will result proportional delays until the partner is replaced, although the other partners can pick up the slack to some extent. The loss of a specialist partner or its key personnel is also problematic for an intellectual property venture, but not usually as severely as in the material artifact case, and some of the other partners may be able to assume some of the responsibility, often at a lesser level of performance. Alternatively, the other partners may be able switch temporarily to parts of the product that do not interact with those being developed by the missing partner, mitigating the cost and schedule hits. The time to recover full capacity is generally less. On the one hand, the start-up instrumentation will be at most acquisition and training on some development tools; on the other, the high level and dynamism of collaborative knowledge, and the need for specialized learning and training, is likely to continue to have some effect well after the replacement occurs.

Overall, catastrophic failure of one partner is likely to have minimal effects on most resource-sharing and service collaborations, versus great effects on material artifact ventures; intellectual property ventures are between these two extremes.

6. A CASE HISTORY

The nature of the product can, (as previously discussed in the introduction) significantly impact the collaborative structure with some manufacturing processes benefiting. Recent case study work [8,25,26] discusses a small-to-medium enterprise (SME) manufacturing company's interaction with its much larger customer. The key application is a knowledge-sharing network, with implications for collaborative business structure and policy. Thus the product is intellectual property with aspects of service.

The knowledge sharing networks operated on many levels, within the SME and beyond the SME to interact with small teams within the larger customer company. These interactions were developed longitudinally to satisfy a variety of products with success reflecting the SME's earlier experiences of a "whole team flat structure" approach, translating into various team-based projects. This approach provided flexibility needed to produce a variety of products, and the required rapid change in production methods.

The SME capability directly reflected the wide and in-depth knowledge of staff, gained over time (and documented longitudinally), through flexible "working team practices". These practices included working beyond SME teams to incorporate the customer and its supply chain network. These capabilities have resulted in company members acquiring the ability to balance company and project vertical structures with horizontal knowledge experiential exchanges. This is not something that is easily achieved within project-based manufacturing organizations. The various "layers" of experience were developed over time and formed the basis for the application of quick and timely in-depth expertise. The horizontal knowledge exchanges of staff members built over time formed the basis of new individual and company knowledge (from various sources) utilizing internal and external networks to update or advance specific or general knowledge. It is interesting to note that capability supported by various combinations of team or co-workers, were fundamentally initiated by individuals. This more flat structured approach at times resulted in knowledge networks developing and moving between the SME and its customers' supply chains regardless of formal boundaries, blurring product, services and supply chain structures.

7. CONCLUSION

Collaboration is affected by the organizational, geographical and cultural dispersion of the participants, and by the form of the collaboration [23]. But it is also affected by the goal of the collaboration, that is, the nature of its intended product. In this paper, we have considered three factors—the role of knowledge, the extent and nature of legal—especially intellectual property—risks, and the consequences of catastrophic failure of a single partner, and argued that there are significant differences based on the nature of the product—whether sharing resources, providing a service, making an artifact, or developing intellectual property. While there are further distinctions within each category, and collaborations that produce multiple or hybrid kinds of product, this classification appears to provide some insight into preparing for and evaluating collaboration.

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Video conference platforms: A tool to foster collaboration during inter-organizational *in vivo* simulations

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ABSTRACT

Inter organizational decision making and problem solving of emergencies and extreme events are complex research fields where scarce experimental data is available. To address this problem, Lemyre et al (2010) developed the *Inter-GAP In Vivo System*, an HYDRA like simulation system (Alison & Crego, 2008) to run behavioural experiments of complex crisis. The system design and testing included three different categories of participants: for pilot testing, first year university students; for theoretical validity, college students engaged in emergency management programs; and for field validity, expert decision makers who had managed major crises in their career. A comparative assessment was performed to select the most suitable video conferencing software commercially available since in terms of costs it was more efficient to acquire a tool already developed and customized it to the experiment needs than it was to design a new one. Software features analyzed were: ease of use, recording and chat capabilities, format delivery options and security. The *Inter-GAP In Vivo System* setup was implemented on the video conference platform selected (Nefsis™). The overall system performance was evaluated at three different levels: technical setup, task design and work flow processes. The actual experimentation showed that the conferencing software is a versatile tool to enhance collaboration between stakeholders from different organizations due to the audiovisual contact participants can establish where non verbal cues can be interchanged along the negotiation processes. Potential future system applications include: collaborative and cross – functional training between organizations.

Keywords: Collaboration, simulation, video conference, inter-organizational problem solving.

INTRODUCTION

The study of emergency management is a complex research arena that involves the intersection of many different disciplines. One of its main challenges is the low likelihood of occurrence of emergencies and disasters, plus different uncertainty factors surrounding each one of these events. For this reason, historical retrospective studies involving qualitative approaches such as ethnography (Latiers and Jacques, 2009), phenomenology (Klein et al, 1989), open ended interviews (Hart, 1997), and case studies based on documental evidence (Lemyre, 2009) have been used to understand the many variables involved in the development of an emergency response. These approaches have the advantage of providing a general view of the events. However *aposteri* reports have a lower reliability level, since they lack the precision of an experimental design. Another problem of retrospective approaches, is the challenge to overcome the social desirability bias (Fisher, 1993), where participants tend to portray an enhanced positive image of themselves while accounting their narration. A second approach employed to study emergency management, are field studies. Field studies or field simulations have the advantage to provide data collection *in situ* and in real time. Field simulations also facilitate transitions from planning to practice, to test different organizational capacities (Hart, 1997). However simulations can be extremely complex and costly (Nja & Rake 2009;Latiers & Jacques, 2009). Oftentimes, field simulations are bounded by specific contexts and can easily become very technical (Hart, 1997).

An alternative approach to research emergencies has been the use of laboratory exercises based on computer games and simulations. The challenge, as Rolo and Diaz-Cabrera (2005) explainit, is for computer simulations to allow participants to experience *complex and dynamic environments,* under controlled conditions that aim to capture the realistic settings of a field study. Brehmer and Dorner (1993) called these

computer simulations "*microworlds"* since they can emulate the realistic conditions needed for research. Three main characteristics of microworlds are described: 1) *opaque*, which means that a micro world must allow researchers to hide from participants as much features and attributes of the simulation as needed. 2) *Complex* to enable participants with novel, uncertain and overlapping activities that challenge their regular professional roles and workloads. And the last characteristic is that micro worlds should be 3) *dynamic*, allowing participants to experience the accelerated step of real emergencies. These features aim participants can have lively experiences and therefore the reactions and behaviours observed resemble real ones. Computer simulation games have also be named as *role playing games* (Woltjer et al, 2006), where several stake holders participate and problems must be solved in a collaborative manner.

However, one main shortcoming of computer simulations is that participants have been university students (Pearsall et al, 2010)(Homan et al, 2007) who lack the level of professional background and knowledge needed to manage real emergencies. Another limitation according to Nja and Rake (2009), is that laboratory based approaches under controlled conditions will not encompass as much characteristics of a real emergency, nor of field simulations. Despite these shortcomings, interesting results have been found under laboratory controlled conditions (Pearsall et al, 2010;Homan et al, 2007), which can potentially inform field simulation studies based on the laboratory settings.

One of these computer simulations was a training system developed by Alison and Crego (2008) called HYDRA. This system was created to train the police in England. However the design of the system was aimed to target only the security forces. For this reason in 2010 Lemyre et al, developed the *Inter-GAP In Vivo System*, which purpose was to run behavioural computer simulations that look at inter organizational problem solving, expanding from previous work (Alison and Crego, 2008) that had focused on the intra organizational level only.

During an *Inter-GAP simulation system* session, participants are assigned to groups of participants, called "*pods*". Each pod is equipped with a computer and communication equipment. Teams work along a simulated emergency event while all their interactions are recorded to be further analysed. The simulation stream is delivered from a separate control room using video conferencing software, with the simulation, tasks and injects rendered following a set script. Each session is initiated with a briefing session where participants are oriented on the materials to be used and the technology available for the experiment, as well as to acquire an informed consent from each participant.

Rationale to use video conferencing software

The experimental design had two main requirements: First, simulated data should be delivered simultaneously to each pod; and second, text, audio and video outcomes should be recorded. This last feature was of vital importance for the experiment given the large amount of data that was needed to be collected in order to perform later analyses.

The commercial video conferencing software was able to provide a suitable solution to meet the experimental requirements. Many advantages were found in commercially available software, such as offering a robust study environment, given that simulation sessions have to be delivered not only locally but also to remote locations. The commercial software also provided the seek feature of storing data outcomes in different formats such as text, audio and video, which was essential for the experiment data collection. Another related significant feature is that video streaming itself, allowed participants to hold fluid "*face to face"* interactions and communications with each other. Therefore non verbal communications through visual cues were possible.

Another relevant feature of commercially available conferencing software is that it represents a readily available cost-efficient alternative. Due to the fact that the experiment was run over a limited budget, and holding strict delivery timelines, it was not possible to develop a full system to then run the experiment based on it. On the other hand, an available feature of the software, not yet fully exploited is the capability of deploying simulations to remote geographical locations. The following sections explain how the software selection was developed, the system tested, then results are discussed pointing out implications for future research.

METHODS

Software selection process

Different video conferencing software providers were considered to be used in the experiment: Nefsis™, GoToMeeting™, NetMeeting™, Adobe Connect™, DimDim™ and WebEx™. Overlaps in the features offered by the suppliers were found (Table 1). However after the assessment, Nefsis™ was the software that best fitted the experimental requirements. Features assessed were:

- Ease of use for participants
- Recording of meeting sessions
- Recording of chat messaging
- Security
- Delivery of information in multiple formats
- Smooth delivery of audio/video files

In terms of easiness of use, most of the applications assessed have a friendly environment that allows users to intuitively navigate along the different software's tools.

Although many platforms offered to record the video conference sessions, Nefsis™ allowed recording them in a commercial video format (.avi). While many of the other providers offer to record sessions in their own proprietary formats, which could only be played afterwards using also proprietary applications.

In terms of chat availability, most firms offered this feature. When assessed, GoToMeeting™ and Nefsis™, offered simple solutions. Nefsis™ allows users to save each chat enabled as a text (.rtf) file which was considered as a powerful solution for research analysis.

In terms of security, the experiment required each session to be kept securely. For this reason software were evaluated on this feature. Nefsis™ offered user access control through virtual private networks deployed for each session to be held. Additionally the software allowed researchers to control the "*opacity"* of the simulation by enabling control of the simulation injects, by individual pod.

Most of the video conferencing software evaluated, allowed the delivery of simulation injects in multiple formats, such as documents, power point presentations, audio and video files, hand writing and drawing; as well as desktop, applications and, web browsers sharing.

For the purpose of the deployment of the experiment simulation we aimed for good management of long pauses and poor transitions . The challenge was to avoid these kinds of distractions while rendering good media files to the participants. Nefsis™ allowed smooth data streaming; at the time of the system design, it was the only software that worked with cloud computing to deploy the video conference simulation.

Table 1. Video conference software comparative assessment

A. Software considered						
A	Nefsis	GoTo Meeting	Net Meeting	Adobe Connect	DimDim	WebEx
B						
1	✓	✓	✓	✓	✓	✓
2	✓	✓	N/A	✓	N/A	✓
3	✓	✓	✓	✓	✓	✓
4	✓	✓	✓	✓	✓	✓
5	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	✓	✓

B. Feature assessed

1. Ease of use for participants

2. Recording of meeting sessions

3. Recording of chat messaging

4. Security

5. Delivery of information in multiple formats

6. Smooth delivery of audio/video files

Equipment and facilities requirements and set-up

The basic equipment and facilities needed to operate the video conference software for the experimental design, are shown in Table 2. Each POD room was equipped with a desktop computer and a dedicated broadband internet connection, a duet microphone / speaker, and a webcam placed at an angle that would capture the image from all the pods participants. The control of the simulation was delivered from a different room equipped with a desktop computer, a broadband internet connection, and a microphone / headset headphone. Nefsis™ licences allowed up to 16 different computers to be connected to each session.

Table 2. Video conference equipment

Quantity	Item	Features
3	POD rooms	Rooms in close proximity to each other to assist in troubleshooting
1	Control room	
3	Web camera	Logitech Web cam C260
3	USB Conferencing mics/speakers	Phoenix PCS duet conference phone
10	Computers	Any brand of PC
1	Microphone/ headphone headset	Logitech USB Headset H360
16	Licences internet web conferencing	NEFSIS web conferencing NEFSIS.COM

System performance evaluation

Technical evaluations were performed over the system, and its experimental set-up. The goal of these tests was to guarantee the appropriate functioning and system layout. System resilience was tested by rehearsing under "real" simulation conditions. These tests also included simulation deployment and reception from remote locations. The system design and testing included three different categories of participants: for pilot testing, first year university students; for theoretical validity, college students engaged in emergency management programs; and for field validity expert, decision makers who had managed major crises in their career.

Pilot testing with participants allowed researchers to update system settings to improve the overall simulation content, workflow, processes, and system performance. The original system set up was designed for 18 laptops, one per participant, and for each researcher involved in the experiment run-through, participating either as technical staff or as experiment observers. This first system set up was intended to run remotely. However,

at this stage of the system performance evaluation, it was noticed that technical staff should also need to be deployed to each remote location to comply with all the experiment requirements, and data collection. Additionally it was noticed that the deployment of the simulation was dependant on the infrastructure available at the delivery point. For this reason, it was decided to run the experiment at the University of Ottawa facilities only.

During the pilot testing with university student volunteers, simultaneous visualization of nine webcams on each monitor saturated the screen, and it took participant's attention away from the core experimental tasks. On Moreover, the only way to connect simultaneously 18 laptops to the internet was through a wireless connection. Given the local wireless infrastructure, the deployment of the simulation presented delays, interference, glitches and echo between computers. For these reasons it was decided to group three participants per computer, to ensure a broadband internet connection and accurate system performance.

In terms of audio and video quality during pilot testing, the webcams proved to be a reliable source for video. However the sound transmitted from the integrated web camera microphone was poor. For this reason usb conferencing speaker / microphones were integrated into the system. These devices have the advantage of cancelling echoes and background noise, while allowing a clear audio transmission.

Participants for system evaluation

University volunteer students were required for the pilot testing sessions. At this level, participants provided valuable feedback in terms of simulation content, workflow processes, as well as perceived easiness of use, technical set-up, and overall system layout. The next level of assessment included junior level career professionals and students related with emergency management programs, military and non governmental organizations. During these sessions the objective was to refine the experiment instruments, simulation materials and provided cues for further analysis. The third evaluation level included senior managers, feedback from this session help to refine simulation's task design, to test work flow processes and overall technical system setup. At all levels, participation in the study was voluntary and consent was obtained from each participant as per ethics requirements.

RESULTS

A total of fourteen *in vivo* sessions have been deployed. They have included participation of senior decision makers, early career professionals and university student participants (to pilot). In terms of system performance, workflow process and task design, the number of challenges to be overcome decreased notably from one session to the next one. Technical and process improvements were immediately incorporated as opportunities arose. The end product was an appealing, efficiently delivered simulation exercise that reflected high professional standards (according to feedback received from senior officers participating).

The experience of using video conferencing software for research purposes brought forth valuable learning insights. On the minus side, one has to mention that the deployment and reception of the study simulation was dependant of the local physical infrastructure. And if not appropriate, the quality of the simulation was not at its full extend. Specifically, an important element of the technical infrastructure is the networking bandwidth available for the deployment of the simulation. Another limitation is the number of participants with individual webcams per session, limited to no more than eight for proper visualization. The loading of the video conferencing software at each computer implied the installation of additional plug-ins and login access requirements, which were not intuitive for end users who are not familiar with the video conferencing software.

Another important constraint while controlling the workflow for the experiment simulation was to control the individual audio settings for both experiment participants and research observers. This posed a challenge, given that these kind of software are design to broadcast simultaneously the same information to all video conference participants. However, the experiment required to hide and control simulation elements for participants at given periods, which pose an enormous challenge to provide a flawless and smooth flow of the experiment simulation.

A last limitation experienced, is the time available to use the video conferencing software, bound to the license period purchased. Box 1 summarizes the limitations experienced using video conferencing software for research purposes.

Box 1. Experienced video conferencing software limitations

- Dependent on local physical infrastructure
- Bandwidth dependent
- Limited number of participants per meeting
- Limited to license duration to use software
- Technical challenges for end users to install the application
- Challenging to control audio settings to follow experiment requirements

On the other hand, the benefits offered by the video conferencing software surpassed the limitations to be overcome. One of these benefits was the accurate work flow control offered by the many video and audio controls, which allow group and individual adjustments. Another relevant feature is the users' access control, which is managed by granting administrative session permissions to each participant. These permissions are not only for access, but also extended to resource sharing of the multiple data formats available to be shared: audio injects, video streaming, whiteboard sharing, power point presentations, desktop sharing, and internet browser sharing.

Another benefit provided by the video conferencing software was the smooth delivery of video and audio streaming. The modularity of the software allowed controlling the video and audio quality which had a direct impact on the simulation delivery performance. In order to provide participants a high quality immersive experience, all the video conference software settings were setup to the maximum. An additional benefit the

video conference software offered, were the multiple options for data collection. For experimental purposes, video and text were the formats chosen to be kept for further analysis. The formats chosen to store the data were .avi for video, and .rtf for text.

In terms of experimental results, the preliminary observational outcomes pointed out the fact that there was an increased group interaction when the video conference option was open for senior managers, enabling them with "face to face" communication. However text was the preferred option for university students. Meanwhile, the junior level career professional used both options, text and video-conference, to interact with each other. Nevertheless, when the video conference option was used by participants, behavioural cues others than explicit verbal communication were used, and visual contact facilitated these interactions. Box 2 summarizes the benefits of using conferencing software for research purposes.

Box 2. Experienced benefits offered by video conference software for behavioural research purposes

- Simulation work flow control
- User access control
- Control of resource sharing
- Smooth video / audio streaming
- Data collection: Audio + video + text
- Facilitates communication between pods
  - Visual contact
  - Behavioral cues
- More group interaction between pods when video conference option was available, for senior managers and junior level professionals
- Text option was poorly used by senior managers and junior level professionals

DISCUSSION

After assessing the benefits and limitations offered by the video conferencing software to run *in vivo* simulations, we found it is a very useful tool for behavioral research purposes. In these terms, it proved to be a cost efficient tool. given tat the research benefits obtained by using commercial software surpassed the investment made to acquire the software license, and the technical limitations of the system. Potentially, video conference software may offer solutions to overcome geographical and environmental challenges. Additionally video conference platforms may assist in fostering collaboration by enabling resources and information sharing. And the most salient feature, in our experience, was that it enabled a virtual "face to face" communication. In terms of future research, video conference software is a potential platform to develop training programs. Given that they provide the necessary conditions to layout modular and flexible training and research designs.

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Plato, Socrates, Hunt, and Rotfeld: Eigenforms of Academic Collaboration

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ABSTRACT

A number of academic institutions profess to offer Interdisciplinary Studies but few truly achieve it, and not without a great deal of effort over and above the normal workload of a professor and a level of patience and perseverance not found in many university students. This paper will report on a successful academic collaboration between two very different disciplines: philosophy and business. It will examine a course taught jointly by the two disciplines in a strategy of imbrication attempted by a college of York University in Toronto, Atkinson College, housing both liberal arts and professional school.

Keywords: advertising, collaboration, cybernetics, education, imbrication, marketing, Plato

1. INTRODUCTION

In the York University academic year of 2003-2004, Professor Claudio Durán and I set out to teach Atkinson College's first and only imbricated course. But we had been talking about it for many years prior to this.

Atkinson College – Atkinson College no longer exists at York University, having merged with the Faculty of Arts to form the Faculty of Liberal Arts and Professional Studies, but for more than a quarter century it was a special place where full-time professors taught their full course load in the evening and summers. The college specialized in offering university study to part-time and mature students, with more than two thirds of our students being full-time working adults returning to university. Another large number were university-age students who could not afford to go to school full-time without working. The college consisted of a large liberal arts component, teaching all the subjects taught during the day at the York Faculty of Arts, and a professional studies side consisting largely of the Department of Administrative Studies, offering a business degree called the Bachelor of Administrative Studies. Both programmes were available only on a part-time basis, although students could conceivably take four evening courses and a Saturday course in a week and proceed as full-time students. We had functioned since 1962 as two separate entities: the liberal arts side of the college and the business side. York University, like other universities in Canada, is government funded.

When I first started teaching at Atkinson College, my department on the fifth floor did not have enough room for me there, so I landed on the sixth floor among the Philosophers. This changed the direction of my research in ways that have been rewarding to me personally and professionally. The move suited me well. While my terminal degree was in business (major in marketing), I had always, since studying at a fine small liberal arts college in Illinois, Shimer College, possessed a strong interest in philosophical discussion and in the roots of our Western education system in Plato and Socrates. On the sixth floor of Atkinson College, among the Philosophers, I met Professor Claudio Durán whose terminal degree was in philosophy and who had always possessed a strong interest in mass media, advertising and ethics. Business and liberal arts are not natural companions, but while our respective departments often battled, Professor Durán and I often met to discuss our mutual research interests, often over lunch or dinner at Atkinson before classes. One of our favourite topics of conversation was the idea of teaching a course together, combining our mutual interest in philosophy, ethics, and advertising.

Professor Durán had often guest lectured in my courses, addressing logic and introducing us to the work of fellow York professor Michael

Gilbert, who originated the theory of multi-modal argumentation. We both now used this theory in our research and in our classrooms. I became a frequent guest lecturer in Professor Durán's course titled Philosophical and Ethical Issues in the Mass Media, where I brought the application of logic and multi-modal argumentation to advertising.

Imbrication – The dictionary definition of the word *imbrication* tells us that it derives from the Latin *imbricare*, to cover with gutter tiles, to form like a roof or gutter tile from the Latin *imbrix*, a gutter tile, from *imber*, rain. The word imbricate means "lying over each other in regular order, like tiles on a roof, as the scales on the cup of some acorns; overlapping each other at the margins, without any involution" [13]. A shorter definition gets to the point of the use of the word at Atkinson College, "to place so as to overlap". I describe the definition in fine detail because at the time that we were asked, as university professors, to develop "imbricated courses", none of us knew what that meant. Dean Ron Bordessa and the Working Group responsible for this strategy had in mind to take the two diverse parts of Atkinson College and put them together in a collaborative way so they were each part of the integrated whole and overlapped.

To understand imbrication, one also needs to understand the difference between multidisciplinary and interdisciplinary studies. Multidisciplinary studies bring together the separate expertise of two or more scholars from different fields of study; they each approach the problem from the viewpoint of their respective fields. Interdisciplinary studies also bring together two or more scholars but they approach the problem together, as a team, each building on the knowledge and expertise of the other. Most universities offer multidisciplinary programmes but they cannot be called interdisciplinary work. We might observe, for example, a course on Long Term Space Travel taught by a professor of physics during the fall term, and then by a professor of sociology in the winter term, each teaching and testing separately. Most undergraduate students are required to take several courses outside their major discipline, one hopes as different as possible from their major discipline. Thus a student might be majoring in marketing but take electives in the Music Department in music of the Middle Ages. A school might offer a joint programme between two disciplines, where each discipline would contribute its own offering to the student's learning. The proposed imbrication would see courses designed and taught together by faculty from the liberal arts and the business sides, with a vision of both professors in the classroom at the same time, teaching together students from different disciplines.

2. THE FIXED POINTS

Plato – Plato lived from 428 or 427 to 348 or 347 B.C. in Ancient Greece where he taught students using the Socratic Method. He was a pupil of Socrates. It has been said that our current education methods in Western society have their direct roots in Plato's teaching and writing. Plato also is known for his theory of Forms, wherein we evaluate what we can or cannot truly know.

Socrates – From Socrates we have no writing at all, only what Plato wrote about him. He lived in Greece from 470 to 399 B.C. before being condemned to death by drinking hemlock for his unusual teaching methods. His unusual method is what we know today as the Socratic Method. In this way of teaching, the teacher asks carefully chosen questions and encourages the student to learn the truth through logically questioning his assumptions.

Hunt – Shelby D. Hunt serves as one of marketing's cornerstones of academic theory, bringing to the discipline a thorough understanding of the field, and of its links to other fields going as far back as Plato and Socrates. He teaches marketing as the Jerry S. Rawls and P.W. Horn Professor of Marketing at Texas Tech University. He has served as editor of the *Journal of Marketing*, and his work has recently been selected to be published in Sage Publications' "Legends in Marketing" series.

Rotfeld – Herbert Jack Rotfeld is a self-labelled iconoclast, Professor of Marketing at the Auburn University College of Business, but with a watchful eye always on the world of

misplaced marketing. He edits the *Journal of Consumer Affairs*, serves as President-Elect of the American Academy of Advertising, and writes a regular column on how marketing can be misused, especially advertising.

Durán and Ripley – Professors Claudio Durán and Louise Ripley (author) are both professors in the Faculty of Liberal Arts and Professional Studies at York University in Toronto. Professor Durán teaches philosophy and Professor Ripley teaches business and women's studies. Both have been winners of the Atkinson College Alumni/ae Award for Teaching Excellence and consider teaching their life's work.

3. TEACHING THE COURSE

Professor Durán's terminal degree was in philosophy, with its links to logic, argumentation, and classical studies, but he also held an abiding interest in advertising and ethics. My terminal degree was in business with its links to advertising and ethics but I also held an abiding interest in logic, argumentation, and classical studies. We both were interested in the role of philosophy in helping us understand questions of ethics, whether in advertising or elsewhere.

While our respective departments fought grand battles on the floors of Council and Senate, Professor Durán and I frequently ate together in a quiet corner of the Faculty Club and tallied all the advantages of working in a college that combined both liberal arts and business. Knowing I was interested in finding ways of analyzing the ethics of advertisements, Professor Durán introduced me to Professor Michael Gilbert, also in philosophy at York, in the Faculty of Arts. We actually met on the picket lines during York faculty's 1997 fifty-five day strike. It was from Professor Gilbert that I learned multi-modal argumentation theory and invited Professor Durán to my courses a number of times to teach my students the basics of logic and argumentation. As my research progressed in the area, Professor Durán invited me a number of times to give a guest lecture in his classes. Particularly suited to this arrangement was his course entitled, "Philosophical and Ethical Issues in the Mass Media". We began to speak regularly and excitedly about the idea of teaching the course together. When the strategy of imbrication was introduced, we recognized our chance.

We planned the course together, creating a new (and online) course syllabus that laid out in detail how the course would be organized, combining readings and instruction in both logic and advertising. We started the course with Plato writing in the *Gorgias* [8] about the teaching method of Socrates and the concepts of argument and persuasion and the good of society. We then moved through Formal and Informal Logic, using the work of Morris Engel [3]. In the second half of the course, we moved to the work of Shelby Hunt, a modern-day marketing scholar who bases his study of marketing theory in philosophy as it came down to us through Plato, Socrates, and Aristotle. Hunt himself says, "…we shall see that many of the current debates in marketing and the social sciences were argued (perhaps better) in Plato's time" [7]. Shelby Hunt introduces his book, *Modern Marketing Theory*, with a quote from Epictetus, a Greek born Roman slave of the second century.

> *Question: Prove to me I should study logic!*
> *Answer: How would you know it was a good proof? [7]*

Plato, Hunt claims, defined knowledge as "justified true belief". For Plato true philosophical wisdom must pass the test of critical discussion, the Socratic Method of today. This fits not only with Hunt's view on how we should view marketing theory but also with the enlightened system of education which encourages more student participation. It also provides a method to examine the logic in advertisements as we look at advertising as in pragma-dialectics, as a dialogue between advertiser and consumer, where we will examine the exchange to understand what tactics are being used in order to sell [9]. Hunt also reminds us of Plato's theory of Forms, which is most useful in examining pictures as verbal arguments [6]. Coming out of the school of thinking of Pythagoras, and enamoured of the concept of abstract terms in mathematics, Plato set forth a theory that abstract ideas or

essences had an ultimate reality outside of how we saw them. What we perceived through senses, Plato said, was only an imperfect copy of the ideal thing, and we could therefore only know things as we perceived them. This links directly to Hunt's chart on the differences between positivist/empiricist science and relativistic/constructionist science whereby we find many realities in a science that s a "social process" as opposed to a science where it is possible to discover the "true nature of reality" [7].

We used a paper by Ripley [10] to study the use of Gilbert's multi-modal argumentation theory [4,5] in examining advertising as it is seen by advertisers. We used articles by Professor Durán on the Chilean newspaper *El Mercurio* [1,2], which provided another link to the use of logic and multi-modal argumentation theory in analyzing arguments.

We wrapped up the course with chapters from Herbert Jack Rotfeld's book, *Adventures in Misplaced Marketing* [12]. This book**,** in its argument that marketing when abused often results in outcomes not in the best interests of society, brought us full-circle back to Plato's work in examining the ethics of persuading the masses, where we had started in the fall. Rotfeld maintains that it is not right to criticize marketing in the way that many people do, citing the number of people who approach him as total strangers and demand, "…how dare you advertise cigarettes to children!" as if, because he studies marketing, he were personally responsible for what is instead a reflection of society's wants. Research consistently shows, says Rotfeld, that "people are very resistant to the persuasive efforts of marketing tools". Marketers wish they possessed the power that critics accuse them of having [12]. There is the further issue of whether an advertiser of a consumer good, such as perfume or body wash, is the one totally responsible for the public's attitudes toward casual sex or violence against women. Rotfeld maintains that they are not, as does Ripley [9,10,11]. Marketers are generally reflecting what a large part of our society already believes. Rotfeld describes two types of misplaced marketing, the first where the seller did not consider the consumer in the proposed campaign, a lack of the marketing concept. The second occurs when marketing is used properly but it may not have been done in the best interests of society, such as the marketing of cigarettes, liquor distillers, gun companies, or pornographers to the wrong people. He cites the example of a new beer appealing to low-income black consumers. All of this is helpful as we contemplate the arguments made in the advertisements that sell these products.

Following from Plato and returning to him through works in logic, argumentation, and advertising, both Professor Durán and I taught together in the classroom for every class for the full year. We tried to avoid both of us standing at the front of the room, lest we intimidate students. We like to think of ourselves as anything but intimidating but two professors at the front of a classroom is an oddity for students. In a college that held evening classes from 7:00 to 10:00 p.m., after years of budget cuts, class sizes grew too large for good discussion, so we arranged the three hour class differently. Half the students came for a tutorial with both professors from 6:00 to 7:00 p.m. There followed a lecture and full class discussion from 7:00 to 9:00 p.m., and then a tutorial with both professors from 9:00 to 10:00 p.m. for the second half of the students. Assignment to tutorials was not rigidly enforced, and students could move between early and late tutorial as it suited their schedules. Formal lectures were rare; we strongly encouraged full class participation and utilized a variety of pair and share, small group work, and other pedagogical exercises that kept students engaged.

The course was well received. Students loved the chance to interact with others from different disciplines and the course produced one award-winning paper by two students, one from philosophy and one from marketing. The Dean at that time, Dean Rhonda Lenton (who succeeded Dean Bordessa) heard about our course and asked if she might visit. We invited her to show up at any time. The Dean arrived during a period when the whole class was together for the two-hour lecture and discussion. Professor Durán was on one side of the room and I on the other, and a lively discussion was proceeding, bouncing from

student to student with occasional input from us. Our dean was highly impressed. At that time we were teaching the course experimentally with each of us receiving only half the full-course teaching credit, something we did not want to continue in a unionized Faculty. The Dean arranged the next time we taught the course together, for us each to get full teaching credit for teaching a full-year course. This is not sustainable, however, especially in a college and university facing continual budget cuts.

4. CONCLUSION

There is no satisfactory answer to the budgetary problems that inhibit fair payment for two professors of an imbricated course. Professor Durán although retired, still teaches at York University and University of Chilé, and I am teaching mostly online. But we still count as some of the best years of our combined eighty-plus years of teaching experience our imbricated course that brought together students of philosophy and business to study with a professor of philosophy and a professor of business, reading the works of men who can serve as tokens for stability in academic work that has come down to us, in many changing ways in a rapidly changing world. What does change, for the good, is our continued ability, while applying the old classics to our teaching, to apply new classics in research to what we already know and are teaching. This is particularly appropriate to a collaborative imbricated course.

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Collaborative Risk Management

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ABSTRACT

Risk is the probability of an unwanted activity occurring causing loss or harm to the organization. Managing risk includes identification, assessment, impact evaluation, acceptance and mitigation. In today's well distributed and diversified organizations, risks exist in virtually every part or function of the organization. Increasingly it is being recognized that one central risk management team may not be in the best of position to identify, assess and manage all the risks across the organization.

This paper proposes the idea of Collaborative Risk Management (CRM) where in the stakeholders across the organization, collaborate seamlessly to determine and manage risks on an ongoing manner. CRM provides collaborative risk awareness and responsibility throughout all levels of an organization, optimizes the use of enterprise resources, and ultimately reduces the overall risk exposure levels of an organization. In this paper, the concept is explored for Collaborative Risk Management for operational risks in a product development and management scenario. There are some clear advantages of CRM like shared ownership, decentralized implementation, optimal resource utilization, leveraging of users understanding of the domain and functional risk areas. Collaborative Risk Management is explained here through the example of a product lifecycle. The CRM approach implies that risk management function is invoked in the entire lifecycle of the product. Within the Lifecycle is a series of discrete phases, each one separated by a checkpoint which is designed to keep the product / solution on track by ensuring that essential governance requirements have been met. In each of these phases the CRM risk function necessarily gets involved in assessing and addressing risks.

Given due management support and organizational structure, organizations can produce risk resistant products by seeing that all necessary stakeholders get involved in the collaborative risk management process through the life cycle of the product. Unlike earlier risk management efforts, in this approach, risks get identified way before the product's launch through a collaborative effort. So, key risks get identified and addressed by the product / solution / infrastructure is ready for launch. No doubt some new risks might crop up once the product is deployed but still in this approach the management can be rest assured that risks have been looked at from the requisite diverse perspectives and that most key risks would have been addressed by the time the product comes up for a launch. Once deployed, with the collaborative involvement of functional teams from across the organization who are much closer to the field of action, a periodic review ensures that new / emerging risks are identified early enough to be addressed before they become disasters. CRM provides all the stakeholders the opportunity to see and think about the risk in their domain while also retaining the big picture. This drives consensus and builds a shared understanding of key risks in a holistic manner. Collaborative risk management stands a strong chance of succeeding in today's distributed and diversified organizations providing rich dividends.

Keywords: Risk, Risk Analysis, Risk Management, Information Risk Management Collaborative Engineering, Collaborative Risk Management

1. BACKGROUND

Risk is the probability of an unwanted activity occurring causing loss or harm to the organization. Managing risk includes identification, assessment, impact evaluation, acceptance and mitigation. In today's well distributed and diversified organizations, risks exist in virtually every part or function of the organization. Increasingly it is being recognized that one central risk management team may not be in the best of position to identify, assess and manage all the risks across the organization.

Generally one central risk management team is responsible for identification, assessment and management of all the risks across the organization. This paper suggests a Collaborative Risk Management (CRM) approach where in the stakeholders across the organization, collaborate seamlessly to determine and manage risks, on an ongoing manner. CRM team gets engaged throughout the life cycle of a product rather than getting involved only when the product goes live or is in production.

CRM provides collaborative risk awareness and responsibility throughout all levels of an organization, optimizes the use of enterprise resources, and ultimately reduces the overall risk exposure levels of an organization. Use of CRM in an ongoing manner for managing risks to products or solutions throughout their lifecycle, from initial inception to ultimate closure adds considerable value to the longevity of the product / solution and the business value it generates. CRM typically involves all areas of the organization involved in the delivery of products or solutions. CRM helps in defining Engagement and Accountability. CRM is designed to provide a simple engagement process to ensure that key groups around the business are engaged with in the right way and at the right time to identify and manage risk.

The CRM team is accountable to the Business Owner for identifying where a particular approach leads to business risk; to recommend alternatives where appropriate; and to articulate risks to business owners. The CRM team should be actively involved with the different departments involved for tracking and managing the progress of the product / solution.

In addition to highlighting business risk, the primary functions of CRM are to promote adherence to standards and best practices (through consultancy and review), to ensure a level of confidence in the stated technical approach such that the time and costs estimates presented are not undermined by radical changes in direction during the project delivery phase and to ensure sufficient information is available to allow business execution teams to complete their planning exercise well in time considering dates and costs.



Figure 1. Illustrative model - Collaborative Risk Management

2. Collaborative Risk Management

Collaborative Risk Management is explained here through the example of a product / solution lifecycle. The CRM approach implies that risk management function is invoked in the entire lifecycle of the product as represented in the diagram below. Within the Lifecycle is a series of discrete phases, each one separated by a checkpoint which is designed to keep the product / solution on track by ensuring that essential governance requirements have been met. In each of these phases the CRM risk function necessarily gets involved in assessing and addressing risks.

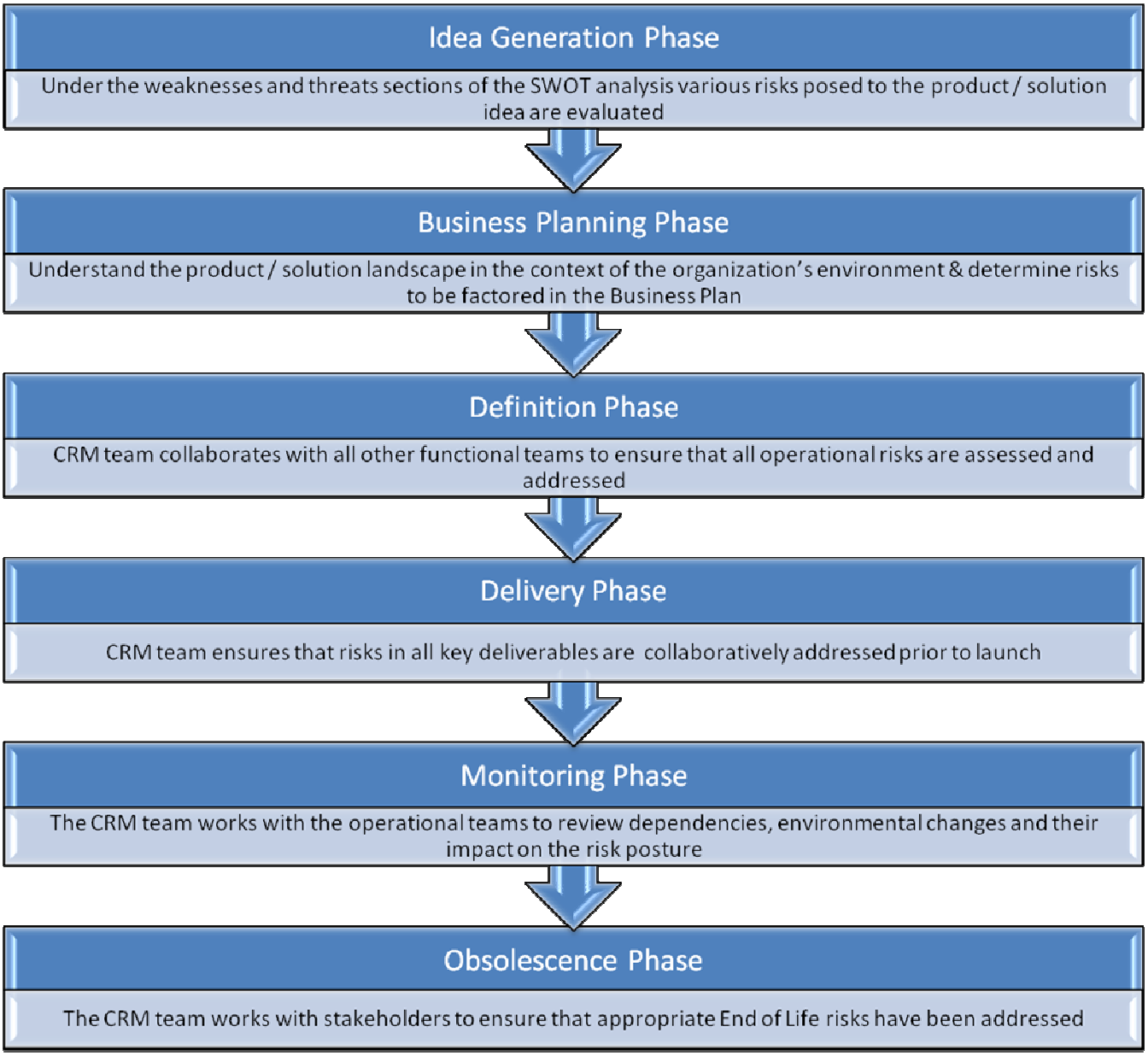


Figure 2. Phases in CRM enmeshed with lifecycle phases

2.1. Idea Generation phase:

This is not a formal phase but rather represents any period of time in which ideas are generated, by anyone in the organization, and documented in a Business Proposal ready for assessment. It is a funnel of ideas to the Business Divisions for review. Ideas are filtered and selected based on strategic alignment, business value and executive risk. CRM team works with the Business planning teams that conduct SWOT (Strengths, Weaknesses, and Opportunities & Threats) analysis for the new project considering strategic alignment and business value of the idea. SWOT analysis does address objective, market opportunity, customers' needs, opportunity costs etc. Key areas addressed under the weaknesses and threats sections are the various risks posed to the product / solution idea.

At the end of this phase the proposal is reviewed at the Idea Approval Checkpoint. The Idea Approval Checkpoint acts as a check post which allows only those proposals to go further which have been passed to pursue. The result of the Idea Approval Checkpoint will be pass/fail. Risks to the project / product or solution that get identified and evaluated would be essential components in the go-no-go decision making process. If the Business Proposal is passed, a Collaborative management team for the project would be created including risk management responsibilities. At Idea Approval checkpoint

new ideas which get selected based on SWOT analysis go to Phase II.

2.2. The Business Planning phase is the second phase of the Product / Solution Lifecycle. Once a Business Proposal is approved and has passed through the Idea Approval Checkpoint (at the end of the Idea Generation phase) a Product / Solution Owner (PO) is assigned to build the product / solution plan, describing it in more detail.
The output of the Business Planning phase is a viable Product / Solution Plan, and it is reviewed and accepted or rejected at the Project Initiation Checkpoint. The purpose of the Project Initiation checkpoint is to confirm that the business proposal is still viable, it supports organizational strategy and that risks to the product / solution have been factored in.

During this phase the role of the CRM team is to understand the product / solution landscape in the context of the organization's environment and determine risks the product / solution faces so that these can be factored in the plan.

2.3. Definition Phase - During the Definition phase the deliverables are defined in sufficient detail to allow development to proceed. Typically a project plan is produced that lays out the overall schedule and critical path. While doing so, risks are captured and analyzed and a level of contingency included in the overall schedule appropriate to the aggregate risk. In this phase the business owners and CRM team work together to address compliance with commercial, technical and services governance policies. The business teams supported by CRM team prepare sufficiently to be able to commit to delivery dates, deliverables and cost. During the definition phase, the CRM Team is responsible for the go/no-go decision of the 'Project Architecture'. In a consultative mode, CRM team collaborates with all other functional teams to ensure that all operational risks are addressed for example: Security requirements are spelt out along with the other design considerations; apprising Architecture Team on the architecture related risks; addressing key risks in managing Business Continuity, Disaster Recovery, Data Architecture, Database and Storage, Data Center Management, addressing Export Requirements, various Operational requirements, Technology Standards, Performance Engineering Resiliency etc.

During the Definition phase the product / solution plan is enhanced with details from the project plan that defines how long, how much and what resources are required to deliver the product / solution.

The Commitment Checkpoint reviews the work during the Definition phase to see whether the product / solution is ready to move into the delivery phase with all risks identified in consultation with CRM team being looked into satisfactorily. Additionally it confirms that the business proposal remains viable.

2.4. Delivery Phase - During the Delivery phase of the product / solution lifecycle, the main deliverables are produced and quality is agreed in preparation for handover of the product / solution to the operations teams. The end of the Delivery phase is marked by a Fitness for Launch Checkpoint. This is the checkpoint when the project transitions from delivery into deployment.

During the delivery phase, CRM ensures that risks in all key deliverables are addressed prior to launch. These deliverables may include different elements like product, infrastructure, content, administration, systems and processes. The CRM team works to ensure that risks in each of the components is addressed e.g. it could mean addressing technical risks in the product and infrastructure, process risks and people related risks etc. CRM team for example could also be responsible for reviewing deviations from the technical approach since the implementation architecture was designed / baselined. Any outstanding deficiencies are captured in CRM Scorecard.

CRM team will essentially highlight any new business risks caused by the approach being pursued to the attention of the business, suggest alternative approaches where appropriate, review the outcome of testing to validate that the selected approach has met specified criteria and get a sense of what are the residual risks in the product / solution. A Fitness for Launch Risk Review takes place in a collaborative setting, the output of which is recorded in CRM Scorecard. Scorecard indicates the concerns related to unresolved technology standards misalignment or any other significant levels of risk.

The purpose of the Fitness for Launch checkpoint is to confirm that the proposition is functional, meets performance requirements, is scalable, stable and ready to be presented to clients and that all the risks represented by CRM Scorecard have been addressed.

2.5. Deployment Phase - During this phase the product / solution is handed over from the groups

who have specified, developed and tested it to those groups who have to sell it, administer it, support it, operate it and maintain it.

At the stage of Ready for Revenue Generation Checkpoint the CRM team confirms that the product can be sold, administered and supported effectively in the target geographies without putting the organization at risk. It confirms that the product / solution meets its agreed performance targets in a production environment, is free of any significant known risks and is ready to be supported on general release. To formally move from project status to 'business as usual' status. CRM team has to ensure that all the known risks that the product / solution faces are addressed.

2.6. In the Monitoring Phase, CRM team is responsible to review risks of the product / solution in an ongoing manner. Typically at a defined periodicity the CRM team works with the operational teams in conduct of a review of dependencies, environmental changes and their impact on the risk posture, new releases and the status of risks in various components impacted through the new release.

2.7. During the Obsolescence phase products / solutions that are no longer sustainable or viable are retired or replaced with products / solutions that better support organizational strategy. Once the migration or closure is complete, all supporting infrastructure is removed and staff supporting the proposition reassigned to other activities. CRM team has to ensure that all the risks pertaining to end of life have been addressed. CRM looks into aspects like media disposal during re-allocation of assets, donation or destruction of assets to ensure that no confidential information goes out of the organization.

The purpose of the Closure checkpoint is to formally confirm that the products / solution has achieved end of life. To confirm that all product vestiges have been removed and that no corporate resources remain allocated to its support, maintenance or further enhancement. The CRM team ensures that appropriate End of Life risks have been addressed.

3. Advantages of the CRM approach include

3.1. Shared ownership – Unlike regular risk management approaches in CRM a much larger section of the functional teams are involved in identifying and managing risks in a collaborative manner. It leads to additional risks being unearthed and greater ownership among teams to understand and address risks.

3.2. Decentralized implementation – The risk assessment and management function does not happen in a centralized ivory tower. Rather it works across the organization in a decentralized manner wherein functional teams across the key functions of the organization implement it in a decentralized manner in collaboration with the CRM team.

3.3. Optimal resource utilization – Since CRM team works with functional teams from the beginning; risks get identified and addressed before they actually emerge; Hence resources get utilized in an optimum manner.

3.4. Leveraging of users' understanding of the domain - Functional teams being aware of the intricacies of their domain are best placed to identify risks and thereby take lesser time in bringing out the risks and helping collaborative risk team in addressing them.

3.5. Overall it results in more comprehensive risk coverage at much lower costs to the organization.

4. CONCLUSION

Risk is a vital function that needs to be addressed for any organization. Given due management support and organizational structure, organizations can produce risk resistant products / solutions by seeing that all necessary stakeholders get involved in a collaborative risk management process through the life cycle of the product / solution.

Unlike earlier risk management efforts, in this approach, risks get identified way before the product's launch through a collaborative effort. In an illustrative example of product / solution development one can see the benefits of utilizing Collaborative Risk Management approach which ensures that risks are identified and addressed all through the life cycle right from Ideation phase, through to business planning phase, definition, delivery, deployment, monitoring and obsolescence phases. There are some clear advantages of CRM like shared ownership, decentralized implementation, optimal resource utilization, leveraging of users understanding of the domain and functional risk areas, there are few minor distinct challenges as well. Stakeholder commitment is extremely hard to come by, if it is not in their organizational line of duty to spend their man hours on operational risk. Hence, it should be part of an organizational requirement and must flow into goal sheets of relevant stakeholders from the top.

By following a CRM based approach, key risks get identified and addressed by the product / solution / infrastructure stakeholders well before it is ready for launch. No doubt some new risks might crop up once the

product is deployed but still in this approach the management can be rest assured that risks have been looked at from the requisite diverse perspectives and that most key risks would have been addressed by the time the product comes up for a launch. Once deployed, with the collaborative involvement of functional teams from across the organization who are much closer to the field of action, a periodic review ensures that new / emerging risks are identified early enough to be addressed before they become disasters.

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Organizational Tacit Knowledge Memorization: A Theoretical Perspective

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ABSTRACT

In recent years, particular attention is paid to knowledge management and organizational learning in general and tacit knowledge management and organizational memorization in particular. This interest is driven by markets saturation, innovation speed and increasing environment uncertainty. Developing distinctive competencies in such circumstances comes from tacit knowledge learning, creation and memorization. In this paper, we analyze first tacit knowledge toward different approaches, we show how organizations can learn from this type of knowledge and how they become a learning organization to create new knowledge, then we present how this knowledge can be memorized independently from individuals.

Keywords — Tacit knowledge, learning organizations, system thinking, organizational memory.

INTRODUCTION

Most organizations evolve today in a complex environment in which competition is becoming more and more intense pushing companies to develop distinctive competencies by mastering knowledge and technology. The critical and distinctive knowledge of a company do not particularly lies on automated information systems that use structured information and explicit business rules. It is thus becoming more and more tacit. Moreover, keeping and developing this knowledge is not an easy task knowing that there is a loss of skills and capabilities due to impending retirement or an accelerated specialists and experts turnover. Neglected for years by academics and professional, tacit knowledge development and use emerge as one of wealth and value sources for most businesses. Soon, many authors raised the issue in terms of organization of knowledge transfer, offering complex information management systems relied on information technology and communications designed to solve a lot of problems. However, given the proliferation of knowledge, the difficulty is no longer relative to the management of all knowledge, but it concerns knowing how to locate and identify key knowledge related to strategic objectives of organizations. This will be to focus on this kind of knowledge, and especially to enable its development and its exchange through more open and collective working practices, as well as teaching methods and scalable and responsive training.

The analysis of organizations with a systemic point of view takes us to adopt a complex thought. This way of thinking allows us to address the organization as a whole. Thus, individual learning will lead to organizational learning, which later will differentiate the organization's knowledge from its individual members' one. Therefore, in this paper, the fundamental question concerns the acquisition by learning, the creation and development and the memorization of corporate tacit knowledge so that it can be disseminated through its individuals.

To address this issue, our paper has been divided into four sections. In the first section we will present a critical overview of the tacit knowledge concept. In the second one, we will show how a company uses tacit knowledge to learn related to action-based routines. The third section will focus on learning organization towards a systems thinking. The last section will deal about organizational memory and organizational knowledge creation, or how an organization constitute embedded organizational knowledge which doesn't belong to individuals when we talk about organization or not to organizations when we talk about networks.

TAWARD TACIT KNOWLEDGE DEFINITION: A CRITICAL APPROACH

Polanyi (1966) says that we can know more than we can tell. His woks have influenced significantly a set of contemporary works on the nature of organizational knowledge. The idea of tacit knowledge is very important for those trying to understand competitive advantage sources. This advantage comes partially from knowledge that can not be expressed and also from the organizations experiences that provide specific skills and capabilities that can not be imitated by competitors (Barney, 1991). While tacit knowledge can generate a unique competitive advantage to the company, it can not easily be capitalized and disseminated between different parts of the same organization (Szulanski and Capet, 2001).

The notion of tacit knowledge was introduced by Polanyi (1966), a philosopher who has become well known because he was cited in the writings of Kuhn (1970) and since then has had a renaissance with the writings of Nonaka and Takeuchi (1995). As noted by Polanyi (1966), "we can know more than they say." means that ineffable knowledge exists in individuals and organizations but they cannot easily identify it. Nonaka and Takeuchi (1995) used the notion somewhat differently from how it was by Polanyi himself. However, because of the influence of Nonaka and Takeuchi (1995) works on knowledge management field, the idea "relatively ambiguous" has been widely adopted. While Polanyi (1966) speaks about tacit knowledge as a backdrop from which all actions are understood. Nonaka and Takeuchi (1995) use the term to denote particular knowledge that is difficult to express.

Thus, in contemporary literature, the meaning of tacit knowledge has little in common with the conception of Polanyi (1966). More oriented towards the vision proposed by Nonaka and Takeuchi (1995), tacit knowledge is defined as knowledge that is not yet articulated. That is to say that it represents a set of rules embodied in the activity in which the individual is involved, that can later, and it's just a matter of time; transmit it in a certain learning process. Today, Nonaka and Krogh (2009) stipulate that "*"tacit knowledge" is a cornerstone in organizational knowledge creation theory and covers knowledge that is unarticulated and tied to the senses, movement skills, physical experiences, intuition, or implicit rules of thumb*".

In his critique of rationalism, Oakeshott (1991), in the same line of Polanyi (1962), distinguishes two types of knowledge, namely the *technical knowledge* and *practical knowledge*. Technical knowledge is the knowledge of rules, while practical knowledge represents skills and capabilities. For this author, it is clear that skills and the know-how, or in other words, competency can not be transmitted from one person to another, and acquired easily by simply following rules. The knowledge can be acquired only through "learning by doing" under the watchful eye of the master (teacher). The value of this analysis lies in its usefulness to the understanding of scientific knowledge (which is often confused with explicit knowledge).

Scientific knowledge is neither mechanistic nor explicit. It is developed by people that are deeply involved and have learned their profession in lots of years teaching others. Scientific knowledge is often seen as purely representative of technical knowledge or set of facts. However, the work behind this knowledge and these facts, intuitions, beliefs, and several hours of interaction with other scientists is the real driving force behind the progress in science. Thus, the metaphor of the "pipe line" behind many discussions on communication (Tsoukas, 1997) emphasizes that Nonaka and Takeuchi (1995), considering the ideas as objects that can be transmitted between individuals in using behavior, reduces practical knowledge to technical knowledge (Costelloe, 1998). Process practical knowledge, which is tacit in nature and therefore initially cognitive, as having content that can be easily set and then translated into explicit knowledge (Nonaka and Takeuchi, 1995), is the reduction of "what is known" to "what can be articulated", hence the concept of tacit or "practical" knowledge is impoverished (Tsoukas, 2002).

Weick (1995) explains practical knowledge from the fact that it redefines the specific differences in all activities to attract the attention of those who are involved in order to distinguish certain aspects hitherto unnoticed, and also to see the connections between the various items imagined disconnected before. This systems approach of practical (tacit) knowledge formation is supported by Katz and Shotter (1996). In that, tacit knowledge is acquired by engaging in practical activity through participation in social practices, under the supervision of people who are generally more experienced (Taylor, 1993), who, by attracting attention from certain things, can see the interconnections (Wittenstein, 1958).

In conclusion, we can say that tacit knowledge has a multitude of definitions and interpretation. Nonaka and Takeuchi (1995) consider tacit knowledge as knowledge not yet articulated or knowledge waiting to be translated or converted into explicit knowledge. This interpretation has been widely adopted in management, is flawed in that it ignores the ineffable nature of tacit knowledge (Tsoukas, 2002). The ineffable nature does not mean that we cannot discuss the possibilities of learning. However, it should limit insisting on the fact that tacit knowledge must be converted into explicit one, and instead focus on the creation of tacit knowledge, taking into consideration his personal feature, in the sense that it cannot be captured, translated or converted, but only displayed and manifested in the activities (Tsoukas, 2001). So for learning organization, the goal is not to transform tacit knowledge into explicit, but promote the emergence of new knowledge from the interaction between the tacit and explicit knowledge of all individuals involved in the performance of its activities, and in order to achieve the ultimate objective of the organization that is learning for the creation of a specific "intangible capital" generating by the fact a sustainable competitive advantage.

ORGANIZATIONAL LEARNING AND TACIT KNOWLEDGE

Organizations can learn only through individuals who constitute them. However, all do not promote individual learning. Some time ago, trying to understand causes already disobedience. In addition, few organizations try to capitalize knowledge developed by their members. Also note that all forms of learning are not necessarily geared towards the formulation, oral verbalization or rather codification. However, researchers tend to focus on learning that manifests in customary forms.

The company, until now, had no such worries. Gradually, as it is concerned with knowledge capitalization, it will provide it in forms that are appropriate to its context. It appears that the new designs are also different from the professional approach (how) as of the theoretical approach (why). In fact, each approach corresponds to a particular purpose and limited in a world that is changing gradually. Today, every company needs to adjust its forms of expression and its formalization standard. It must quickly mobilize knowledge in environments that are more versatile.

In addition, tacit knowledge is mainly personal and comes from the experience of each individual. The fact that knowledge is inseparable from its owner's, implicate that its departure means that it necessarily causes the loss of this individual tacit knowledge. One of the consequences of high turnover within the company is knowledge loss. Conversely, the hiring of workers who have had previous experience in the industry, a competitor, supplier or customer, is a knowledge contribution within the organization (Dostaler and Boiral, 2000).

Organizational learning can be defined as the ability of an organization to organize and enhance the effectiveness of its collective action over time. Nevis et al. (1995) defines it as the capacity or processes within the organization that can improve its performance based on his experience. It should be emphasized again that there is no organizational learning without individual learning, yet the organizational learning process is much more complex because it must be understood from a systems approach. In this sense, individuals' mental models play a central role because, according to Argyris and Schön (1978), organizational learning is based on the "shared mental models".

The concept of organizational learning adopted is the one, now common since the work of Argyris and Schön (1978), that distinguishes in single loop and double loop learning. The single

loop learning is a process of behavioral adaptation / response or correction of errors in organizational patterns established and not challenged. Double-loop learning is a cognitive process of challenging mental models which led to the adoption and production of new patterns of knowledge, thought and action.

For Argyris (1992), tacit knowledge is the basis of a first efficient and effective management, but also, it can also be the cause of his deterioration. The main objective of effective management is the definition and transformation of required behavior to action-based routines, to achieve organization objectives (Argyris, 1993, Argyris and Schön, 1996, Nelson and Winter, 1977). These routines are implemented through skillful actions that are necessarily based on tacit knowledge.

To better understand this, Argyris and Schön (1996) have focused on action strategies, which led them to develop action theories. The individual shapes of two theories of action: Espoused theory (what we say) and Theory-in-use (what we do). Although, they were able to detect many different behaviors, the authors have noticed that they met only two theories-in-use they called Model I and Model II.

Argyris and Schön have invested for nearly two decades in analyzing conscious and unconscious individuals reasoning processes within an organization (Dick and Dalmau, 1990). They assume that people are designers of their actions. These perform actions in order to achieve their goals and learn when they perform actions that seem effective. In other words, Argyris and Schön (1974), argue that all individuals have within their minds cognitive maps from which they plan, implement and correct their actions.

These authors also add that there are few individuals who are aware that cognitive maps, on which they rely to act, are not theories they assert. However, they are aware of maps or theories they use (Argyris, 1980). In simple terms, this finding does not only or simply concern the difference between what people say and what they do. Argyris and Schön (1996) suggest that, there is a theory that corresponds to what people say and another one that deals with what they do. So the distinction is not made between theory and action, but between two different "theories of action" (Argyris et al., 1985), hence the concept of "Espoused theory" and of "theory-in-use".

As a result, Espoused theory represents values and common views on which people believe that their behavior is based on. While theory-in-use is the theory in which individuals' behavior, or maps they use, involves the views and values. In other words, we can say that people are unaware that theories-in-use are not the same as espoused theories, and they are even unaware of their use of theories which implies that much of their knowledge is tacit.

Argyris and Schön (1996) argue that these theories of action determine the total purposeful behavior of individuals. Argyris (1987) suggests that one of the reasons that led him to insist that the actions of individuals are the result of a theory is the claim that what is done by these individuals is not fortuitous. People design their actions and are therefore responsible for this design. Argyris (1987) also states that in designing their action, people are generally unaware of this design and its difference with what is said. This has aroused a question: if individuals are unaware of the theories that guide their actions (theories-in-use), so how can they effectively manage their behavior? Argyris (1980) suggests that the effectiveness results from developing congruence or fit between espoused theory and theory-in-use.

Models developed by Argyris and Schön (1996) are designed to help people becoming aware of the tacit aspect of their knowledge and then be able to chose actions they design and implement. In this context, they developed models, namely single and double loop learning models that attempt to explain processes that create and maintain the theory-in-use of individuals. Thus, the interaction between these theories-in-use stimulates organizational learning.

Organizational learning is an emerging interaction between all cognitive maps of all individuals. According to a systems approach, the organization is not the sum of its parts, but represents a whole with a specific behavior. It is a system of norms and meanings shared by actors, or cognitive maps, called by Argyris (1987) theories-in-use (Tabourbi, 2000).

LEARNING ORGANIZATION AND SYSTEMS THINKING

Knowledge transfer and learning are more efficient in a learning organization. Skule (1999) states that the lacks of knowledge transfer can be associated to a lack of development in the various models that govern all practices within the organization. As learning organizations encourage knowledge transfer, they necessarily help to achieve the processes and structures for double-loop learning. As a result, organizational routines will suggest what the organization needs, and will automatically determine the solutions of problems (Shaffer, 1981).

The concept of learning organization is a concept that has recently appeared in the literature. Garvin (2000) stipulates that a clear definition of this concept has not yet been established. However, there are some definitions which occur more or less often in the literature. Senge (1990, p.1), which is one of the first to study this concept, defined learning organizations an "*organization where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together*". For Pedler et al. (1991, p.3), "*The Learning Company is a vision of what might be possible. It is not brought about simply by training individuals; it can only happen as a result of learning at the whole organization level. A Learning Company is an organization that facilitates the learning of all its members and continuously transforms itself.*"

Kim (1993) observed in her studies that all organizations learn only if they choose it consciously. She concluded that the most important for a company, in strategic terms, is not the speed of learning, things learned or people who learn, but how information is used, processed and transferred as knowledge within the company. Furthermore, the fact that some companies continue to stand even in situations of economic uncertainty, while others decline, is proof that businesses depend on their learning and adaptation ability (Spekman et al. 2002).

For Senge (1990), the basic logic of such organizations is that in a situation of rapid change, only those that are flexible, adaptive and productive will succeed. To do this, they need to discover how to harness the commitment and learning capabilities of all individuals at all levels. For Senge (1990), even if all individuals have an ability to learn, structures in which they operate may not be incentive for thought and commitment. Especially since they may lack tools and ideas to enable them to make sense of the situations they face.

Organizations that spend their ability to consistently create their future require a fundamental change in attitudes of their members. He adds that the real learning is one that goes to the bottom of what is human and that when, individuals and organizations become somehow able to recreate and rebuild themselves. Thus, for a learning organization, it is not just about survival. "Learning to survive" or what is commonly called "adaptive learning" is certainly important, but this needs to be supported by a "generative learning", learning that enhances the ability of individuals to create new things.

In his work on the fifth discipline, Senge (1990) stated that system thinking is presented as the cornerstone of all the other disciplines because it integrates them all together into a coherent set of theories and practices. System thinking helps first to understand an organization as a whole and the interrelations between all its parts, in order to allow individuals to see beyond the immediate context and incorporate the impact of their own actions on others, and also those of others on themselves. Second, since the construction component of a systems thinking is relatively simple, it allows, contrary to what organizations do today, people to develop models that are relatively complex and sophisticated. Senge (1990) states that for complex systems the use of simplistic models may cause blurred vision on the real situation. Finally, systems thinking can make sense of the mechanisms of action and reaction within the organization, and thus to learn how to identify tacit knowledge and allow its transfer and capitalization.

This systemic vision leads us to an interesting observation. Since:

- The environment in which organizations evolve is complex, and thus requires a complex vision,
- All parts within a system are necessarily interdependent,
- The interactions between these parts are as important as the parts themselves,
- The organization is more than all its parts,
- There is a very close relationship between what emerges and those who make it emerge,
- Tacit knowledge is the strategic knowledge in the organization,
- Tacit knowledge is the result of an emerging internal mental schema of an individual,

So we can say that an organization can have tacit knowledge that emerges from the interaction between tacit knowledge and explicit knowledge of individuals. These outcomes are not necessarily formalized or known in an explicit way. Consequently, we cannot talk in terms of concept about capitalization because, in our opinion, to capitalize on knowledge we need to articulate and simplify it. But, based on what we have seen above, the goal of a learning organization is not that of knowledge articulation or simplification, but rather processing this knowledge in its complexity. So the best suited concept is that of memorization, which is a dynamic concept unlike that of capitalization, in the sense that it allows intelligence and complexity. It also allows introducing the concept of intelligence, as for the creation of tacit organizational knowledge by using organizational memory.

ORGANIZATIONAL MEMORY AND ORGANIZATIONAL KNOWLEDGE CREATION

Organizational knowledge is a concept that has become widely used in the literature because it is significant and very expressive instrument in explaining the nature of organizations and their behavior (Kogut and Zander, 1996). The company can be described as a "knowledge warehouse" that is embedded in assets, rules, routines, standard operating procedures and dominant logics (Martin de Holan et al., 2004). In addition, several studies claim that to have a sustainable competitive advantage, the company must have fundamentally organizational knowledge, and at the same time be able to create new one more suited to its contexts (Kogut and Zander, 1992).

Grant (1996) goes further by saying that the primary role of companies, and the essence of their capabilities, is the integration of knowledge. He adds that companies exist because they can integrate and coordinate specific knowledge held by individuals in a more efficient manner than markets, and because they can transform individual knowledge into collective knowledge, in other terms in organizational knowledge. This knowledge is difficult to reproduce and enables companies to be autonomous from there competitors and partners, by holding a sustainable competitive advantage, provided of course by the ability to produce more knowledge depending on the speed of change in its competitive environment.

It is recognized in the literature that organizational knowledge is embedded in a kind of organizational memory that does not disappear with individuals' turnover (Martin de Holan et al., 2004). The organizational knowledge does not belong to individuals, but it has a separate property from the organization as a social actor (Ghoshal and Moran, 1996). Thus, organizational memory is presented as a fundamental organizational system that requires storage; or rather a memorization of knowledge produced by organizational learning process. In simpler terms, learning can be seen as the development of organizational memory (Cross and Bayrd, 2000). For Stein (1995), all current conceptualizations of organizational memory is mainly based on the work of Walsh and Ungson (1991), and define organizational memory as the set of information stored from the history of the organization so that it can be used in ongoing decisions. Organizational memory consists of decision stimulus series kept in a kind of "memory boxes" and have behavioral consequences when they are used (Walsh et Ungson, 1991).

In general, all studies on organizational memory have tended to theorize on a large scale, yet they are not based on empirical works, which makes it difficult to identify measuring variables (Ackerman and Halverson, 1999). Huber (1991), states that the support of a corporate memory analysis is certainly useful, but all works do not clearly distinguish what constitutes the corporate memory. Stein and Zwass (1995) recognized the need for empirical studies in this field. For Ackerman and Halverson (1999), most studies on organizational memory have largely focused on a set of technological systems designed to replace the physical and human factors relating thereto. These studies were very limited in view of too reductionistic definitions of memory and organizational tasks. So it would be interesting to examine the human side of this issue, because the trend today is more oriented towards standardization, but rather is directed towards the

personalization of knowledge to be transformed into idiosyncratic memory.

CONCLUSION

In conclusion we can say that there is a growing interest in concepts discussed in this paper, namely organizational learning, tacit knowledge and organizational memory. In this paper, we show that an organization as an entity interacts with its environment, with its partners, its competitors, but also with individuals that constitute it. It has skills, it learns and has a memory, and all its features are unique to it as a social actor. In the same line of Spender and Grinyer (1995), we can say that the firm is conceptualized as a whole, as a community of practice with institutional dimensions that gives meaning to these practices, rather than as a system of market resources under explicit control of managers. The resulting model is a company designed as a dynamic system, autonomous from its elements and which is partially responsive to managerial influences.

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Dams, Flows and Views: Cross-Aspect Use of Knowledge in Collaborative Software Development

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Abstract

Collaboration between organizations raises significant knowledge management issues, especially in software development of complex projects, in which both product and process are themselves knowledge. While research has examined direct, explicit flows of knowledge within project aspects, or forward between aspects, there is less investigation of the need and support for backward, implicit or emergent flows.

Keywords: Collaborative software development, collaboration, software engineering, knowledge management, ICSD.

1 Introduction

The share and impact of inter-organizational collaborative software development (ICSD), in various modes [19] and with multiple motivations have increased. Concurrent trends of growing complexity, feature space and size of software packages, which are also increasingly knowledge intensive, are characteristic of the majority of projects. Many of these applications can be expected to be long-lived, evolvable, and used in diverse contexts and environments. This combination of factors entails use of sophisticated and specialized organizational, software engineering, and knowledge management (KM) approaches. We consider a software development project *hard* if it is large, complex, and knowledge-intensive, and intended to be long-lived, evolvable, portable, and useful in diverse settings or for diverse user populations or clients.

Collaboration in general, and collaborative software development for hard projects in particular, requires cooperation, information sharing, and interaction at multiple levels. Working more-or-less from the governance business aspects toward the technical and deployment ones, and forward in project time, we identify in Section 2 a number of critical, knowledge-intensive aspects of collaborative software development, particularly crossing organizational boundaries.

In past papers , we and others have investigated the impact of collaboration in hard projects, and recommended changes in policies, processes and artifacts. These papers have addressed both general concerns [4,9,19,22,24,25] and specific areas such as business policies and processes [10,15], risk management [16,17], and technical processes and artifacts [11,12,13,23].

These recommendations affect corporate policy and procedures, software development, risk management, and knowledge management. Major themes are (1) a layered approach, comprising single-organization structures, a collaborative structure, and a method of resolving priorities and conflicts; and (2) methods and/or artifacts to extract, communicate and display appropriate knowledge, possibly including new kinds and forms of information, as well as filters, abstractions and views.

In the KM literature [2.6,7,8,14], knowledge is frequently classified as explicit, implicit or tacit; it may also be useful to distinguish emergent knowledge—knowledge that arises from synthesis of existing knowledge, or is a result, possibly in combination with such knowledge, of the project or product under investigation. Collaborative knowledge (see [5,7,14]), particularly the more difficult to control tacit and/or emergent, poses its own problems, most particularly those of intellectual property, security, privacy, and confidentiality, on the one hand, and credit (cost-benefit) assignment on the other [14]. With care, it is not that difficult to create a structure for the sharing and use of such knowledge, especially if used within an aspect, or when the flow is forward, that is, used as a driver of tasks more immediately focused on the current project, process, or product. It is more difficult when the flow itself is implicit/tacit or emergent, and especially if the flow is backward, that is, from a more product focused back to a more process or policy focused context.

In Section 3 we review and extend a list of drivers, benefits, impediments and risks in collaborative software development for hard projects, thus identifying the dams. Section 4 presents some examples of emergent and backward flows and related views.

The final Section 5 briefly presents recommendations and conclusions.

2 Aspects of software development

Collaboration in general, and collaborative software development for hard projects in particular, requires cooperation, information sharing, and interaction at multiple levels. Working more-or-less from outside in (governance and business drivers to development and domain platform to specific project and product), and forward in time, we can identify a number of critical, knowledge-intensive aspects of collaborative software development, particularly crossing organizational boundaries.

1. Business policy: Includes business vision and plans, risk tolerance, legal (intellectual property, proprietary information, privacy, confidentiality, and related issues), collaboration readiness and advocacy, marketing and management strategies, and issues related to reputation, business culture, and openness to employees, collaborators and customers.
2. Business process: Includes security, risk management and knowledge management, personnel management (including attitude toward collaborative work), culture and trust, marketing, and support for extramural activities.
3. IT and related support: Communication infrastructure and restrictions, establishment of shared representations and glossaries (see [15]).
4. Application knowledge base: Domain (e.g., banking) and product discipline and functions (e.g., auditing) knowledge. Heterogeneous contributions of partners; integration and inclusion of external knowledge, including new developments; supporting extramural use; credit and debit assignment; support of domain expert/discipline specialist consultation and collaboration [3].
5. Technical development environment and resources: Development platforms: computing resources; software tools including change management and dependency tracking.
6. Software engineering process and methods: Includes technical management processes including requirements analysis and quality assurance; people issues such as training and team management; nature of artifacts to be developed in SW process, and patterns of use, dependence and sequencing of these artifacts. Requirements for documentation and views.
7. Customer requirements and intimacy. Initial and ongoing interaction with customer (and possibly other stakeholders), prior to release, or explicit requests for modifications.
8. Project and product artifacts and history: Includes definition and design time software artifacts and change history. The actual artifacts associated with the current project and/or product: Requirements, specification, architecture, design, code, documentation, dependence analysis and traceability, testing and debugging. Interacts with Customer Requirements.
9. Product-generated information: Information resulting from use and/or analysis of product: input-output patterns, including unexpected exceptions or errors, patterns of use and performance based on information from profilers, history, logs, and similar tools, results of static and dynamic compiler analyses and transformations,
10. Customer satisfaction and desires: customer satisfaction survey results, modification requests and theirs severity and scope, ongoing feedback, new feature requests and long-term partnering proposals

Each aspect generates and ideally consumes its own information, and must manage that information for efficient use. Each aspect may but need not exist for each partner and for the collaboration, and some, such as (7) and (10), will necessarily be limited to one or two collaborators as discussed in [our modes paper]. Figure 1 shows the aspect structure, and Figure 2 shows its replication in a collaborative structure/engagement. Figure 2 shows some example flows: *cross-flows* are those between identical aspects; *forward flows* are those downward in the diagram; and *backward flows* include all the others.

Flows out of the collaborative structure are especially likely to involve collaborative knowledge, as are those (not illustrated for reasons of simplicity) with multiple sources in multiple partners. Emergent flows are most likely to include some backward flow, and emergent knowledge is most likely to be (at least in part) carried along such flows.

In our previous papers,we have considered modifications in both the structure in each aspect [10,11,12,13,19] and in its knowledge management to support collaboration [7,8], including supporting flows forward/downward in the process, and some of the more evident feedback flows. Here, we indicate the need for a more careful investigation of the need for additional, emergent or backward flows, to improve the collaboration, to optimize the process and product, to improve partner corporate and technical decision processes, or to improve the acquisition, organization, management, and protection of knowledge.

3 Drivers, benefits, impediments and risks in ICSD

In order to motivate the investigation of knowledge flows, we briefly review the tradeoffs in collaboration and in ICSD. These are based on existing literature and project observations, some of which have been discussed in our previous work and that of others. The identified impediments, and to a lesser extent the risks, become the dams obstructing the flow of needed information.

Drivers

1. Increase product feasibility, market, and profitability by leveraging expertise, knowledge, intellectual property, and reputation and connections of the partners.

2. Improve time to market by resource and expertise sharing, by reducing cost and time for knowledge acquisition, and training, and by parallel development.
3. Establish good working relationships with trustworthy partners.
4. Foster innovation by exploiting collaborative knowledge and collaborative process optimization.

Other Benefits

1. Increased knowledge and expertise from collaborating with specialists at other partners [3].
2. Improved tool, process and development environment, and improved component repository.
3. Better resilience due to extended personnel resource pool.
4. Improved reputation resulting from quality product and association with quality partners.
5. Innovation and insights resulting from development of knowledge and data filters, abstractions, representations and views.

Impediments

1. Corporate inertia and resistance from corporate and technical management, IT departments, and legal counsel [16].
2. Intellectual property, proprietary information, privacy, confidentiality and security.
3. Corporate policies and procedures for sharing information, firewalls, access restrictions, …
4. Difficulty in establishing trust and understanding of differences in social and corporate cultures [1,16,17,21].
5. Inconsistencies in tool suites, software development processes, and so on.

Other risks—business

1. Management contingency policies need to be collaboration-aware [18].
2. Risk management process needs to be collaboration-aware.
3. Customer and vendor contact needs to be centralized.
4. Indirect communication (e.g., via agents).

Other risks—technical

1. Specification needs to be collaboration- and decomposition-sensitive.
2. Software development process not amenable to cooperation and collaboration.
3. Inappropriate definition of component interfaces, in particular with respect to supporting evolution, both before and after release.

4 Dams, flows and views

Definitions and concerns:

- A *knowledge object* is a representation, often an abstraction, of a set of information and analysis results together with a context. The denotation, and especially the connotation, of a knowledge object is in large part defined by the domain, the discipline, the organization, and the social and organizational culture and history/memory and learning capability of an institution. One problem in collaboration lies in assuring communication not just of the object, but of enough context so that common denotations and connotations of knowledge objects can be established. Another lies in assuring that there is minimal leakage of protected information that is not needed by the recipient or the collaboration or underestimation of the cost associated with achieving minimal leakage.
- A *view* is a picture of a product, process, project, or knowledge object, arising from an angle of analyzing an object as to perceive/identify some of its aspects under given/specific interest – employs filtering, results in extraction, generates a knowledge object.
- A *flow* is a communication, with appropriate extraction, translation, filtering and abstraction, of a knowledge object available in one aspect or subaspect of a collaboration, to another aspect or subaspect in which it will be needed, or in which it will be integrated with other knowledge objects, or in which it will be further manipulated for use in a third aspect.

The key issue in ICSD for hard projects is the tension between evolvability on the one hand, and intellectual property and related issues on the other. We have already considered modifications of management and software processes and artifacts, but largely to support later project aspects and phases, or to support change and optimization of the aspect or phase under consideration. Much of our attention has been separately focused on business structure (1)-(3), knowledge management (5), or software development (6)-(8).

However, there are clear examples of the potential utility of collaborative, emergent or backward flows, as well as the protections that may need to be applied.

New information in, or new inferences from, a partner knowledge base (5) can help in meeting customer requirements (7) or desires (10), or in improving product design (8). However, credit assignment for this information, and its use by the collaboration and by other partners remains an issue, especially when the knowledge must be integrated with knowledge available to other partners or developed by the collaboration to be useful.

Inadequacy in collaborative software engineering structures (6) may require changes in technical infrastructure (4), either for the collaboration or for individual partners, or in IT and communication support (3), or even in intellectual property policies and processes (1-2). Alternatively, the problem may be traced back to problems in sharing knowledge (5)—and perhaps again indirectly to intellectual property and security (1-3), or to inadequate development of abstractions, filters or views—a combination of (2, 3, 6).

Finally, as is well-known, information resulting from the design process (8) or the analysis or execution history of the application (9) can reveal flaws in security or confidentiality policies and processes, or be needed to tune or change risk management plans, affecting the business phases (1)-(3) and perhaps the technical infrastructure (4)-(5). But both the information and its analysis may require divulging the internals of software components or proprietary tools.

Figure 1. Aspects of Software Engineering

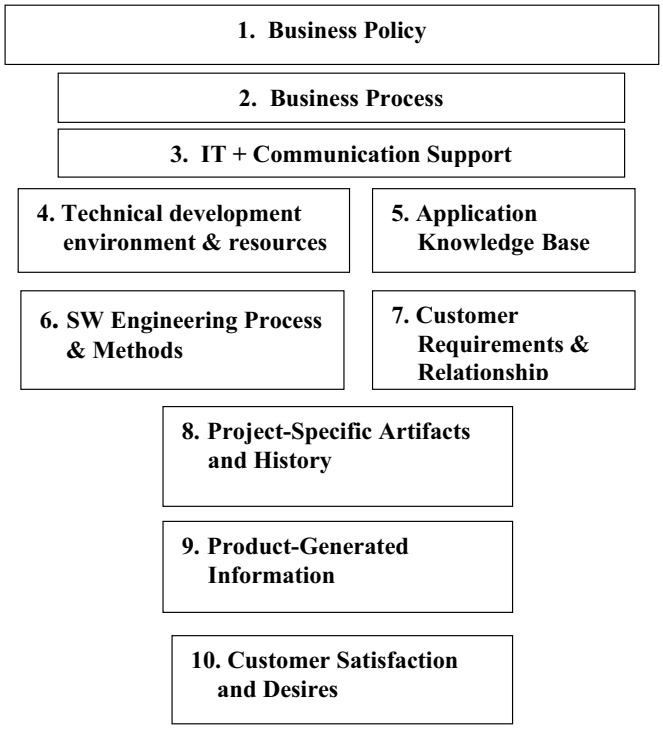
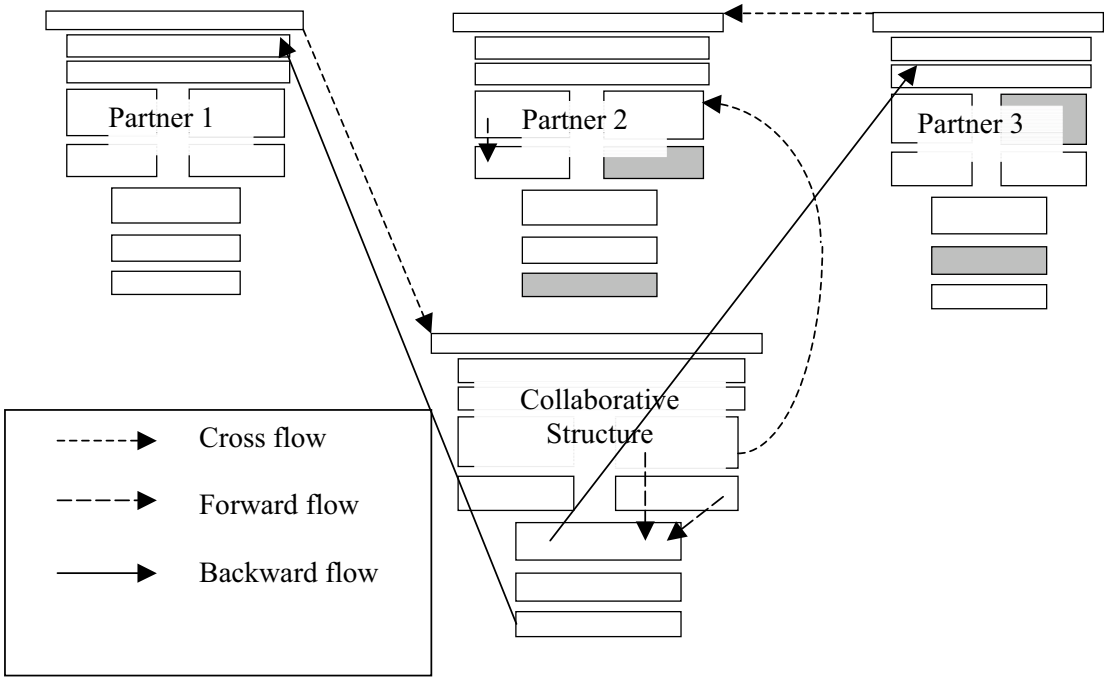


Figure 2. Aspects in Collaboration



5 Conclusions

ICSD, to a far greater extent than collaboration in general, will always be driven by the tension between the overwhelming need for shared knowledge in all phases and aspects of the corporate and technical process, and the need to protect legitimate security, intellectual property, confidentiality, and privacy interests, including those of third parties not involved in the collaboration. Although the risks are real, the benefits are substantial enough to encourage greater use of this fully collaborative mode of development.

However, sharing must be guarded, by filtering and abstracting transmitted knowledge, and by providing constraint views, while still communicating the necessary information. The ubiquity of integrated and emergent knowledge, and the utility of emergent and backward flows, argue that the harder the development project, and in particular, the greater the reliance on dynamic knowledge and product evolution, the greater the anticipation of and the need for filters, abstractions and views, an agreed-on scheme for credit allocation, and an approach for mediation and conflict resolution.

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Metrics Are Needed for Collaborative Software Development

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Abstract

There is a need for metrics for inter-organizational collaborative software development projects, encompassing management and technical concerns. In particular, metrics are needed that are aimed at the collaborative aspect itself, such as readiness for collaboration, the quality and or the costs and benefits of collaboration in a specific ongoing project. We suggest questions and directions for such metrics, spanning the full lifespan of a collaborative project, from considering the suitability of collaboration through evaluating ongoing projects to final evaluation of the collaboration.

Keywords: Collaboration, metrics, software engineering, ICSD, management contingency policies, risk management, intellectual property.

1 INTRODUCTION

Software engineering is essentially collaborative for any but the smallest and simplest projects. But the extent of collaboration has increased from multiple teams at a single site, to distributed teams in a single organization, to collaborating teams in multiple organizations. As collaboration broadens, and as projects become more complex and long-lived, it becomes ever more important to have management oversight, technical coordination and supervision, and quality control. But once the projects become too large for day-to-day personal contact, these command, control, coordination and communication (4-C) factors need to rely more and more on reports and metrics [1,8,9,21,24]—and, indeed, metrics have been created for every phase of software engineering and its management, for project, process and product, for the single-team, multi-team, and distributed models of development [2]. There are also metrics for knowledge management [22,23,24] and for communication [16], which assume far greater importance in a complex, long-lived and evolvable software development project [4,5,6,15]. However, there is little in the literature on metrics specifically devoted to collaboration.

As inter-organizational software development becomes more common [6,19,20,21], metrics need to be revised or created to support this mode of development. There are two major dimensions. First, as we discussed in [12], creating or modifying metrics for the standard criteria for software project, process and product: for example, measures of effort and time, of software quality, of process compliance, and of test coverage. Second, metrics aimed at the collaborative aspect itself, such as readiness for collaboration, the quality and or the costs and benefits of collaboration in a specific ongoing project.

In this submission, we concentrate on the second facet. We consider what metrics are needed, some difficulties, and some issues. We divide our metrics in two dimensions—staging (when are the metrics useful) and focus (corporate, infrastructure, people, project, process, product). It will of course also be useful to adjust the metrics to the type of collaboration anticipated—whether, for example, largely separate design of components for later integration or coordinated or complementary use (strategic collaboration), or coordinated development of a single product or product suite, interacting in every software engineering activity (tactical collaboration), or an intermediate form. We intend to address this issue, as well as propose metrics, in future work..

2 PRE-COLLABORATION METRICS

These divide into generic (ready for collaboration?) and specific (ready for this collaboration?) metrics. Generic metrics should consider the following issues [16].

- Corporate: Are we willing and ready to participate in a collaborative software development venture? A reasonable metric will combine survey data with a checklist of criteria. A survey of key personnel can establish support among management, IT department

heads, technical managers, and so on, as well as attitudes toward crediting employees for success in collaborative ventures. The checklist should include the degree to which policies, procedures and practices favor collaboration: in particular, intellectual property and information sharing, risk management, and knowledge management.

- Infrastructure: Is there a robust, multi-mode communication infrastructure in place? Are software engineering, risk management, and knowledge management processes, practices and tools amenable to collaboration? Which CMMI maturity level [3] is in-place in the organization, and has this been adapted for collaboration?
- People (human resources): Is there appropriate support for training and cultural sensitivity? Are there corporate and technical managers who will be willing and able to work with counterparts in other organizations?

Metrics aimed at specific projects and products should attempt to determine the appropriateness of the project and product for collaborative development, and (if possible) the appropriateness and quality of the proposed collaborators. The latter will definitely include evaluation of past relationships with other collaborators or their key personnel. It is also of course important that the project and product have clear and viable objectives, be a good strategic and tactical fit with institutional vision and mission, and have good agreement with partner experience and expertise.

Technical considerations include the following.

- How natural is the decomposition of this project into components? Are the boundaries relatively clear? Does the component decomposition fit with the expertise of the proposed partners?
- To the extent that components or interfaces are fuzzy, does the software process allow for any flexibility in interfaces?
- To the extent that innovation, novel interfaces, or use of scientific or technical information is part of the product, is there a provision for conferencing and meetings of domain or discipline experts?

In addition, we must be able to measure the willingness of the partners to establish required structures.

- Are the partners, and the collaboration as a whole, willing to create, maintain and support a shared technical infrastructure, including communication media and protocols, electronic and in-person meetings and consultations, shared tools and views, knowledge management, and risk management?
- Are the partners, and the collaboration as a whole, willing to create, maintain and support a management superstructure, both in the individual partners and collaboratively, to provide direction, support and championship?
- Will the collaborative agreement provide for reflection and evolution in collaborative structures and processes, and do such processes exist for individual partner structures, policies and processes?
- Are the partners, and the collaboration as a whole, willing to create, maintain and support methods for resolving ambiguities, conflicts and difficulties, whether technical, corporate, or legal?
- Is there a clear strategy and allocation of responsibility for marketing (or using) the product? Is there a clear allocation of responsibilities for maintenance and evolution (or a process for determining these)?

3 METRICS FOR ONGOING COLLABORATION

In addition to the standard (if modified) metrics, it will be important to have several other classes of metrics.

The first would measure the quality of the ongoing collaboration, complementing schedule and cost tracking with measurements of the clarity of interface specification (have problems arisen? Are they due to differences in language or culture?), risk management (have unanticipated collaborative risks emerged?), management cooperation, or problems with infrastructure? This would be itself complemented by ongoing measurements, assuring that the project and product continued to fit with strategic and mission objectives, and that collaborative and partner support structures were continuing to act and to function as required.

The second, interacting with risk management and knowledge management, aims at early detection of problems—which of course interacts with the first. These may arise from corporate, legal, or people issues in the collaboration, or from stresses and changes in the development process resulting from collaboration. In [7,10,13,14,17,18], we have identified a number of these stresses, and proposed a number of changes to project and process artifacts to support collaboration, good software engineering, and evolvable systems. It should be noted that significant stresses include the quality of both structures and processes for partner and collaborative risk management and knowledge management.

Third, in long-lived and knowledge-intensive projects, it will be necessary during the current project, and for the development and maintenance of trust in ongoing relationships, to be able to assign credit for knowledge and services provided by one partner to another, or to the collaboration as a whole, and costs for the use of others' knowledge and services. Even approximate measures of value will allow such metrics to be maintained.

Finally, it would be helpful, both during the collaboration and in post-project evaluation, to have a metric of the costs and benefits of collaboration, ideally a fine-grained metric so that different areas and forms of collaboration could be evaluated. During the collaborative process, such metrics could focus attention on problem areas, and perhaps indicate areas in which the task decomposition could be revisited. This would also have substantial benefits for future collaborations on similar projects, perhaps suggesting facets or attributes that might be best left in control of a single partner, or as an input on the decision to collaborate or use single-developer mode.

Also note that the quality and utility of these metrics depends both on their timeliness and the quality of data collected. Thus, in addition, a process and accompanying metrics will be needed to assure timely, consistent, and accurate data from each organization, and where relevant, from collaborative structures. As usual, this process will benefit from common or compatible approaches and tools for data gathering, storage and communication, data quality assessment, and so on.

4 POST-COLLABORATION METRICS

One class of post-project metrics will mirror pre-collaboration and/or mid-collaboration metrics. How well did a particular corporate facet or collaborative function perform (communication support, intellectual property control, risk management, etc.)? How well did the collaboration function, and what problems need to be addressed? Did project management and software process function as expected, or what should be changed?

A second class deals with the overall success of the project and the collaboration itself. The real questions that need to be answered are: Was the project a success? Did the product meet its functional and non-functional requirements? Did the project, process and product meet quality targets? Did collaboration help or hinder in meeting schedule and budget? And did the project and the product fulfill partner and collaborative business objectives?

If it was not a success, was the project worth trying? Was the collaboration a success? How did collaboration affect the success of the project? One tricky point is that some projects would never have been undertaken by any of the partners acting alone.

Finally, what have we learned? What changes are needed—in structures, artifacts, staging, or management? Are revisions needed in collaborative configuration and change management, risk management, knowledge management, or metrics and quality assurance themselves?

5 CONCLUSIONS

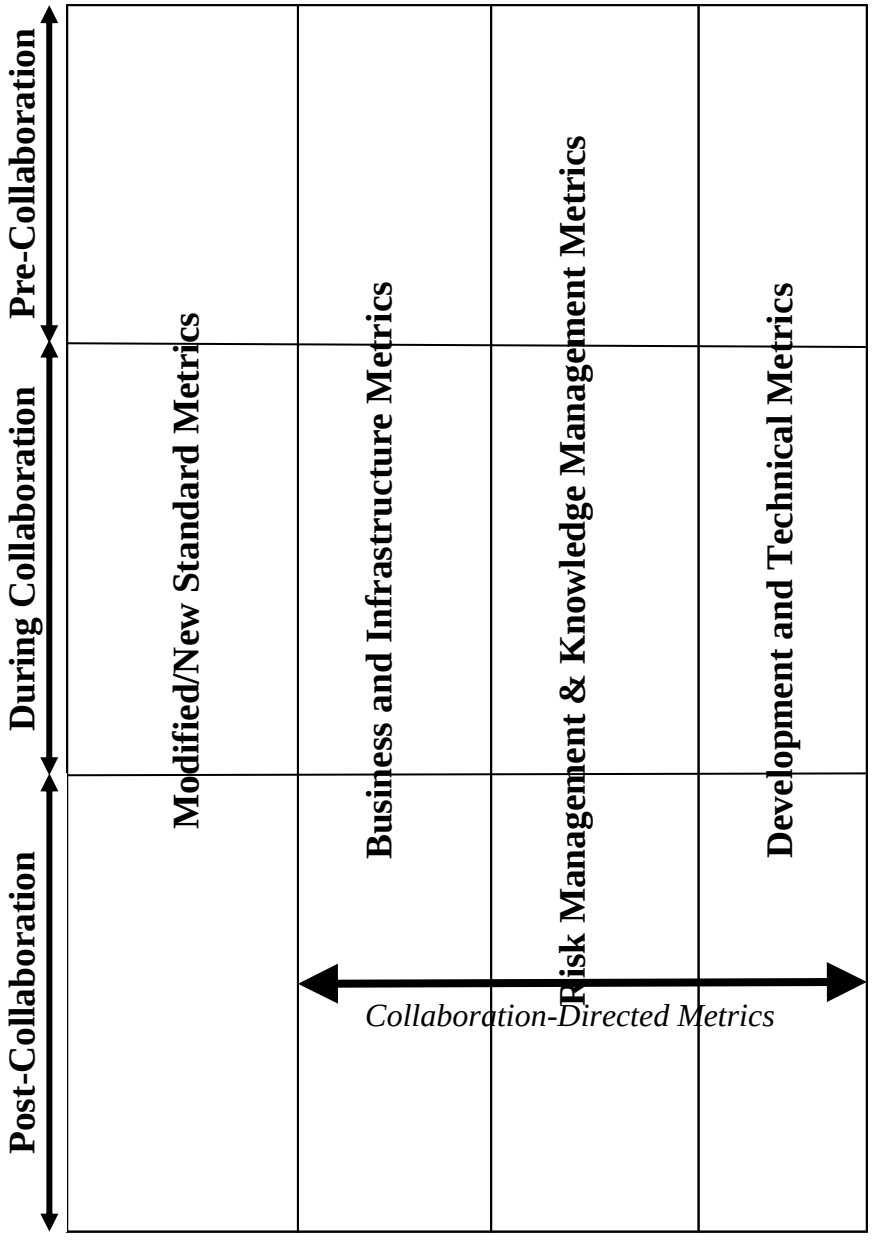
We have argued a need for metrics for collaborative software development, and in particular metrics aimed at the collaboration itself, and have considered many of the important questions that will have to be addressed by such metrics. See Figure 1 for an overview. Many but not all of these issues apply to collaboration in general. Future work will entail

- Developing metrics, via interviews, surveys, and case histories, and applying these to collaborative software development projects.
- Applying our approach to a broader range of inter-organizational collaboration on other technical projects.
- Integrating these metrics with new or revised versions of traditional metrics into a metric suite.
- Investigating interactions of these metrics, and their interaction with ongoing technical and business processes, with the aim of determining correlations as well as co-regulative negative and positive synergistic feedback/feedforward loops.

Acknowledgements

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Figure 1. Overview of Metrics for Inter-Organizational Collaboration



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Distributed Processes on Virtual Platforms: Designs of Effective and Innovative Collaboration Spaces

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Introduction

In this study we examine designs of virtual spaces from the point of view of participants' interactions and human centered processes. Virtual spaces have become extensions of modern organizations' physical space where thoughts are exchanged with an array of stakeholders and where traditional organizational structures are challenged. These new types of spaces and new ways of collaboration offer new opportunities for innovation and collaboration across time-zones and physical locations (e.g. Hippel, 2005).

Collaborative web technology has become ubiquitous. Today, about 2 billion people use the Internet (Nielsen Online, 2011). At the same time, as the number of users continues to grow the manner of use is changing. The initial approach to consuming Internet services – as passive recipients – is now changing to that of participation through the use of different types of Web 2.0 tools (e.g. Twitter, Facebook, Second Life). Web 2.0 is a category of Internet tools and technologies created around the idea that the people who access the Internet, and use the Web should not be passively constrained – absorbing what is offered – but rather, should be active contributors, helping to co-create content and customize tools for their own, their communities, and their organization's benefit. Web-based tools offer places to "meet" and collaborate with an array of people asynchronously and synchronously. Common to Web 2.0 tools is that they create virtual spaces and new collaborative structures that extend beyond the borders of physical space, time, and organizational arrangements. However, in a large part of the spaces created by these technologies, people do not interact creatively and effectively.

Our paper is based on observations of two distributed collaboration processes. The first case study is a distributed project team - a group of eight people, located around the world, working on a two month project. They are using PBworks wiki, Skype chat/voip, e-mails, and Google documents as their collaborative work space. The second case study is an online conference of about two hundred people that took place in an array of free asynchronous and synchronous Web-based platforms (for example Ning, Second Life, Twitter, Webex, Skype). Both cases are examples of collaborative virtual processes that were self-organized and effective, even though people working together came from different cultural backgrounds and most of them had not worked or did not previously know each other.

Thus, our research interest goes beyond the technological characteristics of the Web based tools to include the strategies of participatory interaction and the role of leadership behavior, whether embodied in one person or acted out by many, intermittently, to sustain the environment's attraction and productivity. We develop a set of propositions as a result of our exploratory, discovery-oriented research, that is, our systematic observations of the virtual encounters we study. In short, we elaborate on factors that create successful virtual collaboration spaces.

The relation of spaces and structures to innovation and effective collaboration

Certain spaces, places or environments are often reported to be more conducive to bringing about innovation and creativity than others (e.g. Bunnell & Coe, 2001). In a similar vein, organizational arrangements, structure, and locality are central to a number of economic theories and ideas that are at the core of much management thinking and theory relating to competitive advantage. Furthermore, writers such as Giddens (1990) and Castells (1996) argue that recent technological advances have created structures and connections that are no longer local, but global. In this regard new ways of using the Internet has resulted in wider information networks, which have not only led to new forms of organizational structures, but also provided enhanced possibilities for creativity and innovation (Hippel, 2005).

However, further studies on structures and knowledge transfer in the age of the "information economy" suggest that certain type of knowledge and ties do not transfer as easily as one might expect (e.g. Brown & Duguid, 2000). Critical information and knowledge both between, outside, and within firms *"can be accessed better or at lower cost within the cluster…"* (Porter, 2008: 232). One explanation is that finding and interpreting weak signals, and accessing knowledge about pioneering concepts relating to products and markets can be difficult through more non-local arrangement such as Internet connections. This is because, in general, tacit knowledge (Nonaka, 1994) and complex knowledge (knowledge that is difficult to codify (Storper, 2000) (e.g. feelings, culture, values) is difficult to transfer. Furthermore, as, Powell & Grodal (2005) posit, social ties found locally are important for innovation and entrepreneurial activities. As espoused by Porter (2008), local proximity supports complementarities between like businesses within the cluster, which serves to develop shared cultures and values. In terms of innovation, local proximity helps to discern trends, and to perceive need and opportunity. In terms of management of projects and project teams, local proximity gives control.

In summary, most research agrees that certain types of spaces, places, networks and organizational structures have the ability to catalyze innovation and create effective collaboration. Use of information technology is generally seen as creating new types of spaces, giving wider access to knowledge resources, and to lower the importance of geographical locations. However, literature suggests that more complex information and deeper personal ties do not transfer as readily using the new communication channels and that web based collaboration spaces may still not be as effective and innovative as physical spaces. Furthermore, distributed teams and distributed processes may be harder to manage.

We propose that collaborative spaces have been looked at in a simplistic way, and that the special advantages of the web environment, in terms of designing spaces and structures for effective and creative distributed human interaction, have not been studied sufficiently. In this paper, we have looked at two different settings of web based collaboration spaces, which both were designed to accommodate facilitated self-organized processes for people that had common goals or similar interests.

Research questions, case environments, and methodology

Research questions: This research contemplates, based on our two cases, on the human factors – participation and leadership-related – necessary to make virtual collaboration more than a distraction. Indeed, we ask: What are the characteristics of lively virtual collective spaces with potential for co-creation? Also, we look at how people co-create and manage in two different collaborative self-organized virtual spaces.

Case 1: Distributed project team. This team of eight people, who had never worked together before, wrote a major funding application in two

months time. They resided in Finland, US, Afghanistan, Nepal and Australia and also did some traveling during the project. The team did not have a single leader, but consisted of junior and senior professionals with different types of expertise. The team self-organized and each member was allowed to give tasks to each other. In practice, a junior grant writer gave most tasks in the project management tool, but after discussions with other members and also these tasks were constantly modified by all team members. According to the team's grant writing expert an undertaking of this kind usually would have taken about 6 months, however she had never worked in a team that was geographically so dispersed. The team had created a collaboration space by using PBworks wiki (for timelines, tasks, organizing, document sharing, and professional discussions), e-mail for reminders and one-on-one /few messages, and Google documents for co- creating their output. They used Skype voice over internet for one-on-one/few connections couple of times a week and Skype group chat for the entire group in daily communication. Professional co-creation and organizing of the work took place in Google documents and PBworks, but the shared Skype-based chat environment "Kitchen" provided an opportunity for casual interaction on sharing daily life, exchange of ideas, discussions on emergent issues. The Kitchen provided a place to not only tackle difficult problems, organize and coordinate activity (also across time-zones) but also celebrate successes along the way and as such, was of fundamental importance to the project. The other virtual spaces that supported collaborative work were more linear in their structures, and the interaction in the Kitchen was deemed by the participants to have been fundamental in building trust (by getting to know about participants daily life and personality), maintaining the motivation (by feeling how others were working hard and how each team member's work was appreciated), and the collective abilities to accomplish the task.
Data: All material and documents from all different virtual platforms are saved. Skype chat discussions from the two-month project are saved. Chat discussion text is our primary research data.

Case 2: Unconference. Our second source is based on observations from a case that, in a wide context, aimed to examine the use of Web-based tools as a means of facilitating the co-creation of innovation and collaboration within dispersed communities. In this respect we organized an unconference and explored a number of relevant themes. An unconference is a participant driven meeting of any number of people that are motivated by a common issue and where the meeting is self-organized without typical management hierarchies. Most unconferences follow a self-organizing management ethos, where very few rules create striking and efficient formations and effective work. Usually the term has been employed to describe such conferences in a physical environment, but our unconference was different in that it was a virtual event hosted through the use of Web-based tools.
The event was titled "Making the Most of Collaborative Worlds – Physical, Virtual and Blended Collaboration". Themes in the sessions varied; for example "Creating an innovation lab ecology", and questions such as, "How do we connect the world through creativity?" Our unconference attracted about 200 people from around the world co-creating and co-learning in 16 virtual sessions in an array of Web tools. Participants were professionals from different fields and backgrounds interested in collaboration: people employed by large and small companies, NGOs, international organizations as well as business consultants, facilitators, and entrepreneurs.
Data: With regard to data capture, the planning phase of the unconference was recorded on a wiki (a website that facilitates the development and editing of interlinked web pages on the Internet) and Skype chats. The unconference programme was recorded on a private social networking site (Ning) together with conference participant profiles. Most tools provide some record of the events and some automatically record all the interactions that took place and due to this capacity we are able reproduce

the situation exactly as it unfolded. To enhance this data some participants were interviewed. To date, six interviews have been conducted around the theme of innovation/collaboration, and Web-based tools. To ensure further depth, additional interviews are ongoing. Given the extent of the data sources an initial storyboard of the data was produced.

Operationalizing Virtual Participation and Leadership: We define participation in a virtual environment as any act of making oneself visible to the other participants in that shared space. Such acts are typically in written format as opinions, suggestions and questions. Occasionally these expressions are accompanied by an emoticon, to express a particularly strong feeling of frustration or joy. Humor is also often communicated by the corresponding emoticon. We have counted and calculated the different acts of contribution and classified them by type and source. We then examine these contributions systematically to look for patterns, in particular, instances where they have led to instances of the group creating new ideas or finding a solution.

Leadership is defined and operationalized as any act that seeks to establish order, offer guidance or help make sense of ongoing activity, organize activity, and/or provide motivation for and inspire others. It is thus a behavior that can be manifested by many as the project did not have a formal, appointed leaders per se. We have identified these instances and examine their nature as well as their occurrence in the particular virtual context. We also look for other roles that emerge. For example, someone might begin to act as the task master, the jester (Välikangas & Sevon, 2010) or the voice of conscience in the discussions.

Findings

Nature of a virtual project. In the case of the unconference, it became clear that certain freedoms are typical to virtual encounters that are not usually available in face-to-face meetings. In virtual situations, people can remain anonymous as to their legal identity and choose a certain (sometimes visual) representation (for example, an avatar). Furthermore, there is the potential to be (deliberately) engaged or detached from the interaction. Many participants, for example, multitask while being in virtual situations. In addition, in most virtual environments there is a certain protocol that needs to be followed to signal various intents of contribution. Furthermore, it is possible to have one-on-one communication even at the same time as a group discussion is going on. In the case of the distributed project team it became clear that virtual encounters are more than passing: they require persistence over time, the handling of complexity in the activities to be accomplished, and goal-orientation. People are held responsible for their actions as they are known entities. Or communication can be asynchronous and the time before giving personal input into a discussion can be used in checking facts, lobbying, coming up with ideas etc.

The emerging propositions. Based on our analysis, we present our preliminary findings by way of themes that lead to the formulation of a set of preliminary propositions pertaining to the nature of collaborative virtual work. These propositions address 1) the critical issues of creating and maintaining the virtual environment as a productive, helpful space in which to accomplish complex tasks; 2) the roles that contribute to such collaboration; 3) the leadership issues; 4) the meaning of absence in such environments; 5) informal vs. informal type (like celebration of successes) of contributions. Taken together, these propositions define the emergent understanding of how virtual shared environments can become productive, creative spaces for multiple participants across the world to accomplish complex activities together without knowing each other ahead of time. This is, admittedly, a difficult task and worthy of more research. Our study however makes an important step in systematically studying the interactions over time and drawing preliminary conclusions as to virtual behaviors and productive virtual spaces

Discussion and Conclusions

We believe there is a great need to research virtual spaces not only as technologies and tools but as significant environments for interaction (Orlikowski & Iacono, 2001, Orlikowski & Scott, 2008). This study takes the first step toward that direction, using as its empirical material two virtual collaboration cases that were successful in accomplishing their rather complex tasks with multiple people across the world. It can be argued that virtual environments have great potential in these kinds of work situations, which would otherwise be difficult to accomplish due to distance and large time differences. We thus believe that it is important to study how to design virtual spaces that empower the participants to work effectively and creatively.

We look at structures, cultures, practices, and the social and technological aspects in engaging in a distributed collaboration environment (see also Orlikowski, 2007). There have been very few studies on the practice of Web innovation in an everyday context. Frequently, little attention is paid to how Web-based practices differ from physical practices. In our study we found that people are able to use the environment to their advantage; the potental to be somewhat anonymous and fluidly move between sessions (sometimes while 'attending' multiple sessions), to go in and out of the meetings and become engaged (and disengaged) therein, leading to innovation through collaboration.

We found that some people (outsiders) not considered to be sufficiently connected to "innovative" by themselves are able to learn and thereafter innovate on concepts that are introduced in Web collaboration; albeit that these individuals may benefit from networks developed in physical space. This is important with regard to where people come from and the networks they belong to prior to taking part (and engaging) in a Web-based collaboration, their connectivity after such an event, and the environment in which they continue their innovative efforts (i.e. in virtual spaces) for benefits that may well accrue in their local environment. In this regard, in the case of "outsiders", a more facilitated collaboration situation created an environment in which they were more likely be engaged, and therefore contribute to co-creative efforts.

Overall, our examples look at how co-creation and co-learning communities can self-organize and create and restructure innovation networks and how self-organized leadership contributes to the success of this venture. Although the data requires deeper analysis, there is certainly evidence that the use of Web-based tools can foster innovation in virtual spaces, and the findings serve to challenge the broader notion that Web-based collaboration is not as effective as face-to-face collaboration.

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Socio-technical Systems for Connecting Social Knowledge and the Governance of Urban Action

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ABSTRACT

This paper seeks to expand our focus to understand how communities can assemble and manage knowledge to support more rational decisions regarding government services and actions in the community environment. We focus on the knowledge transfer interface between communities and urban councils, with a view to extending theoretical understanding of such transfers, and the socio-technical knowledge support systems interfacing between action groups and councils.

1. Introduction

In a world facing global warming and growing scarcities of water, power, mineral and food resources, there is reason to be concerned with the design and practicality of socio-technical systems for multi-level governance. These systems form the interface between people's urban systems and their physical environment. These are complex systems that are co-manage with constrained activities typical of urban and regional administrative juggernauts. The work is informed by several years' experience researching theory, technology and practice of building and managing tacit and explicit knowledge in hierarchically complex organizational systems. This paper discusses the trialing of Google Apps as knowledge management tools for community action groups creating links within, between and beyond groups and their networks with a view to understanding practical connectivity, crucial for sustainable social networked structures.

2. Background

Humanity's growing population makes ever increasing demands on limited resources of our planet that we need for survival, more and more people are moving into urban environments where their impacts on the world environment are greatest. Folke (2006) emphasizes that human societies with their interconnected economies rely on what are called ecosystem services and support for survival. According to Folke "a major challenge is to develop governance systems that make it possible to relate to

environmental assets in a fashion that secures their capacity to support societal development.... It will require adaptive forms of governance". Brondizio (et al. 2009) makes the case that such adaptive governance needs to be multilevel to build and maintain capital assets necessary to manage and sustain environmental affordances over time. Such capital assets are physical (i.e., built infrastructure), human (i.e., acquired knowledge and skills), and social ("value of institutions as a form of social capital formed through diverse processes involving the development of trust, norms of reciprocity, and networks of civic engagement, including the rules and laws within and between levels of organizations"). In the framework summarized by Brondizio et al's "social capital" is adaptive knowledge embodied in the connections and capabilities of multiple levels of organizational structure, i.e., what Nelson & Winter (1982) called "organizational tacit knowledge". Berkes (2009) makes many of the same points and stresses that multiple levels of social organization need a knowledge sharing framework that allows all levels to be rationally involved in "co-managing" the resources. The research discussed in this paper has been concerned with the analyzing and designing of knowledge sharing frameworks that would make co-management possible and effective.

3. Theoretical and Practical Framework

3.1 Framework Background

The theoretical and practical framework has emerged from an "invisible college" (Kuhn 1970) interested in the Theory, Ontology and Management of Organizational Knowledge (TOMOK). TOMOK's theory combines evolutionary epistemology and autopoiesis to understand knowledge in hierarchically complex (i.e., multilevel) systems. The project and case study frameworks, have to date, combined three major threads of TOMOK's work approach:

- *Theory*: e.g., Hall (2005; 2006) Hall (et al., 2005; Hall et al. 2007) Nousala and Hall (2008) Hall and Nousala (2010; 2010a) Nousala (2010) Vines (et al 2010).
- *Case study and practice*: (Nousala 2006; Nousala (et al. 2005; 2005a), Hall (2006a), Hall and Nousala (2007), Nousala & Tersiovski (2007), Nousala and Hall (2008), Nousala (et al., 2009), Hall (et al. 2009), Hall and Nousala (2010), Nousala (2010), Nousala (et al. 2010), Vines (et al. 2007;2010)
- *Technology implementation and practice*: Hall (2001; 2001a; 2003a 2006b, 2010a,), Hall (et al. 2002), Hall (et al. 2002a), Hall and Brouwers (2004), Hall (et al. 2010), Hall and Best (2010).

The research and projects focused on what interfaces were required between urban and regional governing bodies and community groups (where local community knowledge may be transferred and used by decision makers to produce better results). The work also focused on emergence and the roles of communities in generating and sharing tacit knowledge, and making it explicit within larger organizational structures. Finally, the research focused on the pragmatic design and implementation of collaborative authoring systems in hierarchically complex organizational environments.

3.2 Theoretical Framework Discussion

The Nobel laureate Herbert Simon (1947; 1979) argued administrators can never make perfectly rational decisions. Rationality is

bounded by cognitive limits on how much knowledge/information a mind can acquire, hold and process in the limited time available to make decisions. The best that can be done is to maximize the availability and quality of information to produce the knowledge needed and minimize overloading decisions with irrelevant information. However, it is the nature of administrative systems that decision makers are often hierarchically and geographically far removed from problem situations they manage. In other words, committees or individual administrators making decisions about local issues affecting people often have too little appropriate knowledge, and what they have is probably out of date and/or irrelevant. On the other hand, local inhabitants encounter problems directly and probably either have or can easily acquire the kind of detailed local knowledge for proposing solutions, which need to be incorporated to be effective. Unfortunately, existing bureaucratic systems provide few effective links between decision makers and sources of real-world knowledge they need to maximize the rationality and effectiveness of their decisions. Similar arguments can be made regarding the implementation of administrative decisions in the environment. With appropriate administrative support, local individuals could apply solutions, or at the very least be apart of the process.

3.3 Practical Frameworks Discussion

Past studies of various knowledge-based groups have been known as "communities of interest" or "communities of practice" and are found within larger organizations. In the urban or governmental domains such emergent communities are often known as "action groups". People in action groups have or can easily acquire significant amounts of personal knowledge and documentation relating to their areas of concern (Smith 2010; Smith and Nair 2010; Hocking and Wyatt 2010; Kuruppu 2010). Organizational knowledge managers need to work towards implementing social and technological systems that help collect, transform and make such knowledge available in usable forms for decision makers. The literature survey suggests that most research into relationships between government and community groups have had a top-down focus, i.e., where governments seek to push information (e.g., on health issues) into the community.

Another example of the nature of usability of pooled personal knowledge comes in the form of communities or action groups. In the field of cultural heritage, actions in the 80s and 90s utilized digitalization of artifacts as a method for preservation and transferring cultural information to the public and a multitude of interested groups. A decade later, and with the benefit of hindsight, more is understood, and its local knowledge and interaction that enhances these cultural collections that act as a focus for virtual communities of practice.

4. Field Work

The field work involved working with community action groups to identify the kinds of knowledge they were actually holding (Nousala and Jamsai Whyte 2010 Smith 2010, Smith and Nair 2010, Vines et al. 2010) and tested for utility of social technologies such as Google's cloud applications for community knowledge building and sharing (Hall 2010, Hall and Best 2010, Hall et al. 2010). This work followed experiences from 2007-2008 in building a knowledge base to support

reference literature and working drafts for the TOMOK group, using a collaboration platform known as BSCW (OrbiTeam's Basic System for Collaborative Working). The BSCW platform was abandoned due to hosting and server issues. In January 2010, following the announcement that Google Docs could manage all kinds of document file formats, TOMOK was subsequently successfully transferred. TOMOK's extensive knowledge base as a wiki using Google Apps, proved so successful that a subsequent trial (also successful) used the tools as a support system for a knowledge intensive community action group (Hall et al., 2010). The demonstration template (Hall and Best 2010) offered a range of capabilities to support community action: e.g., data collection with the capacity for imaging and geo-tagging, data aggregation, building knowledge bases from specific literature, collaborative authoring with document tracking capabilities, presentation development, social networking, membership management, financial tracking and the like.

5. What has been learned so far…

Urban councils and their delegates are responsible for providing services necessary for civil life, maintaining peoples' health and amenities. To do this functionaries need to know who, what, where, when, why and how-to relate to problem areas. Hall, Nousala and Best (2010) discuss epicyclic knowledge acquisition through building and acting in urban environments. Figure 1 shows the epicyclic knowledge concept built on from ideas from Hall (2003; 2005), Nousala (2006), Vines (et al 2007;2010) and Hall and Nousala (2010a). Figure 1 illustrates the theoretical application of the epicyclic knowledge framework to illustrate the acquisition, of building and acting in the urban environment. The knowledge related concepts in this paper have been informed by knowledge-based autopoietic systems at least three nested levels, highlighted by the discussion in the accompanying text of figure 1:

- *Individual people ("**I**").* When concerned about a problem individuals are motivated to collect explicit knowledge eg; documents, images, maps, records, etc building personal knowledge in the process. . This knowledge building may involve cycles of **O**bserving, **O**rienting, constructing **T**entative **T**heories, and acting to **E**liminate **E**rrors (Hall et al. 2010).

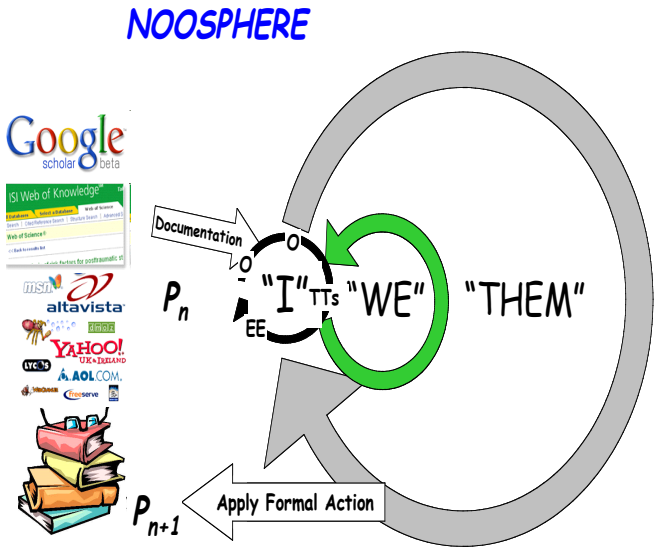


Figure 1. Knowledge cycles in urban governance (derived from Vines et al. 2010). Noosphere is the sum of human knowledge. Individuals, groups and councils all draw from and add to this store of knowledge as consequences of their activities.

- *Community action groups ("**WE**").* Where individuals in the community face similar problems, they may share concerns and knowledge to stimulate the emergence of a community group (Nousala and Hall 2008) to resolve the problem. Group knowledge building may involve sharing personal knowledge and building a group repository of documentation and observations. The success and sustainability

of the group will depend to a considerable degree on the success of the personal interactions in assembling useful knowledge and action plans (Hall et al 2010).

• *Councils ("**THEM**")*. Councils are complex bureaucracies, organized into departments responsible for problem areas. Decisions to formalize actions tend to be centralized, where the bounds to rational decision making are likely to be the greatest (Hall et al. 2009). Committees or officers making decisions often have little or no personal knowledge of specific problems. Groups close to the problems can play important roles by collecting, organizing and presenting their collective knowledge in formats easily used by functionaries (Hall et al. 2010).

Noosphere described by Krippendorff (1986) as the space occupied by the totality of information and human knowledge collectively available to man. As discussed by Hall (et al 2010) the concept of Noosphere initially emerged from discussions between Valadimir Vernadsky (who also coined the term "biosphere"), Teilhard de Chardin, and Edouard Le Roy. Hall (et al 2010) goes on to discuss how Turner (2005) reviewed to enhance the concept in such a way so as to make it possible to employ it in figure 1, meaning "..the noosphere is the net product of the global diversity of knowledge ecologies…" (Hall et al 2010).

6. Conclusion

Surveying of the literature shows that social technology has most frequently been used to push information from higher-level governance into the community. Very few works were found that demonstrated the social technologies gathering and communication information to higher levels of governance. This included the lack of involvement of community groups in areas of governance that affect them directly. Based on experience to date, the freely available Google Apps have offered a platform for directly interfacing community action into the processes of urban governance.

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A Cooperation Model Applied in a Kindergarten

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ABSTRACT

The need for collaboration in a global world has become a key factor for success for many organizations and individuals. However in several regions and organizations in the world, it has not happened yet. One of the settings where major obstacles occur for collaboration is in the business arena, mainly because of competitive beliefs that cooperation could hurt profitability. We have found such behavior in a wide variety of countries, in advanced and developing economies. Such cultural behaviors or traits characterized entrepreneurs by working in isolation, avoiding the possibilities of building clusters to promote regional development. The needs to improve the essential abilities that conforms cooperation are evident. It is also very difficult to change such conduct with adults. So we decided to work with children to prepare future generations to live in a cooperative world, so badly hit by greed and individualism nowadays. We have validated that working with children at an early age improves such behavior. This paper develops a model to enhance the essential abilities in order to improve cooperation. The model has been validated by applying it at a kindergarten school.

Keywords: cooperation, model, collaboration, essential abilities, interactions.

1. INTRODUCTION

The state of Puebla is a region where some industries have flourished in the past like the textile and rustic furniture. However due to globalization and world competition many textile mills and furniture factories have closed leaving many people unemployed and the regional economy has come down.

The creation of clusters in a region has been extensively validated [1] as a strategy to successfully transcend globally. However this implies for many organizations to compete but at the same time working together, sharing objectives, knowledge, information, and resources, collaborating intensively with related and supporting organizations, which have to do with cooperation. We have been working with different clusters trying to promote collaboration as a natural tendency on adults.

However it is been very difficult to infuse such virtue in their DNA. It is not difficult to conceive that children could have an easier tendency to collaborate with their peers. This could be achieved if they are motivated appropriately to respond more naturally to the virtue of cooperation.

2. DIAGNOSIS

We found that a cooperative behavior is absent in the majority of the firms in the region of Puebla, México. One of the consequences has been the foreclosure of most textile and furniture firms and also because of the lack of innovation and creation of clusters.

Based on questionnaires applied to business consultants we found that even though there is some evidence of improvement in the entrepreneur's cooperative behavior, they tend to work individually and in isolation. Entrepreneurs need to learn to cooperate in a global world, where a national and international cultural competence is necessary for survival.

3. STRATEGY

We usually understand and comprehend the world and the people around us through education. Based on the theory of constructivism which states that knowledge is built on previous experiences, it is very difficult to change the way of thinking and behavior of an adult. That is why it was decided to evaluate a strategic shift in the way most adults were educated, by developing the abilities of cooperation in children where mental structures are under development. These essential abilities are described next within the context of a cooperative model developed as a framework for this research work.

4. MODEL FOUNDATION

To search for the essential abilities for cooperation, a simple definition of cooperation is proposed here as working together having the same objective, measuring its performance as a collective achievement rather than the traditional individual performance evaluation criteria.

4.1 The essence of the human being

Studies of the human brain for practical purposes have been typically divided in two parts, the emotional and the rational hemispheres. The emotional part deals with sensations and feelings and responds to stimulus instantaneously.

People with the ability to control and handle emotions, but at the same time understanding the emotions of others have more possibilities to live a plain full life. The physiologist Savory considers that emotional intelligence consists of five domains: "knowing your emotions (self awareness), managing your own emotions (self-mastery), motivating yourself (motivation), recognizing and understanding other people's emotions

(empathy), and managing relationships (social abilities)" [2].

The rational or cognitive side of the brain analyzes the stimulus to comprehend the events giving them meaning and finding conclusions. It is intriguing that many organizations do not relate with other institutions because they don't trust them mainly because they do not want competitors to know their strategy and the way they manage their business. This comes from a deformation of the concept of competition. Competition in Latin literally means consensus, not beating others as understood nowadays. There is even a common saying in some Latin-American economies, "if you do not cheat you do not progress". Cheating could provide a short term success in some cases, but not a long term one. This entrepreneurial reasoning must change.

When economic transactions are performed with truth, meaning transparency, responsibility, honesty and justice, an environment of confidence, communication and dialog is created. As a result, love and affection arises, creating a sense of community, where transactions become distributive instead of commutative where reciprocity and solidarity are present to create a reinforcing environment.
Pope Benedictus XVI [3].states that "The essence of a human being is the perception of an interior impulse to love in a truth way. Love and truth never abandon us completely because they are the calling that God has put in our hearts"

4.2 Relationship with others
Some conditions in organizations that foster cooperation are presented next. In regions or countries where clusters of organizations are present, there are continuous and direct interactions amongst members, building strong linkages. The more frequent the communication and information sharing the better for the advancement of the cluster, which translates into better understanding of each other´s culture, technical language, and face to face contacts, building knowledge which is the basis for innovation [4].

The direct observation of processes and products enrich the creation of knowledge [5]. There must be trust between the parts because of the important information that flows in transactions. For instance, a superior example of cooperation is in place at the Mondragon Cooperative System in the north of Spain [6]. The root of their success is based on the idea of sharing, cooperation, caring for others having "love" as the center of the society. They started with an education program based on trust, collaboration and moral values. The philosophy of the economic activity is based in the concept of "equilibrium", which translates as equilibrium, having the purpose of promoting unity in the diversity in a society. It has three characteristics:

1. Identify the importance of the person and the group.
2. Allowing the existence of different responsibility levels according to capabilities.
3. Considering what it is called "opportunity", meaning placing the events in the present. There is a limit in the size of the organization for the benefits of personal relationships, intimacy, confidence and better communication.

4.3 Education
Communication is the condition which makes education possible. Education presents two complementary aspects, one related with the transmission of information and knowledge, and the other with the interactions of the actors of the process. The foundation of Constructivism is based on the social interactions and the intelligence built around it [7]. According with this perspective the particular worth of a human being is not the capacity to understand the world, but by the constant interpretation of the minds of others manifested by different forms, such as in words, actions, and developments among others. Such capacity let us learn from others and understand our own mind. Constructivism is the predecessor of the cooperative learning [8].

Five elements are required for cooperative learning [3]:

1. Positive interdependence. That means the need to work together.
2. Individual and group responsibility. The group members have common objectives and each member assumes its responsibility.
3. Stimulate interactions.
4. The members of the group have the personal and team abilities required.
5. Group evaluation rather than individual [9].

5. MODEL DEFINITION

The framework for this research is represented by a model that consists of seven modules. The first module of the model is called "Vocation", meaning the natural tendency, the reason for the existence of something, the inspiration to follow. The authors believe that there is an intrinsic and continuous search of our vocation. We could say, that in a supportive environment, a vocation is supported by the creator's need to work together.

The second module is defined as the "Values" component. Values represent the foundation and the base of behavior of individuals and groups. They are the guidance and orientation of any process activity, describing the behavior of each person and the relationship with others.

The "Organization" element is the third module of the framework for cooperation. It represents the setting where the actors perform, where the vocation and values of the people take action. It is the environment that influences the interactions and their performance. It is desirable to promote collaboration across the entire organization in order to achieve better results.

The fourth module reflects "The Success Factors" of the cooperative model. They represent the key elements that guarantee the cooperation across individuals and organizations. The main success factors have been grouped in two different levels for the purpose of this research.

The first level includes seven factors:

1. Common objectives
2. Principles and rules
3. Common language.
4. Frequent interactions
5. Trust environment
6. Well defined roles
7. Innovativeness

The second level of success factors of importance
Have to do with the operationalization of the model and include:

1. Balance of interests and needs
2. Common technology
3. Limited group size
4. Training
5. Change adaptation

The sixth module of the model is comprised of "Performance Indices" with respect to a) human capital, b) profitability and return on investment, c) Innovation and d) growth. The framework can be adapted to any environment to enhance collaboration. For the specific application of the framework to the kindergarten case, the only indexes used pertain to human capital, as one would expect.

The Community module the seventh module and represents the surrounding environment of the organization. It has to do with people and their culture, believes, values, habits, education, and authorities. For the kindergarten case, the community relates to the families of the school children**.**

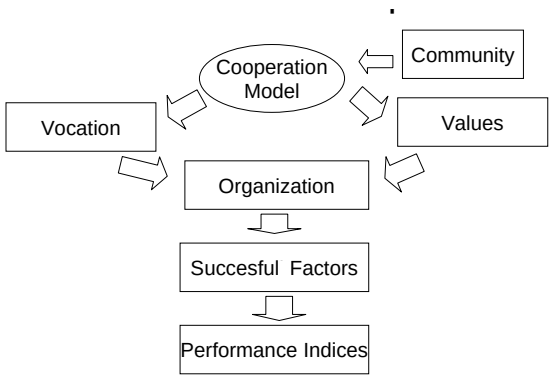


Figure 1. General Model for Cooperation

6. ESSENTIAL ABILITIES

One of the key elements required for cooperative learning according to Johnson and Johnson [4], refers to a disposition of the group members to cooperate. That means, that they have the personal and team abilities required for collaboration. These could be intrinsic to the individual due to cultural heritage or developed by each person as part of the evolution in the pursuit for cooperation to accomplish any vocation.

These abilities has to do with getting along, solving differences, taking decisions, respecting and serving others as we would like ourselves to be treated. With respect to an individual and from the emotional intelligence perspective, we focus in four domains: self awareness, self-mastery, empathy and social abilities.
The cognitive ability is another important one related with the capacity to understand and to learn the need to cooperate, as well as its advantages. The last ability is comprehensive, and is called the ability of cooperation and has to do with generosity, the ability to give unconditionally, as Mother Theresa used to call it.

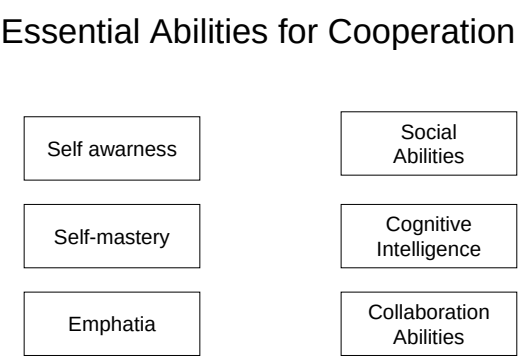


Figure 2. Essential Abilities

7. APPLICATION OF THE MODEL

The cooperation model was applied in a kindergarten mainly because their vocation and values are in line with our definition of cooperation. So we decided to work with children to prepare future generations to live in a cooperative world.

The Public Secretary of Education in México (SEP) created the Educational Program for Kindergartens in 2004, which is based on competences, such as knowledge, skills, attitudes, social abilities, and values that children acquire through the learning process, evaluating the performance under different circumstances.

Even though collaboration is mentioned in the fundamental purposes of the SEP program which are the essence for the development of competencies list, collaboration itself as a competence is not in the list. We propose to include specifically to learn to work in collaboration, as one of the competences in the field of Personal and Social Growing in the aspect of interpersonal relationships.

7.1 Development fields

According to SEP [6], there are six development fields where these capacities need to grow:

1. Personal and social growing.
2. Language and communication.
3. Mathematical thinking.
4. Knowledge and exploration of the world.
5. Artistic expression and appreciation.
6. Physical development and health. [10].

The same way medical doctors use a treatment to cure a patient; we decided to carry out a comprehensive treatment to improve the essential abilities to enhance cooperation. The treatment consists of applying didactic situations in the six development fields just mentioned.

For each didactic situation a standard format was used to facilitate processing of the information. The format included the name of the didactic situation, its purpose, the capacities to develop, the development field, the didactic sequence, aspects to evaluate, aspects to think about and materials to use.

7.2 Guidance of the application of the didactic situation.
The following section provides guidance for the application of each didactic activity.

Name of the didactic situation. The teacher asks students how much idea they have about the subject. The objective is to create an environment of trust and a common language.

Purpose. The teacher explains the main purpose of the activity, with common objectives and instructions.

Didactic Sequence.
1st Step. Definition of teams and roles (states the rules, establish the responsibilities, balance of interests, size of the teams).
To define the teams we used the Puzzle Aronson Technique [7].
2nd Step. Preparation of material (creativity and innovation).
3rd Step. Doing the activity (confident environment, frequent interactions, adjustment to change, and innovation).
4th Step. The teacher asks questions about the points to think about.
5th Step. Knowledge building (Create a drawing representing the activity just developed. Put it in a wall of the classroom together with the other didactic activities).

8. EXAMPLES OF DIDACTIC ACTIVITIES

The main purpose of the activities is to promote the spirit of collaboration. Some of the activities designed for this research are:

- Knowing my team
- Let´s go buying
- The hospital of collaboration
- Using wastes
- Travel to the universe
- Play fair
- The great firemen team

Each activity is evaluated in general terms using a standard format represented in Figure 3. Each student is evaluated using the format shown in Figure 4. The activities have been validated with experts in childhood education and pedagogy, as well as by the principal and teachers of the school.

Date:

NAME DIDACTIC ACTIVITY _____

TEACHER: _____

SUCCESFULL FACTOR:

	THEY WERE PRESENT
COMMON OBJECTIVES:	YES__ NO__ SOME (explain)_____
PRINCIPLES AND RULES:	YES__ NO__ SOME (explain)_____
COMMON LENGUAJE:	YES__ NO__ SOME (explain)_____
FRECUENT INTERACTIONS	YES__ NO__ SOME (explain)_____
ENVIRONMENT OF CONFIDENCE	YES__ NO__ SOME (explain)_____
WELL DIFINED ROLES	YES__ NO__ SOME (explain)_____
INNOVATION	YES__ NO__ SOME (explain)_____
BALANCE OF INTERESTS AND NEEDS	YES__ NO__ SOME (explain)_____
LIMITED SIZE	YES__ NO__ SOME (explain)_____
TRAINNING	YES__ NO__ SOME (explain)_____
COMMON TECHNOLOGY (KNOWLEGE FORUM)	YES__ NO__ SOME (explain)_____
CHANGE ADJUSTMENT	YES__ NO__ SOME (explain)_____

Figure 3. General Didactic Activity Evaluation Form

FORMAT TO EVALUATE
A STUDENT IN ONE ACTIVITY

- DATE:_____
- STUDENT NAME:_____
- DIDACTIC ACTIVITY _____
- Scale technique:
- Scale of Likert:
  - 1=I Totally disagree
  - 2= I disagree
  - 3=I am Indifferent
  - 4=I agree
  - 5=I Totally agree
- SELF AWARNESS: :___:___:___:___:___:
  1 2 3 4 5
- SELF-MASTERY: :___:___:___:___:___:
  1 2 3 4 5
- EMPHATIA: :___:___:___:___:___:
  1 2 3 4 5
- SOCIAL ABILITIES: :___:___:___:___:___:
  1 2 3 4 5
- COGNITIVE INTELLIGENCE: :___:___:___:___:___:
  1 2 3 4 5
- COLLABORATION ABILITY: :___:___:___:___:___:
  1 2 3 4 5

Figure 4. Student Activity Evaluation form

9. PRELIMINARY RESULTS

A small kindergarten was selected as our research laboratory. Teachers follow a closed companionship with their students. The successful factors of the cooperation model mentioned in the Section 5 are present in general in all the activities developed during the school day. The teacher was trained in the application of the didactic activities and in the use of the evaluation forms. A group of seven children between four and five years old was chosen to implement the research. At such age, children already have self awareness.

A social map was created with the teacher before applying the model, relating each student with the rest of the group. The social map will be revised at the end of the year to evaluate the performance of the group and of each student.

Student	Self mastery	Self awareness	Empathy	Social ability	Cognitive intelligence	Cooperation abilities
1	=	=	+	=	=	+
2	+	+	+	+	+	+
3	=	=	=	+	+	+
4	+	+	+	+	+	+
5	=	=	=	+	=	=
6	=	+	=	+	+	=
7	+	+	=	+	+	=
TREND	=	+	=	+	+	+

Figure 5. Preliminary Results

After the application of seven didactic activities the tendency of two of the essential abilities (self awareness and empathy) have remain equal, but four have improved considerably in several children (Self mastery, social abilities, cognitive intelligence, and cooperation abilities). We will keep working with this kindergarten to search for the improvement of all essential abilities.

10 CONCLUSIONS

We firmly believe that cooperation, collaboration and sharing are basic values that need to be present in society if we wish for this world to change for the well being of humanity. The efforts of several organizations to reverse the trend of individualism and selfishness are promising. We are excited about the preliminary results with children and we are in the process of establishing a similar construct for higher levels of education.

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A Ubiquitous Enterprise Performance Management Model for Performance Centered Business Activity

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ABSTRACT

Wireless technology has truly changed people's way of doing today's business, both for individuals and companies. Applying wireless technology to the core information system like ERP system can bring ubiquitous benefits to companies. Meanwhile, the significance of integrating ERP system with business intelligence (BI) has come to more and more people's realization because it can help companies shorten the life cycle of data-to-knowledge, which is essential to decision-making. In order to capture the benefits of "mobility" and improve the timeliness of decision-making support, it is necessary and important for companies to incorporate the wireless application and BI integration to an ERP system. In this paper, we focus on how to apply the wireless technology to the ERP system and address the problem of integrating the BI as well. Based on the current ERP system, we proposed a model of Ubiquitous Enterprise Performance Management (U-EPM) system, which is expected not only to streamline the process of mobile business performance management, but also help companies to achieve better effectiveness and efficiency in doing business activities.

Keywords: Ubiquity, Business Intelligence, Business Process Management, Enterprise Performance Management, Mobile Business Performance Management

1. INTRODUCTION

Nowadays, ERP system has been widely used in companies to manage their business processes. However, few of them can achieve the full benefits from ERP system. On the one hand, companies are not organized in such a way to benefit from the new information tools provided by, and the new disciplines required of, the enterprise systems [1], and on the other hand, the ERP system has its own deficiencies, such as lack of flexibility, limitations in accessibility, disorderliness of data delivery, etc. Meanwhile, there are many technique solutions could be applied to extending the current ERP system [2]. On the one hand, wireless applications provide new opportunities for companies to equip their ERP systems with "mobility" so that users can access and manage the ERP system ubiquitously, which can meet the customers' needs of ubiquity better as well as improve the efficiency of business management [3]. On the other hand, to maximize the utilization of data in the ERP databases, it is significant to integrate the ERP system with BI, which can process the "redundant" data in ERP system to knowledge for decision-making support [4]. By adding the "mobility" and "BI" to an ERP system, not only the accessing and operating of ERP system could be ubiquitous, but also the redundant data processing in ERP databases would be eliminated. Moreover, a real-time decision-making support provided by BI analysis could be achieved. Therefore, the efficiency and effectiveness of the whole enterprise performance management inside a company could be improved significantly. Thus we are trying to identify some distinct characteristics of such a system as below:

- Ubiquity: by application of the wireless technology, users can login the system in anywhere and anytime, which meets the demands of mobile business.
- Intensiveness: since the BI can process data from the ERP system to generate KPIs and metrics analysis that feed reports or dashboards for decision-making support, the ERP system could be intensified by the BI integration.
- Instantaneousness: for the time being, the business environment is changing faster than ever before. By shortening the life cycle of data-to-knowledge and instant delivering, the real-time decision-making support can be achieved, which can help companies to have the ability of quick even instant response to the changing market.

The contributions of our paper are outlined as follows:

- We propose the model of ubiquitous enterprise performance management (U-EPM) to capture the mobility and business intelligence for an ERP system.
- We illustrate the differentiated functions of U-EPM with specific scenarios analysis.

- We propose an evaluate model, and apply it to compare U-EPM with the SAP mobile, BPM, and BPA system.

Thus, a brief review of related works is given in section 2, and in section 3 we sketch a general model of U-EPM and illustrate the components. Some specific scenarios are given in section 4, and in section 5, we compared it with SAP Mobile, BPM and BPA. Finally, in section 6 we draw the conclusions and provide possible future directions.

2. RELATED WORK

With the notion of extending the current ERP system by the wireless technology and business intelligence, the related researches could be mainly divided into two areas, one is applying the wireless technology to the business management systems based on the ERP system, and the other is developing the BI system with the combination of ERP system to provide timely decision-making support.

A. *Moible Business Information System*

With the rapid development of wireless technology, many ERP system researchers have focused on the possibility of applying wireless technology to the ERP system or the business management system based on the ERP system. with wireless applications. Dabkowski and Jankowska [3] have developed a multi-tier framework for mobilizing ERP system, which can realize the real-time data transmission between the ERP system and a variety of wireless devices. Alternatively, Massoth and Paulus [5] have proposed a real-time sales operation and inventory management system for ERP system on the platform of BlackBerry. A mobile E-business system is designed by Zheng et al. [6], which is based on open source software to deal with the end-to-end security problem.

Utilizing the mobilized business management system can bring the benefits of ubiquity to companies, which can meet the customers' requirements of mobility better and improve the efficiency of management inside. A research by Willis and Brown [2] indicates that mobile ERP system can help solve the problem of data capture and improve the effectiveness of business activities. A further work is done by Rodina et al. [7], which indicates that real-time knowledge of the market, sales and customer specific information could help the company shorten sales cycle, reduce cost, improve customer satisfaction, increase competitive advantage and productivity, increase revenues, and improve personnel support.

B. *BI system*

Through recent years, many BI researchers have focused on the architectures of developing BI, e.g., Data Warehouse Bus Architecture [8], Corporate Information Factory [9], Data Warehouse 2.0 [10], etc. Besides, there are many tools to support these architectures, such as data warehouses [11], online analytical processing (OLAP) [12], data mining [13], etc. Beyond data warehouse, Golfarelli et al. [4] introduce business process management (BPM), which is a new approach that can quantify the enterprise strategy and targets, in order to decentralize decision making for BI. After the business process management system (BPMS), a business process analytics (BPA) is proposed by Muehlen and Shapiro [14] in a recent research, which introduces the concept of BPA and discusses three kinds of processes (first historical analytics, then real-time analytics, and finally forward-looking analytics) in BPA.

3. MODEL DESIGN

A. *Conceptual Model*

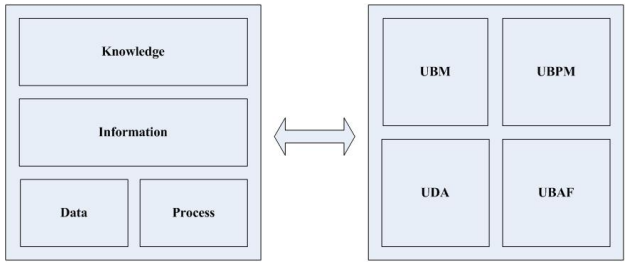


Figure 1. The conceptual model of U-EPM

The conceptual model of our proposed ubiquitous enterprise performance management (U-EPM) is presented as Fig. 1. The left part is the data-to-knowledge cycle inside a company, which acts as the data source for different U-EPM functions. The right part is the functional modules including UDA, UBAF, UBPM and UBM. The four functional modules and their relationship with data sources are illustrated as follows:

- Ubiquitous data accessing (UDA) – Data & Information: it is going to provide the function of accessing data via ubiquitous techniques so that the latest and timely information could be provided to users. The related sources are information and data of the organization to UDA.
- Ubiquitous business activity facilitation (UBAF) – Information & Process: it enables the business activities ubiquitously, thus the users' work efficiency can be improved. The corresponding sources for UBAF are information and process.
- Ubiquitous business process management (UBPM) – Information & Knowledge: it is focused on conducting BPM in real-time in order to help decision-makers. UBPM cares on knowledge and information sources.
- Ubiquitous business monitoring (UBM) – Information & Knowledge: it is mainly responsible for monitoring key processes to manage risks and ensure coherence of the business. So the UBM is based on sources of information and knowledge as well.

B. *System Model*

By considering traditional ERP, BI systems and existing ubiquitous technologies, we propose a four-layer model of ubiquitous enterprise performance management (U-EPM) system and presented it as follows.

Data Management layer: data sources are consisted of data from the ERP system and other data, which are required by BI analysis. To manage them more efficiently, they are stored in a center database system. Data tools, including data extractor and processor are used for real-time data extraction and preprocess from the database.

Performance management layer: it aims to manage the performance more efficiently and it is consisted of three components, which are BI analytics platform, business monitoring center and business activity invoker (BAI).

- *BI analytics platform:* its main function is performing BI analysis for business process management (BPM) and it contains four tools, which are the Data warehouse, OLAP

analytic cubes, data mining engine, and rule engine. The *Data warehouse* is used for storing the processed data by some real-time data processing tool or directly extracted from the database, and providing the right data according to the requests of the BI analytics platform. *The OLAP analytic cubes*, which extend two dimensional data structure to a multidimensional data model, can support viewing and analyzing data from various perspectives. The *data mining engine* aims at performing data mining algorithms according to different requirements. The *rule engine*'s role is further processing the timely results from data mining engine and delivering them to users.

- *Business monitoring center:* its functions are not only monitoring some sensitive business processes (e.g., inventory, cash flows, etc.) but also examining results from the BI analytics platform. The center divides potential dangerous warning into several levels. A warning message will be sent to corresponding users in low level of warning while some functional modules will be locked in high level warning are activated.
- *Business activity invoker:* it is mainly responsible for involving the business activity in functional modules of ERP system. That is, the BAI allows valid users to access to the ERP system and conduct corresponding business activities throughout a wireless terminal.

Access control layer: it contains two parts, one is the *Authentication agent*, which can be implemented by some existing security techniques (e.g., face recognition, fingerprint recognition, etc.) to authenticate valid users, the other is *Access control server*, which aims at authority management so that suitable authorization are providing based on different roles.

Interface layer: the interface can be compatible with various terminals such as PDA, Smartphone in order to support multi-channel access.

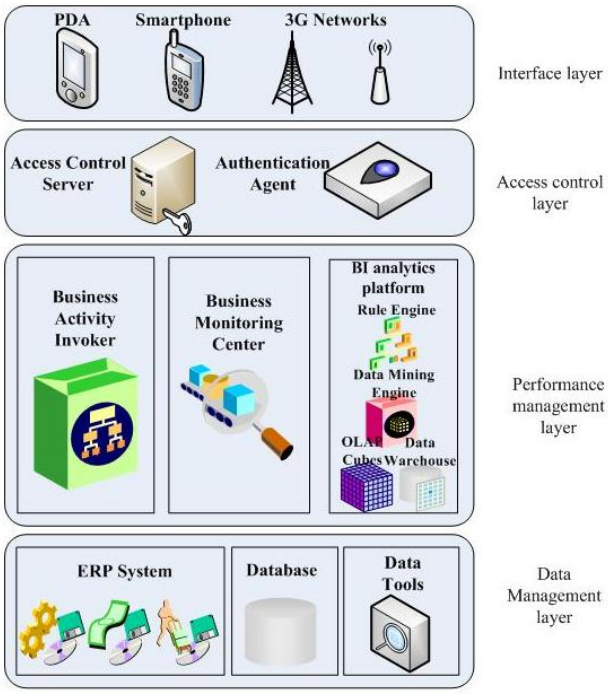


Figure 2. The model of U-EPM

4. SCENARIO ANALYSIS

In this section, we conduct some scenarios analysis in order to demonstrate how the four modules of conceptual model of U-EPM to enhance and improve the performance management of the enterprise.

A. *Scenario 1 (UBAF)*

Enabling the business activities ubiquitously can improve the efficiency of users' workings as well as achieve better customer satisfaction. Suppose that a sales manager is having a negotiation with the customers, and they come to an agreement that if the customer makes orders at once, he would get a discount. However, the orders contained the discount information which related to the pricing or promotion programs in the company's ERP system can not be operated flexibly because they are tied to the financial accounts. So these orders couldn't be accepted immediately by ERP system, unless someone modifies the pricing or promotion program modules to meet the customers' requirements. With the U-EPM system, however, the sales manager can login to the system via his 3Gs equipped PDA or Smartphone, and access to the related functional modules in ERP system by activating the business activity invoker, then he can make the orders contained pricing or promotion information for his customers directly.

B. *Scenario 2 (UDA)*

Providing the newest and timely information can support users' business activities better. For instance, when a sales representative meets his customers outside the company and the customers want to know more information about the product and have the intention of ordering, then the sales representative is likely to have the needs of checking some information (e.g., inventory, price, etc.) of the products to make sure that whether it can meet the requirements or not. After login to U-EPM system with his 3Gs equipped PDA or Smartphone, he can just access to the newest information by one or two easy clicks.

C. *Scenario 3 (UBPM)*

Conducting BPM in real-time can help decision-makers save time in decision-making, which is very important to business as time is money. For example, a company's CEO maybe has the possibility to get a bad news that one of the key customers is going to cease the cooperation with the company because of a lower price offered by another competitor company in the market when he is on business travel, normally he'll stop the travel and go straight to the company, convene a management board meeting to work out a solution and negotiate with the customer to persuade him to continue the cooperation by offering a new price or other benefits to him. The processes above may take a couple of days and when the CEO calls the customer's number to negotiate with him at last, the best time might be missed. With U-EPM system, the company's CEO needn't go back to his company first. Instead, he can login to U-EPM system by his personal wireless devices (e.g., PDA, Smartphone, etc) as soon as he gets the news, and access to the data/information related to the customer's order, then he can use the BI analytic platform to generate a forecasting report about the impacts on the sales revenue if the company lost such a customer and calculate the marginal profit of the product with the purpose to identify the lowest price his company can offer. So the processes of working out the solution can be done just in

several minutes. Besides, he can check the related inventory information as well as perform the mock programs in some key business performance areas if the lowest price is accepted by the customer to observe the exact changes in the future business. After maybe 5 or 10 minutes, the company's CEO can make a phone call to the customer to have the negotiation by the efficient working with U-EPM system.

D. Scenario 4 (UBM)

Problems arising in some key processes of business such as inventory and cash flow would cause significant damages to the whole business. So monitoring these key processes ubiquitously can reduce risks and guarantee the coherence of business. For example, when a sales representative is making full orders of product A for this customer and the system detect such an event could have potential risks to business because there are great demands of product A in the market at that time and the price of raw materials of product A is rising. Therefore, the U-EPM system would inform the sales representative by sending the warning message that the full demands of product A couldn't be met right now and provide the available quantity of product A for ordering to the sales representative. Hence a risky activity is avoided by the UBM function in U-EPM system.

5. Evaluation Model and Comparison Result

In order to compare our U-EPM system model with existing ERP & BI systems, an evaluation model is proposed based on metrics derived from an internal research report [15] by an ERP provider company. Then, we demonstrate how this evaluation model is applied to make the comparison between U-EPM and representative baseline system models such as BPM, BPA and SAP mobile.

A. Data Source

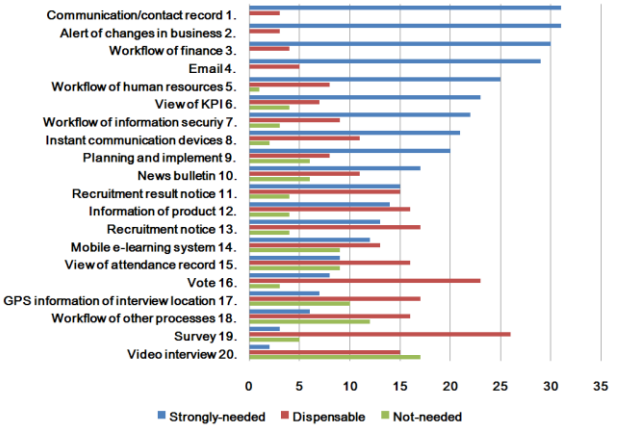


Figure 3. Functions Needed in 3G Application Rank

The data source is obtained from an internal research report, which is a survey on the needs of 3G applications in current ERP system on 34 companies in China. As summarized in Figure 2, the top 20 functions of 3G applications cared most by the middle-management of these 34 companies are provided.

B. Evaluation Model

From the data source and existing systems such as SAP mobile, BPM and BPA, we observe that there are main four functional areas including ubiquitous accessibility, real-time decision-making support, process optimization and effective business monitoring to form our evaluation model as shown in Figure 3. This model can be divided into following major steps.

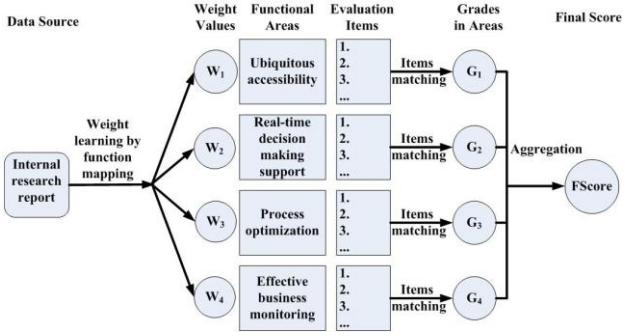


Figure 4. Evaluation Model

- Weights Learning: The weight values for four functional areas are learned from the internal research report since it is unsuitable to determine weight values arbitrarily. The functions rank in Figure 2 reflects degree of importance for each function and these functions are related to four functional areas, that is, we can learn weight values by mapping the rank of functions and functional areas.
- Items Matching: For a specific functional area, we further divide it into some evaluation items, as shown in Table I, which can directly compare with functions of a particular system model. Then the score will be given throughout how much functions the system model contains.
- Grades Aggregation: The final score is aggregated from the grades from each functional area by weighted sum. The final score reflects the degree of how much the functions of a system model are satisfying enterprise common requirements.

C. Baseline System Models

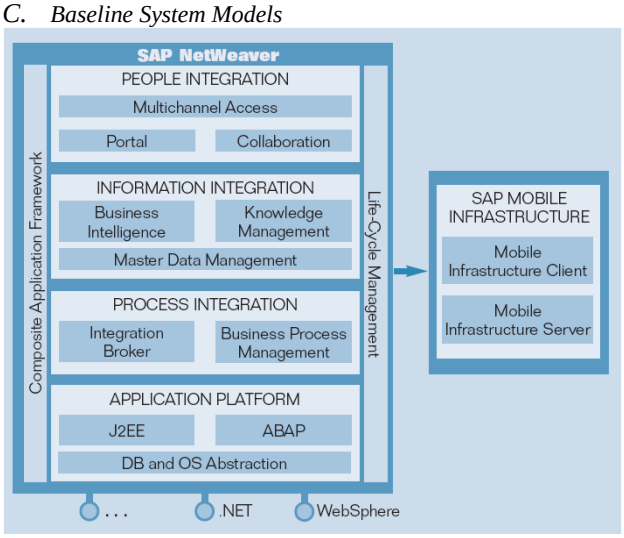


Figure 5. SAP Netweaver and SAP Mobile system model [16]

We propose the following three baseline system models in our evaluation.

- BPM: Business Process Management, which quantifies the enterprise strategy and aims, is introduced in [4].
- BPA: Business Process Analytics (BPA), which supports real-time analytics, is proposed in [14].

- SAP-M: SAP Mobile, which is new product by SAP, and its features and model are described in [16]. The Figure 4 shows the genetic system model of SAP Mobile.

Note that we only consider the genetic model of SAP Mobile as shown in Figure 4 rather than the concrete product in our comparison since BPA, BPM and U-EPM are genetic system models.

D. Comparison & Results

TABLE I. MAPPING BETWEEN FUNCTIONAL AREAS AND FUNCTION RANKINGS

Functional Areas	Function Rankings
Ubiquitous accessibility	***1, 8, 10, 11, 13, 14, 17***
Real-time decision-making support	***3, 5, 6, 9, 12, 18***
Process optimization	***3, 4, 5, 7, 15, 18, 19, 20***
Effective business monitoring	***2, 11, 13, 15, 16***

To learn the weight value of four functional areas in the evaluation model as illustrated in Figure 4, we also did the mapping between these functional areas and the function rankings in Figure 2, and the mapping results are presented as Table I.

After doing mapping between functional areas and functional rankings, we calculate the sum of Reciprocal Rank (RR) score which is commonly used in information retrieval and then normalize it by the sum of all RR score from the four areas and the equation is shown in Equation (1) as follows.

$$W_j = \frac{\sum_{F_i \in A_j}^{\forall i} \frac{1}{FRank_i}}{\sum_{\forall j} S(A_j)} \quad \text{Eq. (1)}$$

where $FRank_i$ denotes the function F_i rank in the Figure 2, A_j denotes the area j, $S(A_j)$ is sum of RR score for each area j without any normalization, and W_j represents the sum of RR score after normalization.

After learning the weighted values for each functional area, we then match the functions of each system model to evaluation items in all areas. The result of item matching is shown in Table II. For a specific system model S_a, we can compute the grade G_j for each area.

$$G_j(S_a) = \sum_{E_i \in A_j}^{\forall i} M(E_i, S_a) \quad \text{Eq. (2)}$$

where S_a is a system model (e.g. ERP, BI), E_i is an evaluation item in function area A_j, and $M(\ )$ is a matching score piecewise function in Equation (3).

$$M(E_i, S_a) = \begin{cases} 1, \text{if } S_a \text{ contains } E_i \\ 0.5, \text{if } S_a \text{ partially contains } E_i \\ 0, \text{if } S_a \text{ does not contain } E_i \end{cases} \quad \text{Eq. (3)}$$

where 1, 0.5 and 0 denote score for three different cases: the system model S_a contains, partially contains or does not contain the evaluation item E_i.

TABLE II. ITEMS MATCHING FOR U-EPM & SAP M., BPM, BPA

Functions	*Evaluation items*	*U-EPM*	*SAP Mobile*	*BPM*	*BPA*
Ubiquitous accessibility	1.Real-time communication between interanl & external	✓	✓	×	×
	2.Ubiquitous access to data/information	✓	✓	✓	✓
	3.Real-time data entry & update	✓	✓	✓	✓
	4.Instant business activity availability	✓	×	✓	✓
Real-time decision-making support	1.Real-time data extraction	✓	✓	✓	✓
	2.Real-time data processing	✓	✓	✓	✓
	3.Real-time BPM	✓	✓	✓	✓
	4.Real-time BPA	✓	✓	×	✓
	5.Offline access to analysis reports	✓	✓	×	×
Process optimization	1.Eliminating paperwork processes	✓	✓	✓	✓
	2.Opimization of data processing	✓	✓	✓	✓
	3.Backup of anaysis results for quick	✓	×	×	×
	4.Over-the-air installation	×	✓	×	×
Effective business monitoring	1.Check the consistency in key areas	✓	✓	✓	✓
	2.Alert of changes in key processes	✓	✓	✓	✓
	3.24/7 service provided	✓	✓	✓	✓

Notes: ✓ : Yes × : No ✓ : Partially

Finally, we calculate the *FScore* for each system model, and the equation for calculate it is shown in Equation (4) as follows.

$$FScore(S_a) = \sum_{\forall j} W_j \times G_j(S_a) \quad \text{Eq. (4)}$$

where W_j from Equation (1) and $G_j(S_a)$ from Equation (2) It can be represented as the following piecewise function. Note that *FScore* scale is ranged from 0 to 1, and higher the value is, the better performance of system's function is.

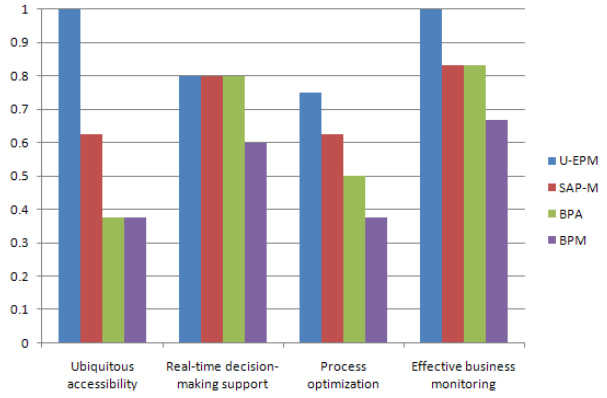


Figure 6. Scores for four different functional areas

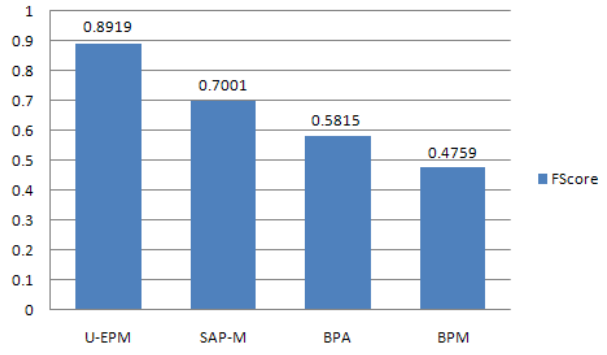


Figure 7. FScore for U-EPM, SAP M., BPA and BPM System Models

6. Conclusion

In this paper, we have proposed a four-layer model of U-EPM system, which comprises the ERP system, the data warehousing, the BI analytics platform, the access control and the 3G network applications. As the current ERP system is restricted by its own shortcomings, it offers an innovative way of extending the current ERP system with both "mobility" and "business intelligence" that can improve the efficiency and effectiveness of enterprise performance management for companies. More importantly, the U-EPM system has distinct advantages in doing performance centered business activities compared to traditional ERP system, and some specific scenarios are given by us. Through proposed evaluation model, we compared the U-EPM with the SAP mobile, BPM and BPA system, and it performs the best in our evaluation. For future works, a possible direction is identifying the suitable business metrics for companies in different industries to increase the personalization of the system.

Acknowledgment

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Collaborative Engineering of Inter-Enterprise Business Processes

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ABSTRACT

Enterprise 2.0 and cloud computing are two of the most popular topics of the last years. Researchers and Business Analysts see great opportunities and potential for a kind of business application revolution. Unfortunately the revolution has not started yet. There are different reasons for this; one is the lack of concepts for integrating the new into already known principles. We are sure that combining the power of cloud computing with principles of social networking and methodology of business engineering can open new horizons of global value creation. In this paper we describe a concept how cloud computing technology can be used to support new ways of inter-enterprise collaboration using the example of logistics.

KEYWORDS: Collaborative Business Engineering, Cloud Computing, Enterprise 2.0, Distributed Modeling, Model Driven Architecture

1. INTRODUCTION

What exactly is "cloud computing"? Unfortunately, the term is not clearly defined. In common usage all software and web services which are distributed through the World Wide Web are referred to be cloud computing.

Following this definition of cloud computing a lot of telematics solutions are included. Internet-based fleet management systems have been controlling thousands of vehicles for years. Millions of parcels are tracked and traced using internet technologies. Seen from this point of view logistics industry has been an early adopter of cloud computing. It seems to be no coincidence, that internet based technology is highly interesting especially for this industry.

What is the reason for that? Logistics is particularly strong driven by globalization related changes. Outsourcing, insourcing and global relocations are growing business topics beyond the classical transportation, handling and warehousing. These topics in conjunction with increasing cost pressure require more powerful and flexible IT systems. On the other hand term contracts are shortened year by year and cycles change very fast. One impact is that traditional IT solutions get increasingly to their limits. Here, cloud computing can produce relief.

There are some additional factors, which are neglected in the discussion so far. It can be assumed, that cloud computing can be the basis for new innovative business solutions not only in logistics. Remembering the vision behind cloud computing - it is the availability of infinite resources of the internet, which can be completely adapted freely and without any delay to the actual demand. Considering the huge investments that are done in the area of dynamic cloud infrastructure, this vision is becoming more and more reality.

Cloud computing creates a fast growing new field for innovative business solutions, just waiting to be cultivated.

The currently discussed approaches are limited to only a fraction of the possible ways, as the opportunities and risks of cloud computing are usually considered only for pure software services and only in the context of a single company.

With cloud computing, it is secondarily a matter of providing and consuming "everything" as a usable dynamic service, whether it is computing power, accounting, simplest work done by human labor, a ready-made software solution or any other service. This extreme form is known as "Everything as a Service". The logistics are, almost by definition, at the interface between the real world and IT solutions. It seems to be an obvious idea to transfer a logical representation of logistics services from the real world as web services into the cloud. And who could be more qualified to do that than innovative logistics service providers?

Right now in Germany several promising research projects are running on that issue. The goal is a standardized model of the logistics domain, to be used as a basis for intercompany overall definition of services in IT and real world. But this makes sense only if these services can be offered, searched, consumed and billed across companies.

If we succeed in bringing "everything as a service" into the cloud, whilst better supporting inter-enterprise collaboration, totally new opportunities for the development of new businesses can become reality. Business development in logistics would be no longer driven by the customer only. Chances especially for small enterprises can rise.

2. A COLLABORATIVE BUSINESS ENGINEERING PLATFORM

This requires switching over the "modus operandi" of the participating companies from reactive transmissions to active acts.

There is a scientific discipline that delivers methods for such an active creation of new businesses. Business engineering deals with development of new business solutions that arise from the transformation of industrial to the information society. Business engineering is the method-oriented and model-based engineering design for companies in the information age.

It needs suitable cloud-computing solutions that are tailored to the business developer and decision-makers in the companies. This clientele expects solutions, that are easy to use and offer immediate benefits. So how would such a solution look like? Modern distributed modeling tools could be a base for such a solution if they provided fitting models not only for software engineering but for business engineering as well.

After years of research SALT Solutions has developed a platform that fits these demands. The figure below shows the platforms architecture.

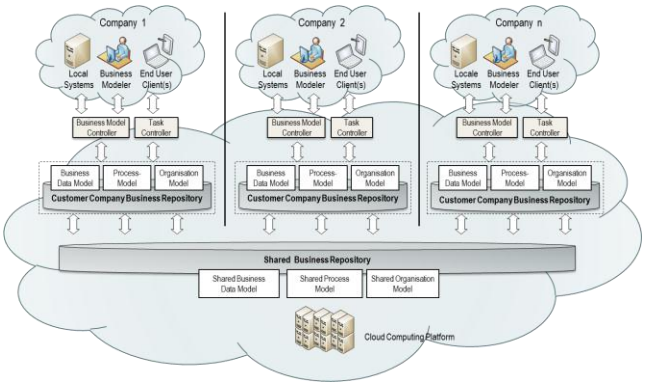


Figure 1: A cloud computing platform architecture for collaborative business engineering

How is it intended to be used?
Business users can use a business modeling tool to create their own business models and to design businesses by "drag and drop". The platform generates an executable prototype of the new business solution without any delay. After successful completion of testing, the prototype can be transformed into a software solution, and automatically deployed into the cloud.

How can that work?
Distributed modeling and model-driven architecture are not that new. Neither is the creation of business applications by service composition. But on closer examination, most of the known examples are rather trivial.

In our opinion the road to success lies in the combination of three key factors:

1) To provide the "right" models.
2) To provide the right way of adopting/adapting the models.
3) To define simple and complexity-restricting transformation rules.

How does the right model for our purpose look like?
We think UML diagrams are far too abstract and sophisticated to be understood in an intuitive way. We use a kind of map, inspired by material flow diagrams. It provides a synoptical view on three aspects of value creation: Value flow, data flow and financial flow.

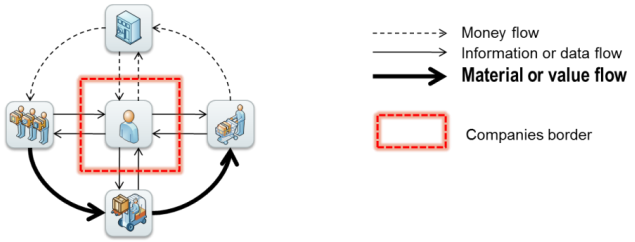


Figure 2: A synoptical cycle model of a companies business

Additional there are three general restrictions:

1) All models are based on cycles.
2) All data structures are constructed on self-similar hierarchies of master-detail or parent-child structures.
3) All flows of money, information and material/value are modeled in coherency.

These restrictions enable a formal definition of integrity rules which assure the consistency of a model even if it is changed.

What is the right way of adopting and adapting these models?
Our models can only be created by choosing a template and enrich it with more detailed information. In fact it is the decomposition pattern we use to create holarchic[1] structures. All processes are derived from enterprise architecture templates. An apparent disadvantage is that no process can be created in a green-field-approach. However, is this really a disadvantage? We think not, because it enables us to define a set of straightforward pattern for transformation rules.

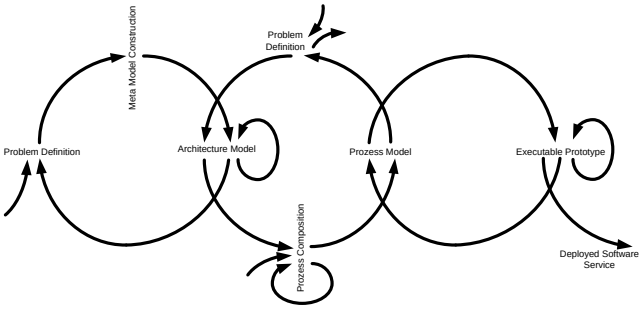


Figure 3: Three iteration cycles of model transformation

The models are always executable and cannot end up in an undefined state. They can be used to simulate the generated software so the model developer can test them in real situations.

This way each company can create its own enterprise architecture model and the processes within. Because all the model artifacts are derived from the same shared business repository they are compatible with the models of other companies. So we can go one step ahead and enable model driven ad hoc projects as virtual

[1] A **holarchy**, in the terminology of Arthur Koestler, is a hierarchy of holons – where a *holon* is both a part and a whole. The expression was coined in Koestler's 1967 book *The Ghost in the Machine*.

organizations. The transformation of executable models to the appropriate software for the project is much easier that way.

It is the mission of the task controller component to transform inter-enterprise process steps into service calls and provide appropriate end-user interfaces. This transformation is strictly task-based in context of the specific collaboration business. This way the trusted access to the data stored in the cloud can be assured, which is one of the major issues in conjunction with cloud computing.

This way inter-enterprise collaboration can be supported much easier. Business collaboration in a new dimension can come into existence.

3. STATE OF THE ART

An interactive platform similar to Wikipedia (as a web site available for anyone easily and usable without any technical knowledge) for collaborative business engineering in heterogeneous and virtual teams is still lacking. At least there is no platform that supports the whole process of bringing an idea to implementation and measurable success. One reason may be that the combination of open innovation and business engineering is currently poorly understood. In the past there was no need to open up business engineering process. Quite the opposite: opening was seen here as a risk.

Open Innovation starts at the independent single player and sets the interactive work sharing of such to the center of attention. It is discussed that Open Innovation promotes dissolution of rigid organizational boundaries at inner circle and the outer edge of the enterprise.

4. SOLUTION

How can the supposed risk changed to a chance? In our opinion it is important to create a win-win situation for all potential stakeholders.

The idea was born to consider Business Engineering processes first as innovation processes instead of pure technical processes. This way, methods of innovation research and innovation management could be incorporated. The result is a framework for "Collaborative Engineering Business (COBE)". Base of the framework is the conceptual model of a classical engineering process with three dimensions of integration and life cycle consisting of four phases:

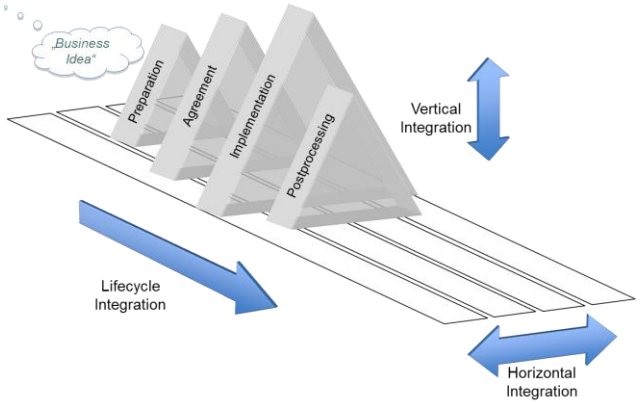


Figure 4: Lifecycle and integration model

The phases are based on a common lifecycle of virtual organization. The horizontal dimension of integration represents different organizational units or individuals, while the vertical integration dimension represents hierarchical structures within an organizational unit. These dimensions are used as frame for synchronization and escalation mechanisms. All decisions are made by collective assessments.

In context of Business Engineering are two major challenges to be solved. The first challenge is to track down ideas and inventions as the nucleus for innovation in all three dimensions and to evaluate positive and possibly negative effects on other dimensions. The second challenge is that in all three dimensions of integration act different people, each with different individual experiences, goals and knowledge.

According to Everett M. Rogers following five factors play an important role [1] for the successful implementation of innovations:

1) Relative advantage of an innovation
2) Compatibility with an existing value system
3) Complexity and the perceived simplicity at initial contact with the innovation
4) Trialability or the possibility of experimentation with the innovation
5) Observability of an innovation

All these factors have strong social components that are completely hidden in the classical business-engineering approaches. We fill this gap through the explicit consideration of the so-called "soft facts" and "soft skills". The soft factors (soft facts) include images, moods, but also knowledge and their subsequent behavior and practices (support / resistance) and soft skills are personal attributes that enhance an individual's interactions, job performance and career prospects..

To this end, we selected several current approaches from other disciplines and combined them in appropriate manner. The first approach is adopted from the “Collective Mind Method” developed by Koehler and Oswald for usage in software development projects. It points out that the key for a successful or failed project in software development is a common sense, a “Collective Mind”. Key component is the project design, a joint assessment of the project settings, the project environment and project momentum by all stakeholders.

The goal is the creation of such a joint project understanding – a collective mind - as a condition for a conscious control of the "soft" criteria for success. [2]

We have generalized and expanded the Collective Mind Method and applied Business Engineering specific methods. The Collective Mind method provides the control and methods kit, which is the methodological pillar representing the Collective Business Engineering and integrates the important soft factors into the framework.

In combination with the usage of special graphical visualizations for enterprise architecture, business processes and business models we address the factor "Observability". Software maps are special graphical representations of information, value, and cash flow. In contrast to existing visualization technologies they should be understandably by “non-techies” without any prior technical or modeling knowledge.

Our approach to "Collaborative Business Engineering" is (by its structured nature) perfectly suited to develop special software tools for its implementation. Such a tool must support collection, processing, evaluation and development of all relevant

information and ideas as well as their relationships and interactions – a new class of business software.

The main advantage is the ability of permanent “Triability”, which is enabled by a complete model driven approach in conjunction with automated transformation of all the models to prototypical software services in the cloud.

Beside modeling components for business models and business process models there is are components for modeling and controlling the projects Collective Mind over the whole life cycle of the innovation.

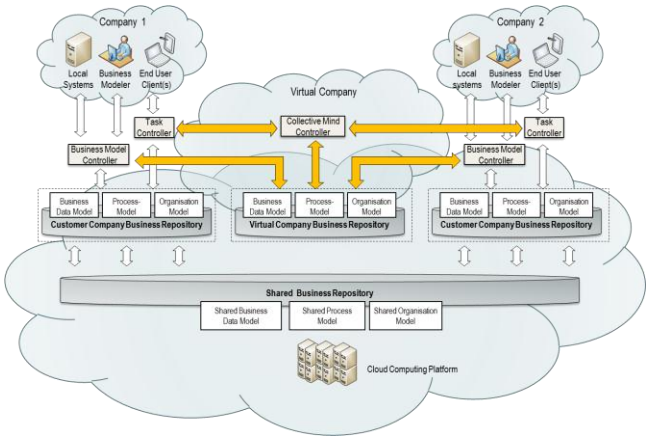


Figure 5: Collaboration at the platform using virtual organization

The initial business idea is transformed to a description of the target state, the necessary steps for the implementation and the resulting values are derived from. The model therefore describes the shared vision and mission and the desired organizational culture and provides the framework for policies, objectives and operational action.

Each potential stakeholder or organization can define its own mission statement which can be used as criteria for assessments according to the Collective Mind Method in the following phases of the collaborative project.

In addition, all the requirements derived from the initial idea are formulated in form of user stories well known from agile software development. [3]

These user stories can be viewed by potentially involved stakeholders and evaluated continuously. They can be reevaluated if necessary - when new knowledge is present. The assessment is open and allows the horizontal integration between all stakeholders through transparent information exchange.

The possibilities for the assessment of user stories go significantly beyond established standards (namely assessing the costs and benefits). Rather, the stories can be evaluated by any number of criteria, as a function of different contexts, its own mission statement. Its values can be weighted differently. This multi-criteria evaluation allows an active participation of all stakeholders, including those from different "cultures", because the symptoms of failures (different opinions) in large projects are visible early. In addition to evaluating all stakeholders can deploy new user stories or add links between the stories. In this way, for example, conflicting demands and ideas are discussed and recognized early. This approach succeeds this way the principle of "prevention rather than cure".

In particular, this approach supports a proactive dealing with changing conditions and (too) late over time identified problems or ideas.

Finally, the multi-objective evaluation mechanism is also the basis for decisions and thus the vertical integration dimension.

Managers receive unprecedented (because mathematically underpinned) support in uncertain (because complex) decision-making situations.

5. METHODOLOGY

The mathematical base is the modeling of networks, i. e. systems of nodes (e.g., individual actors or actions) and their connections (the influence of nodes to each other). In classical graph theory is only the existence or absence of a connection between two nodes relevant. In real networks, these compounds are multidimensional. Between two actions exists not only physical and monetary relations, but also any action can produce any marketing-related, confidence building, just "soft" effects.

Plus, every action (and ultimately a project as a whole) has often not only one, but several objectives. In addition to direct economic (profit concerns, achieve new customers), it focuses on strategic and political considerations (strengthen locations, initiate start-ups) environmentally-oriented (spare resources) and so on.

All these objectives must be taken into account in decisions. Each COBE project is thus to consider multiple criteria. The underlying structure is therefore a multidimensional and multi-criteria decision network.

The only analytically treatment of such networks is impossible, but the net must be simulated, i. e. the impact of any action on the project objectives must be pursued by computer-based methods of numerical mathematics. It is both

1) Calculation of effects
2) Visualization of causal chains and
3) Optimization of procedures

All three components together make the foundation for a tool for Collaborative Business Engineering.

The calculation of effects makes it possible to conduct a cost / benefit analysis of various possible options to fulfill a customer request (e. g. the choice of the stakeholders, taking into account interests and experiences of customers, etc.).

Visualization is a key component in our approach for in integrating the "human factor" in the project implementation: it permits the illustration of the consequences of an action, whether the change of a parameter (e. g. cost increase), but also subjective decisions within the network and thus contributes significantly to increasing transparency of project implementation.

Finally, optimization is the (automatic) finding the best solution – or more realistically - the automatic suggestion of a number of good solutions and the description of their respective advantages and disadvantages, so that the editors can select and implement one. A service to be provided can now be interpreted as a path within the interconnection network. Their costs are in the simplest case, the sums of the costs on that path of nodes touched.

To find the optimal solution for a given task is then the search for the best path and can be solved by standard methods of global optimization.

The functioning of the described approach requires

1) The comprehensive coverage of both the targets and the data of all stakeholders involved, i. e. the correct implementation of the preparatory phase as the base of the whole approach.
2) The realistic and up to date assessment of the various actions and their interrelationships. This requires both a constant maintenance of data and a vote on the assessment of the effects of an action - it can indeed quite different stakeholders views are different.

More, the impact of real decisions are often not predictable, at least not at the time of decision - or probabilities can be provided if necessary with the decision makers, which in turn influenced later decisions and changes in the environment are. The modeling of the network also needs this (probabilistic) aspect into account, therefore.

6. LEARNING FROM THE COLLECTIVE

Another new and important approach within this idea is the representation of best practice patterns via a recommender system. It means that we use information about projects, problems and solutions and analyze them. For new projects and situations we can provide important information and solution ideas, which are based on the experience of already existing users.

Recommender systems have been developed as a computer-based intelligent technique to solve the problem of information and product overload. Recommender systems are tools for the creation and dissemination of recommendations. The purpose of these systems is to filter information and provide valuable recommendations for the user. Recommender systems are currently mainly used in e-commerce, to introduce users more products

The goal of the recommender system in this context is to work like a human brain. It should storage all the data which exist and all the results - especially the rating of the project results.

For new projects the stored data can be analyzed for similar combinations and cases. Based on the results of the similar data we can provide recommendations for the project.

With this recommender system we can provide help and support from other company’s experiences.

7. SUMMARY AND OUTLOOK

This paper presents an integrated framework for the structured and tool-supported transfer of new ideas into products and services based on a multidimensional and multi-criteria decision network with special reference to so-called "soft" factors before.

The framework integrates so well as market and business strategies, allowing "hybrid innovation." Pure technology skills are accompanied by agile business models and attractive, emotional marketing activities.

The central challenge in the mathematical description of the underlying decision network is in addition to the expected high number of information (requests, offers and services) in the control of the dynamics of the network, i.e. the fast change of its structure. The development of appropriate simulation, evaluation and optimization algorithms require further research.

Herein lays the central challenge for both the development of appropriate tools as well as for its use: The management of such complex, dynamic with probabilities weighted networks is very expensive. To operate in particular the pursuit of a "divide in", i.e. alternatives permissive several project's progress with a substantial increase in the complexity associated and places high demands on the supply of network data, but requires particular novel forms of visualization and user interaction.

It is envisaged to continue research activities in this direction.

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Analysis of the information about doctoral degrees presented in the Spanish universities websites

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ABSTRACT

Globalization has intensified competition, as evidenced by the growing number of international classification systems (rankings) and the attention paid to them. Doctoral education has an international character in itself. It should promote opportunities for graduate students to participate in these international studies. The quality and competitiveness are two of the most important issues for universities.

To promote the interest of graduates to continue their education after the graduate level, it would be necessary to improve the published information of the doctoral programs. It should increase the visibility and provide high-quality, easily accessible and comparable information which includes all the relevant aspects of these programs.

The authors analysed the website contents of doctoral programs. It was observed a lack of quality of them and very poor information about the contents, so that it was decided that any of them could constitute a model for creating new websites.

The recommendations on the format and contents in the web were made by a discussion group. They recommended an attractive design; a page with easy access to contents and easy to find on the net and with the information in more than one language. It should include complete program and academic staff information. It should also be included the study's results which should be easily accessible and includes quantitative data, such as number of students who completed scholars, publications, research projects, average duration of the studies, etc. It will facilitate the choice of program.

Key words: doctoral degrees, web, data quality, quantity of information.

1. INTRODUCTION

Globalization has intensified the competition, as evidenced by the growing number of international classification systems (rankings) and the attention paid to them.

Due to the significant increase in the offer of doctoral programs, not only in Spain but throughout the EHEA, the institutions involved in these studies point out the competition between them as one of the more important ten questions for them.

In the EUA study it was indicated that 38% of institutions consider competitiveness an important issue, while the broader issue selected was the quality of the program with 60% [1].

The growing internationalization in universities, especially at the doctoral level, is also of great importance. Doctoral education has an international character in itself. It should promote opportunities for graduate students to participate in these international studies. This can be done, for example, by increasing international mobility grants, the organization of workshops, conferences and summer schools, developing jointed doctoral programs, and the co-direction of work. The use of new technologies such as teleconferencing or e-learning will also be used to promote the internationalization of doctoral programs.

Although in 2008, some countries have decreased in number of doctors, the percentage of those on all graduate students is more or less stable. According to Eurostat (Statistical Office of the European Communities) the percentage of students in doctoral degrees in the countries of the European Union (EU), compared to the total number of graduate students, is less than 10%. The average in the EU with 27(countries) was 2.78% in the period of years from 2000 to 2008, lower than in the U.S. and Japan. In the U.S. and EU there is an increase of the number of graduate students, meaning that students do not reject higher training cycles [2].

In order to promote the interest of graduates to continue their education by accessing the training of graduate level, it would be necessary to increase the visibility of supply and provide readily accessible data to allow in-depth knowledge of the doctoral programs.

From this perspective, it is of great interest to provide quality information and make it comparable

with other institutions in order to provide interested students the choice of program and university. It is therefore necessary to use the existing communication mediums.

A website is, in essence, a digital business card, either for companies, organizations, individuals, etc. Also, the new trend oriented to Web pages is not only attractive to our visitors, but is also optimized to be quickly located by search engines through the source code. Reaching this dual purpose may pose a conflict with the quality of the content.

The objectives of this study are to analyze the accessibility and visibility of the information network of prestigious international universities and propose a basic outline of information in the publication of a doctoral program.

2. MATERIALS AND METHODS

In the analysis of web pages, some general questions have been considered. The "five classic criteria": Authority, Accuracy, Objectivity, Currency, Coverage [3] are not useful for the objective proposed in this study because university pages generally cover these criteria. More useful are other elements, such as information access, navigation, design, and language. Combined together with some specific information sought in this study, such as staff, the program, or the results obtained, form the elements of analysis considered at each site. The presence of these issues and the quality of it has been discussed in the web of six European universities, six U.S., and five Asian universities, comparing degrees of doctor of an area of knowledge equivalent to each.

The list of universities is as follows:

In Europa: Hohenheim University (Alemania), Agrosup Dijon (Francia), University of Leuven (Bélgica), Wageningen University (Holanda), Università degli Studi di Bari Aldo Moro (Italia) y Agricultural University of Athens (Grecia).

In USA: Virginia Tech (Virginia), University of California (Berkeley), University of Minnesota (Minnesota), University of Illinois (Illinois), Cornell University (Ithaca), Washington University. (Washington).

In Asia: University of Tokyo (Japan), Kyoto University (Japan), National Taiwan University (China), University of Hong Kong (China), Chinese University of Hong Kong (China).

Berelson [4] discussed how the content analysis is "a research technique to describe the objective, systematic and quantitative content of communication." Therefore, the methodology used for the data examination was content analysis. This research technique allows formulation, based on certain data, of reproducible and valid inferences that can be applied to their context [5]. In this work the aim was to describe the content of web pages by examining frequencies.

The recommendations on form and content in the web pages were made by making decisions based on expert opinion, obtained through a qualitative research technique widely used today: the discussion group. Overall, the discussion group is a conversation with a group of people, who know the subject of discussion and are interviewed with planned questions. The topics are pre-defined but flexible. The atmosphere of discussion within the groups is permissive and non-directive [6]. Assessment through focus groups is designed to obtain information on a defined area of interest. People who are interviewed in groups should be individuals skilled in a certain subject or have much experience in the area.

The discussion group formed for this work is an already established group of people; most know each other and the type of so-called natural groups. Natural groups should be selected close to or own contexts of study groups [7]. Focus groups are considered the most naturally suited for the study of social cognition, such as curricular competencies. Moreover, working with natural groups ensures that the social context of interaction, basic rules of conversation, and attribution of meaning are shared by groups [8].

The natural group formed for this work (authors) brings together experts with the following characteristics:

i. Spanish nationality
ii. PhD in Engineering
iii. Extensive teaching experience in the area (more than 5 years old and more than two different materials)
iv. Varied experience in corporate management (leadership of working groups, teaching management work, membership of national and international groups working in academic organization, etc.).
v. Gender diversity and range from 35 to 65 years of age.

3. RESULTS

First of all, there was an analysis of the contents of the websites of the 17 selected universities. This evaluation was completed with the recommendation of several aspects to consider, in terms of quality and quantity of information that should be considered for the proper dissemination of doctoral degrees through web pages.

3.1. Content analysis of web pages.

In most European universities selected, the first page of the site offers little and unattractive information. The information access is placed on the edge of the pages. The design is outdated and unattractive. The pages are not dynamic and images don't link. The design is hypertext. When available, the information on the general faculty of the university does not specify which teacher is responsible for each topic. There is usually no presented information on PhD. programs. And only

one university was found to have information on the number of doctorates achieved per year.

In general, the information in American Universities is focused on studies degree. The Doctor degree contains information regarding the requirements to overcome by the students (usually number of credits). Navigation is easy. The design is classic and simple. There is not specific information on websites about the staff and they do not identify who is responsible for the different subjects. The information is displayed only in English. Finally, there has been nothing found on results in any of the pages.

Regarding Asian pages viewed (we have selected the best globally positioned), the information is not comparable to those found in Europe. In general, the information is arranged in agreement with the students requirements. The information has been consulted whenever it appeared in English so it is not known the contents of the information in Chinese or Japanese. The University of Hong Kong displays more information than the rest.

Table 1 shows the results of all tested pages, counting the universities where adequate information has been detected in more than one language, accessibility or navigation, and attractive design.

Análysis		Universities		
Type	**Features**	**UE**	**USA**	**Asia**
Quality	Access	17	17	40
	Navigation	0	33	20
	Design	0	67	40
Number	Language	67	0	100
Includes iformation	Teachers	0	0	0
	Program	0	0	20
	Results	0	0	0

Table 1. Table percentage (%) of colleges with good quality content analyzed on the total of the 17 universities considered

In the overall analysis of these features it is apparent that the information on faculty performance and course programs is very poor. Navigation and page design is best in American universities and poorest in European ones. Accessibility and the number of languages are better in the pages of Asian universities.

3.2. Recommendations on the image and use of website.

There are three important points to analyze when we consider the diffusion of doctoral programs in the university web pages:

1.- Attractive. One of the first things that invites the user to remain on the website and explore its content is the appeal of the web design and consistent in their ways. This is most appreciated by Internet users when deciding on the choice of web service.

2.- Easy to use and appropriate information structure. It is very important that the users find a website that meets their needs, because that first impression will be largely set to re-use. It is necessary that web design is focused on users so that they can interact with web sites in the most easy, convenient, and intuitive way as possible. For this, the Web design should be focused primarily on the user and designed for him. In this case, we assume that the user is the university degree and is looking for information to decide whether to continue his training as a researcher, or if he seeks to select the most appropriate program for him. Do not forget the many international programs, meaning the candidate could be from any part of the World.

3.- Easy to find the page with search engines. To have an attractive and well designed website based on the current guidelines of web design is useless if you can not achieve a good position in major search engines.

3.3. Recommendations on the contents to be included in web pages.

The team author of this work established the following as important elements for assessing the quality of doctoral programs and providing guidance to future students of these postgraduate studies.

1. Nº students enrolled
2. Nº new students
3. N º of teachers and categories
4. Nº of subjects face
5. Nº of e-learning courses
6. Nº of subjects offered
7. Nº of subjects that the student must attend
8. Nº of publications related to the thesis of those programs:

a) International or national JCR
b) Other International
c) other National
d) Communications in Congresses
e) Reports
f) Book Chapters
g) Books

9. Nº of research projects related to those programs
10. Nº of students with scholarships
11. Nº of languages in which information is given
12. Nº of foreign lecturers
13. Nº of different Spanish universities involved
14. Nº of different foreign universities involved
15. Nº of mentions of "European Doctor" or similar
16. Nº of Awards Outstanding Doctoral Thesis or Doctoral Awards
17. Nº of weeks of stay by doctoral students in foreign research centers for conducting thesis
18. Nº Thesis rejected in the first round for corrections
19. Nº of theses completed
20. Average time for completion of the thesis
21. Nº of evaluators of the thesis, outside the University.
22. Has a quality references
23. Has a quality assurance system
24. Has satisfaction surveys to graduates
25. Percentage of doctor graduates with work
26. Percentage of doctors graduates to work in research and teaching.

This information should appear on the network along with a detailed program for the certification, list of teachers, and research proposals.

4. CONCLUSIONS

In some of the best universities in the world, analysis of web pages doctorates show a generally poor quality and limited content related to the doctoral program.

In view of the results it is not recommended any model of the analyzed pages. Therefore, the working group made up of experts recommended an attractive design, a page with easy access to content, and dynamic and important links. It should also be easy to find on the net and not be forgotten that the new doctoral programs should strengthen its international dimension, so that the information should be useful for any professional, no matter its nationality.

In terms of content, it should include comprehensive information on programs (materials and schedules) and the professors who teach. The results should include an easily accessible form; most of the 26 quantitative data collected in this work and can give an idea of the overall quality of doctoral programs, facilitating the choice of program for students interested.

ACKNOWLEDGEMENTS

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Internationalization and Globalization in Higher Education Through Mobility: Erasmus Experience in Turkey

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ABSTRACT: It is an unavoidable fact that Higher Education and teachings must upgrade themselves from being local to global. As a result of globalization, higher education systems become more and more internationalized through mobility programs. In addition to this, the knowledge era requires global skills from the university graduates and this force the universities to give importance to internationalization policies more than before. The aim of this study is to assess the results of Erasmus mobility between the EU and Turkey in higher education. Exchanging students and academic staff will give a broader perspective and important international experience to participants. But data from Eurostat shows that academics mobility from the EU to Turkey has remained low however in increasing trend not only for students but also for academic staff. It is important to investigate the reasons of this low mobility. What kind of measures should be taken to increase this rate? In addition to this provided feedback about the impact of these mobility programs should be taken from participants to update and betterment of existing system. This paper is aimed to explore the mobility trends of the Universities of Turkey which may help to contribute some insights for the betterment of the Higher Education System in the Europe especially in Turkey.

Keywords: Erasmus, internationalization, globalization, mobility, university, higher education

1 INTRODUCTION

Higher Education and teachings have been upgrading themselves from being local to global. Therefore, higher education systems getting more and more internationalized through mobility programs. Universities have to continuously update their systems and increase the productivity of their services to benefit more from these global development opportunities. In addition to this, the knowledge era requires global skills from the university graduates and this force the universities to give importance to internationalization policies more than before.

The education and training policies of the EU have gained impetus following the adoption of the Lisbon Strategy in 2000. Here, the EU's most valuable assets were knowledge and the innovation in which the strategy sparks in light of increasing global competition. It is hardly surprising that the EU currently funds citizenshipbuilding programs which encourage EU citizens to take advantage of opportunities to live, study and work in other countries. The best known of these is the Erasmus program, under which lecturers have taken part in inter-university exchange and mobility over the last 13 years. Erasmus program that covered university staff training and teaching became part of the EU's Lifelong Learning Program in 2007. Currently more than 3,100 higher education institutions (HEI) in 31 European countries participate in the Erasmus program. Turkey is eligible for the Erasmus program since 1 April 2004, under which for mobility makes short guest lectureships at European partner institutions possible. Just as the higher education institutions across the EU member states stood out in organizing mobility actions for teachers within the Erasmus program, academic mobility between the EU member states and Turkey has been taken place since then. The Higher Education Council (YOK) has already initiated to implement Erasmus program. The Council has encouraged universities to participate in academic mobility schemes, and thus academic staffs to seize opportunities in a sense that mobility may offer them to improve their knowledge and skills, and to enlarge their horizons throughout Europe. The aim is to enhance the quality and reinforce the European dimension of Turkish higher education within the context of transnational cooperation.

This study is based on the recent publications of the European Commission and The Higher Education Council (YOK) as well as a number of independent studies in this field. The study relies on a number of basic facts. This study is also aimed to explore the mobility trends of the Universities of Turkey which may help to contribute some insights for the betterment of the Higher Education System in the Europe especially in Turkey.

2. REVIEW OF EXISTING STUDIES

In recent years, the term "globalization" surpassed the "internationalization" in the frequency employed in economically advanced countries. The term "globalization" suggests that increasing border-cross activities in higher education take along a blurring of borders, while "internationalization" is based on the assumption that national systems continue to play a role in the process of increasing border-crossing activities. The first is pushing higher education system to a single world state system. Of course, not all universities are (particularly) going to be international, but all are going to be subjected to the same processes of globalization [1].

Most scholars working on academic integrity problems have focused on the fundamental values of integrity. From this perspective, the paucity of empirical study by Olasehinde-Williams [2] on measures of academic integrity problems among lecturers in Nigeria is considerable. The study is related to the conceptual framework which was developed by the authors (Figure 1). The debate focuses on the interrelations between cultural dimension of social communication situation and lecturer mobility, introducing the concept of 'bounded mobility' to explain this complex phenomenon. In the context of education and professional activities, mobility decisions are not isolated decisions, but rather seen as an instrument of internationalization. Mobility is then bound to be a relative concept: the perception of prevalence of academic integrity problems among lecturers in tertiary institutions is cause of concern. The concept raises questions about any forms of academic integrity problems.

Hönekopp and Werner (2000) suggest that a major incentive to move is to chance to increase one's skill in host countries in the context of integration theory. This assumes a movement away from the less productive to the more productive workplaces in the integration area.

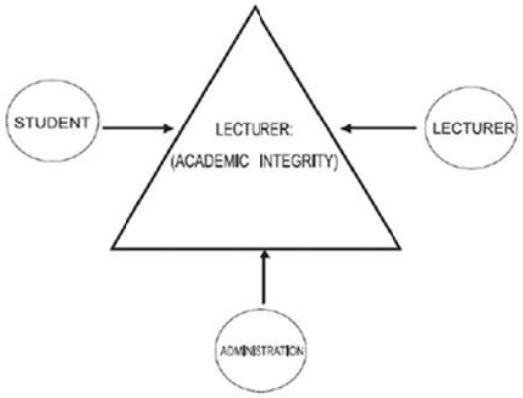


Figure 1. Dimensions of perceptions of lecturer academic integrity.

The key point of these studies in academic mobility activities is a unique chance to obtain education, training and work experience in another European country. To that extent, academic staffs acquire a new expertise and professional skills, and in addition develop their capacities to adapt to new environments. Mobility is the method as well as the aim of acquiring this new quality or qualification. Mobility needs to be seen as a method suited to enhance the ability for cultural integration on the part of institutions/organizations and to enable individuals to live and act in varying multicultural contexts [4].

Scarino, Crichton & Woods, (2007) argues that increasingly diverse lecturers bring a range of diverse backgrounds and expectations to the teaching and learning process. With internationalisation, there is a notion of transcending barriers or borders. The process of transcending necessarily entails some form of 'crossing-over' that, in turn, entails the recognition of additional social, political, economic, educational realities that participants bring to the learning process. This recognition is best achieved through collaboration with participants (both educators and students) in the educational program. In this sense, international education is per force collaborative [5].

Higher education institutions are active internationalization programs mainly for two main reasons. First of all, globalization has removed the barriers between the nation states and increased

the access of knowledge mainly through technology. Global communication systems have weakened national boundaries and allowed for the rapid dissemination of knowledge [6].

3. ERASMUS PERFORMANCE IN EU COUNTRIES

There are four main types of mobility in Turkish Universities: exchange through bilateral agreements, the Erasmus Program, the Erasmus Mundus Program and the international summer school. The International Cooperations Offices (ICO) and departmental exchange coordinators are the main implementers of these programs. All these programs give both to incoming and outgoing university students and staff the chance of mobility. This study aims to evaluate the effectiveness of Erasmus program among these mobility programs from the views of the outgoing and incoming students and academic departments with the aim of improving of the mobility programs in the University.

Data on mobility flows is supplied by the European Commission [7]. The number of Erasmus staff mobility increased considerably between the academic years 2007/08 and 2008/09 years. As Figure 2 shows, the highest number of outgoing staff mobility was recorded in Poland or 4341 (11.9% share, followed by Spain with 3682 (10.1%), Germany with 3117 mobilities (8.6%) and then the Czech Republic with 2595 (7.1%) in 2008/2009 years. As for Turkey, the number of outgoing staff mobility was 1595, representing a 4.2% share of the total Erasmus placements in 2008/09 [8].

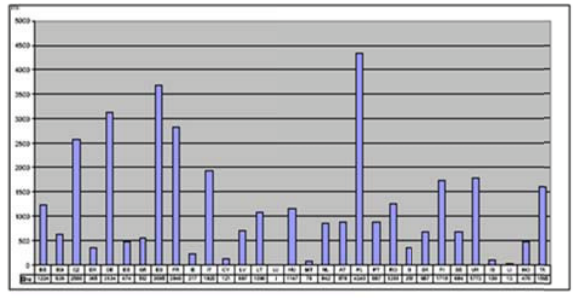


Figure 2. Outgoing Erasmus staff mobility for teaching assignments and staff training from the 31 participating countries in 2008/09 [7].

Figure 3 shows that the distribution of incoming staff mobility between the 31 participating countries in the same academic year. It is clear that Turkey remains below the EU average. The total number of Europeans moving to Turkey was only 165 in 2008/09. Germany received a relatively high percentage of foreign staffs from within the EU and the EFTA countries, with 3781 mobilities followed by Spain with 3445 incoming mobilities and Italy with 3222.

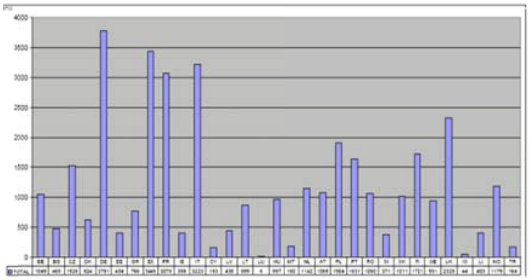


Figure 3. Incoming Erasmus staff mobility for teaching assignments and staff training from the 31 participating countries in 2008/09.

Crucially, inbalances between inward and outward mobility should be taken into accountry as far as Turkey is concerned. In most countries, the number of incoming mobility is higher than outgoing mobility in 2008/09 academic year. By contrast, Turkey experienced a reverse balance just as several other countries including Belgium, Bulgaria, the Czech Republic, Hungary, Spain, Lithuania, Poland, Romania, Liechtenstein and the UK. In comparison with other countries, the greatest balance in the ratio of incoming and outgoing teachers was observed in Germany, the Netherlands and Iceland. Thus, Turkey was characterized by the second best country with 1054 outgoing versus 1020 incoming. Overall, these figures indicate that Turkey has a low percentage of academic staff with a foreign nationality; other countries received higher percentage of incoming staff mobility for teaching assignments. Although there was a marked drop in the growth of the percentage of foreign staff in Turkish higher education in the 2008-09 academic year mobility appeared to be leveling off compared to 2007/08 academic year. So, the greatest imbalance in the ratio of incoming and outgoing teachers is the cause of concern. Perhaps it is fair to say that Turkey is the main country of supplying academic staffs in the EU, despite it does not score high mark on aca-

demic mobility, which refers to the lifelong learning programs. Overall, Turkey falls within the middle bracket for all EU countries.

4. ERASMUS PERFORMANCE OF TURKEY

The Erasmus program is managed by the national agencies located in the participating countries. The Centre for EU Education and Youth Programs was structured as an organization linked to Prime Ministry, State Planning Organization as the national agency of Turkey. The Centre has been charged with the duty of introducing the European Union education and youth programs in Turkey; to execute, coordinate, monitor and report to the European Commission of the operations for participating in these programs; to realize the necessary negotiations with the European Commission and to sign the contracts of implementation. The primary priority of the Centre in 2004/2005 was to involve the possible highest number of individuals in Erasmus mobility with the possible highest amount of funding within the budgetary limitations. One other priority was to achieve a balanced distribution of Erasmus activities through the institutions, subject areas and destination countries [9].

Teachers exchange performance of Central Anatolian universities is much better than others. The number of outgoing students by geographical regions is given in Figure 5.

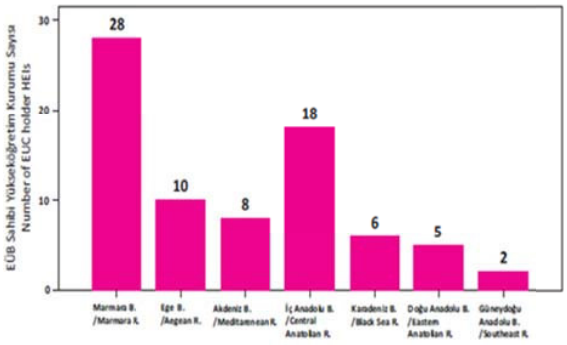


Figure 4. Distribution of Turkish Universities in Erasmus program by geographical regions [9]

As shown in Figure 4, the best performance has been performed by Marmara and Central Anatolian universities. These universities are top universities in Turkey also located in the most developed cities that's why they have better connection between universities in abroad. As shown in Figure 5, the number students from Marmara region is much more than the rest of other regions. It can be concluded from this graph, these universities in Marmara is becoming globalized faster.

The state universities of Turkey have sent more students and teachers than foundation universities for Erasmus program as shown in Figure 6. The foundation universities are shy for exchange because many of them focused on financial balance of university to show better performance in short term. However this kind of exchange program is useful for long term targets. According to this graph, state universities in Turkey focus on long term targets more than foundation universities.

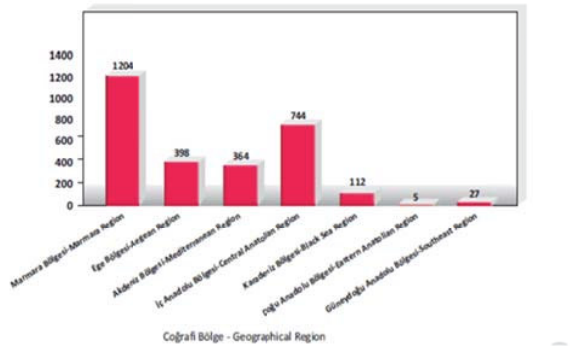


Figure 5. Number of outgoing students by geographical regions

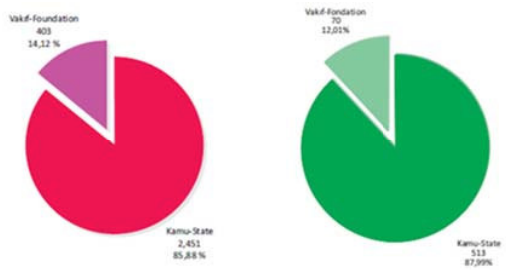


Figure 6. Distribution of outgoing students and teachers by state/foundation status of sending

As shown in Figure 7, %81 of outgoing students are undergraduate students, %12 is master students, %7 is Ph.D. students. Because graduation students percentage is low in Turkey. Basically many of students prefer to study instead of master degree because of financial reasons. Increasing average income will lead to increase this percentage. The average study period of out-

going students is shown in Figure 8. Most of the students prefer 4-6 months period which means one semester. One semester period is optimum solution for students in order to have abroad experience. In addition to this increasing periods cause difficulties in financial support.

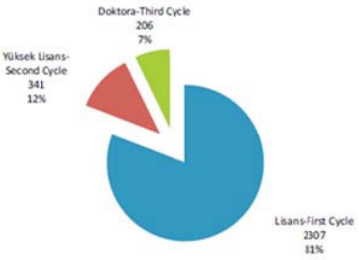


Figure 7. Distribution of outgoing students by cycle

Generally teachers prefer one week duration exchange program which means 1-8 hours teaching or seminar hours. This duration is the most preferred because more than one week research may cause delay of education in home country. However one week interrupt does not cause problem on going education. According to status of teachers, most of the outgoing teachers are assistant or associate professor (%52,47) in Turkey. Because assistant or associate professor have to pass academic barriers in order to get next position at university. That's why they are very eager for innovation, mobility, research. In contrast to this figure, professors are very static because education system does not enforce them for better academic performance in Turkey.

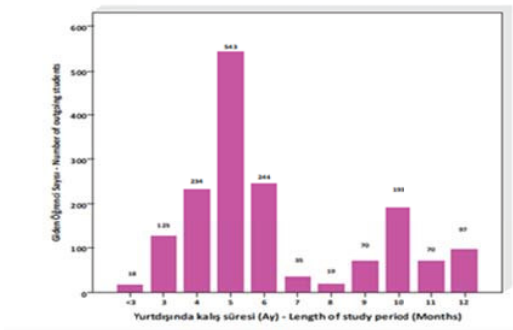


Figure 8. Distribution of number of outgoing students by length of study periods

The comparison of outgoing students and incoming students trends can be followed from Figure 9. As shown in the graph, outgoing students number has been increasing faster than incoming students. That means student exchange is getting more and more popular among Turkish students.

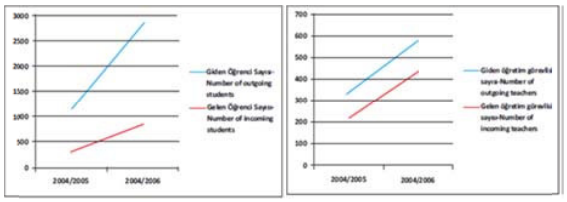


Figure 9. Increase of outgoing and incoming students and teacher according to years

There are three basic reason of this result. One is increasing economic performance of the country supply more opportunity to students. Second reason is language barriers have been exceeded by Turkish students. Third reason is the performance of national agency which coordinates Erasmus mobility in Turkey performing much better than previous years. In addition to this almost all universities in Turkey has international office helps students and teacher. However increase rate between incoming and outgoing teacher is close to each other different than students.

This fast increasing rate among students also caused by used funds can be seen in Figure 10. There is also increasing rate in teacher data but lower than student's rate. This is also a reason for previous figure.

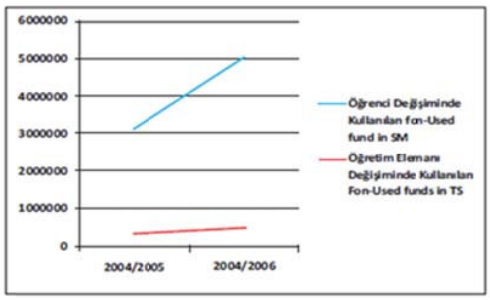


Figure 10. Increase of used funds for student and teaching staff mobility

According to statistics, the most active faculty in Erasmus mobility is engineering and technology faculties. One of the most important reason for this case is many of these faculties has one year English preparation classes. In addition to this many engineering faculty has hundred percent

English educations. As a result of this engineering students can easily overcome language problems and apply to Erasmus mobility. Than engineering education is close to each other so students can easily adopt new county education. The second active department in Erasmus mobility is management and business administration departments. The similar language case is also exist for these departments. In addition to this general number of students in these departments is much more than others respectively. According to outgoing teacher's data, parallel to student's data, the most active faculty in Erasmus mobility is engineering. Because language level of these department teachers is very well.

4. RESULTS AND DISCUSSIONS

Internationalization and globalization is an avoidable fact in recent years. The most important issue for internationalization and globalization is sustainability. The main problem of internationalization is limited financial resources. Universities worldwide are suffering from a lack of specific internationalization budgets and monitoring systems, caused by world's economic crisis. However Erasmus program is very important tool for mobility of higher education which leads internationalization and globalization in Europe. Turkey has a member of Erasmus program and has been increasing her contribution. According to statistical data, the mobility of Turkish students and teachers has been increasing. However the percentage is still less than desired. In order to increase mobility in Turkey, less active universities establish in different region must be activated and their contribution should be raised. Teachers' percentage and rate is far below than desired level especially in these regions. Internationalization is a prevalent goal of contemporary higher education institutions in Turkey, however significant barriers to its institutionalization exists. There are some basic reasons of this result. First is language barrier, second is financial limitation, third is cultural difference, and forth is geographical distance. In order to overcome these difficulties, first full time lecturers should be encouraged and financially supported. Because, they have key role for developing mobility. In addition to this, a lack of linguistic diversities in Turkey appears to be a real burden for inward mobility. This barrier hinders the social integration of mobile lecturers, since more informal communication takes place in Turkish as mother tongue. The mobility performances of universities have fully or partially English education universities is much beyond the others.

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Quality and Higher Education in International and National Context

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ABSTRACT

The aim of the paper is to evaluate the influence of the international Bologna process on the European Higher Education Area (EHEA) and development of higher education in Latvia. Research on the concepts and approaches of "quality assurance" in higher education (HE) indicates that there is a number of differences between the common understanding of the general approaches of Quality Management developed by quality professionals and used in business, and the "quality assurance" methodology in EHEA which is built on three processes only – evaluation, accreditation and audit. Higher education institutions (HEI) are looking for a higher level of effectiveness across all functions and processes and are often choosing the Total Quality Management approach as a strategy to succeed. Requirements of external international environment are a competitive force asking for new competence of graduates – ability to align with international labour market requirements. Therefore the paper also reflects on issues of the influence of the Bologna process, European Qualifications Framework and European Union (EU) mobility programs on the skills and abilities of HEI graduates in international and national context. The paper includes authors' proposals for clarification of the meaning and content of the concept "quality assurance" in education.

Keywords: Quality Assurance, Higher Education, Quality Management, Bologna Process

1. INTRODUCTION

In the Berlin communiqué of 19 September 2003 the education ministers of the Bologna process signatory states invited the European Network of Quality Assurance Agencies (ENQA) [the European Association (Network, until 2004) for Quality Assurance in Higher Education], "through its members, in cooperation with the EUA (the European University Association), EURASHE (the European Association of Institutions in Higher Education) and ESIB (the National Union of Students in Europe, today the European Students' Union, ESU), to develop an agreed set of standards, procedures and guidelines on quality assurance", and "to explore ways of ensuring an adequate peer review system for quality assurance and/or accreditation agencies or bodies, and to report back through the Bologna Follow-Up Group to Ministers in 2005" [8].

In 2005 ENQA published the "European Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG)", which were accepted by the European higher education ministers at the 2005 Bergen meeting. The ESG consist of three parts: internal quality assurance within higher education institutions; external quality assurance of higher education institutions; and external quality assurance of quality assurance agencies. The third part of the ESG was designed to answer the question of what the next step will be once quality assurance agencies meet the ESG. First, meeting the guidelines allowed for full membership of ENQA. As of July 2010, ENQA counts 39 full members, all meeting the ESG. Second, the education ministers' summit argued for need of more transparency in the accreditation process, not limited to just European public quality assurance agencies, therefore an independent register of trustworthy quality assurance agencies EQAR – the European Quality Assurance Register for Higher Education, was established in 2008. The EQAR publishes and manages a register of quality assurance agencies that substantially comply with the ESG; it currently has 26 members from 12 European countries.

2. QUALITY TERMINOLOGY IN HIGHER EDUCATION AREA

In order to apply the ESG in practice, a common understanding of its terms across different linguistic and national contexts is a prerequisite. The majority of people working with the quality assurance issues in the European higher education institutions and accreditation bodies work in their native languages rather than English, thus creating room for different interpretation of the meaning of terms when translating them from English into local language. In addition, there is no guarantee that even native English speakers will always mean the same things by the same terms. This was clearly demonstrated during the ENQA workshop in Warwick in June 2006 which brought together representatives from a wide range of higher education quality assurance agencies, representing 16 different countries and at least 12 different languages. The discussion focused mostly on the use of English as a 'mediating' language for the European quality assurance community and the impact that this has on the clarity of communication [5].

For example, different understanding and usage of the term 'quality assurance' was discussed, a term imported into higher education from the world of business (and primarily from the sector of manufacturing) as is the related term 'quality control'. In France, for example, 'quality management' has often been used instead of 'quality assurance' in the translation, with the intent of instilling a sense of responsibility in the academics to manage quality for themselves. An interesting point was also raised by a Russian delegate explaining that in their system the word following 'quality' depended on the audience addressed i.e. *quality assurance* for broader society, *quality control* for regulators and *quality enhancement* - for the higher education sector.

Many of the difficulties in communicating ideas, processes and procedures regarding quality assurance arise both from the number of languages used and, interestingly enough, to a great extent from having adopted English as the common international language to ensure a common understanding. In addition, many terms used in quality assurance do not easily translate from English into other languages and vice versa. The use of English as the mediating language can also give rise to

misunderstanding and even a misplaced sense of effective communication [5].
ENQA refused to draft and publish a much needed "Glossary of Terms in Quality Assurance in Education". According to ENQA, there have been numerous requests to develop authoritative and comprehensive glossaries of concepts, words and terms used in quality assurance in Europe, but these have invariably proved to be of limited value because of the difficulty in agreeing on the meanings of the concepts and words themselves in English.
Different authors at different times have given definitions of in quality terminology according to their own vision. Therefore the authors would like to emphasize the significance of 'speaking a common language' if we are to reach the common goal – harmonized and improved outcomes and outputs of higher education in international context.

Quality assurance in quality management
The second paragraph of the ESG executive summary is marked with the following footnote: "The term 'quality assurance' in this report includes processes such as evaluation, accreditation and audit". Let us review, how this statement fits in the theoretical framework of quality theory in general and that of quality in higher education in particular.
The quality movement over its long period of historical development still does not have a well-established basis in management theory. According to B.Bergman & B.Klefsjö [3] and D.Kroslid [13], the development of the quality movement can be considered from two viewpoints: either as a four phase (Quality inspection – Quality control – Quality assurance – Total Quality Management) movement, or as movements of two schools of thought – the deterministic school and the school of continuous improvements. Such world-famous quality 'gurus' as Deming, Juran and Ishikawa are related to the latter one.
According to Juran's approach [12], managing for quality makes extensive use of three managerial processes:
- designing or planning for quality;
- compliance, controlling or assuring quality;
- improving or creating breakthroughs in quality.

These three processes are all interrelated and are known as the *Juran Trilogy*.
If we look at the definitions provided by the international standard ISO 9000:2005 - Quality Management Systems - Fundamentals and Vocabulary, we can find the following terms and explanations:
- *quality management* includes all the activities that organizations use to direct, control and coordinate quality. These activities include formulating a quality policy and setting quality objectives. They also include quality planning, quality control, quality assurance, and quality improvement.
- *quality planning* involves setting quality objectives and then specifying the operational processes and resources that will be needed to achieve those objectives.
- *quality control* is a set of activities intended to ensure that quality requirements are actually being met.
- *quality assurance* is a set of activities intended to establish confidence that quality requirements will be met.
- *quality improvement* refers to anything that enhances an organization's ability to meet quality requirements.

The simplified structure of Quality Management and its components according to the provisions of the standard ISO 9000:2005 is depicted in Fig.1.

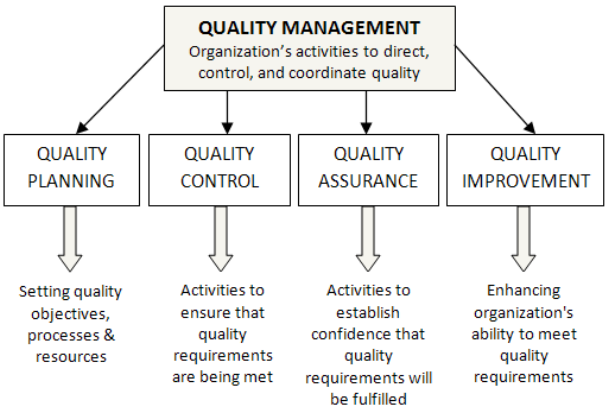


Figure 1. Relationship of Quality Management and its components [according to ISO 9000:2005]

If we compare the above mentioned models of quality management, it is evident that quality assurance as a set of activities providing confidence, that quality requirements will be fulfilled, plays a certain role as in the four phase model of B.Bergman & B.Klefsjö, as it does in the Juran Trilogy and the quality management structure of ISO 9000:2005 standard.

The meaning of quality assurance in higher education
As mentioned before, the term 'quality assurance' in ESG implies evaluation, accreditation and audit processes.
The glossary [9] gives the following explanations of these processes in the context of higher education:
- *evaluation of quality* is the process of examining and passing a judgment on the appropriateness or level of quality.
- *accreditation* is the establishment of the status, legitimacy or appropriateness of an institution, program or module of study.
- *audit* is a process for checking that procedures are in place to assure quality, integrity or standards of provision and outcomes.
- *assurance of quality* in higher education is explained as a process of establishing stakeholder confidence that provision (input, process and outcomes) fulfils expectations or measures up to the threshold minimum requirements.

Australian Universities Quality Agency (AUQA) explains in its glossary [2] the term 'quality assurance' as follows: "The policies, attitudes, actions and procedures necessary to ensure that quality is being maintained and enhanced. It includes checking that the quality control (QC) procedures are in place, are being used and are effective. It requires actions internal to the organization, but may also involve actions of external bodies. It includes course design, staff development and the collection and use of feedback from students and employers.
In manufacturing, quality assurance (QA) is a managerial level task. Because the line/managerial distinction is blurred in academia, and because the analogy with production is not perfect, the QC/QA distinction is not sharp. Quality audit (qv) reviews both QC and QA procedures.
Quality assurance is also used as a general term, to refer to the range of possible approaches to addressing the concern for quality in HE."
As noted also by N.Dragulanescu and R.China [7], quality assurance' is a generic term in higher education which lends itself to many interpretations; it is not possible to use one definition to cover all circumstances. Similarly, the word 'standards' is employed in a variety of ways across Europe,

ranging from statements of narrowly defined regulatory requirements to more generalized descriptions of good practice. The words also have very different meanings in the local contexts of national higher education systems [8].

It is the authors' belief that without considering the overall context of quality management these three processes – evaluation, accreditation and audit – alone cannot ensure quality of education. There is just one question to answer before we can discuss the quality of education – what do we understand by each of the terms and is our understanding uniform?

Historically, accreditation has been the most visible element of reflective review within higher education. Through a process that includes self-assessment and peer review, the professional, special focus and accrediting agencies, accreditation provides a regularized, structured mechanism for quality assurance and improvement for higher education community [15]. Following the logic of ESG terminology and its explanation in the glossary [9], accreditation essentially is a process that comprises audit and evaluation – in order to establish the status, legitimacy or appropriateness of an institution, program or module of study (*accreditation*) it is necessary to check whether the procedures are in place to assure quality, integrity or standards of provision and outcomes (*audit*) and to examine and pass a judgment on conformity of the level of quality to established requirements (*evaluation*).

The term 'quality assurance' is in fact broader in ESG than its authors' footnote definition stating that it "includes evaluation, accreditation and audit". Part 1 of the ESG, devoted to internal quality assurance within HEI confirms this: "*Policy and Procedures for Quality Assurance:* Institutions should have a policy and associated procedures for the assurance of the quality and standards of their programmes and awards. They should also commit themselves explicitly to the development of a culture which recognizes the importance of quality, and quality assurance, in their work. To achieve this, institutions should develop and implement a strategy for the continuous enhancement of quality. The strategy, policy and procedures should have a formal status and be publicly available. They should also include a role for students and other stakeholders [8]." This requirement clearly indicates that there should be not only quality assurance, but also quality planning, quality control and quality improvement components in HEI; or – speaking in terms of ISO 9000 standards, HEI should have a *quality management system.*

Quality management systems for higher education

Quality management – planning, control, assurance and improvement – systems started to emerge in European higher education at the same time as Bologna process begun, and were gradually developing in both the regulatory and voluntary spheres of HE, taking into account the differences in study goals, content and activities of academic and professional studies.

In the *regulatory sphere* of higher education – fields such as medical, maritime, construction, pharmacology, food, etc., the most appropriate way of conformity assessment of the study programmes or modules, according to the authors, would be either a quality management system designed on the basis of standard ISO 9001 requirements or a conformity assessment based on internal (the first party's) audit statement, external (the third party's) audit report developed according to the requirements of ISO 19011, and possibly the issuance of the self-assessment and/or peer assessment reports.

In the *voluntary sphere* the higher education institutions can choose one of two options:

- to develop a quality management system based on ISO 9004, IWA-2 (guidelines on application of ISO 9001 to higher education institutions) which envisages preparation of conformity certification documents: internal conformity self-assessment report and external peer assessment report in accordance with the requirements of standard ISO 17040, or
- to create a quality excellence system according to quality award models; this option envisages preparation of quality award application and assessment of conformity through the recognition of excellence by a professional institution.

The excellence model in HE extends the current business excellence models (EFQM Excellence model in Europe, Baldrige model in the USA) to address the specific needs of higher education and it does so, taking into account the standards and terminology used in accreditation. The result is a model that benefits from the strengths of both the excellence awards and accrediting frameworks [15].

Combining all these factors affecting quality in HE, a dynamic model of a national higher education Quality Management System (QMS) in European context is proposed (Fig.2).

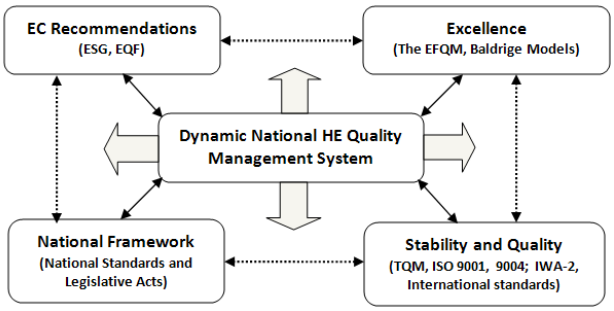


Figure 2. Main factors that can influence the evolution of National HE QM system in the context of current approaches

This model integrates the principles of Quality Management [11] and process approach; appropriate criteria of Excellence models; requirements of international standards (ISO 9001, 9004, IWA-2); ESG recommendations; descriptors of knowledge, skills and competence for learning outcomes of the levels of qualifications defined by the European Qualifications Framework; as well as national legislative acts related to accreditation and quality of higher education institutions.

3. REQUIREMENTS OF EXTERNAL ENVIRONMENT TO EDUCATION AND INTERNATIONALIZATION ASPECTS IN LATVIA

As demonstrated earlier, quality in higher education is affected by several factors and development of quality management system should take into consideration all of these. These factors, however, are not limited to regulatory frameworks and internal aspects of higher education institutions; the quality of higher education nowadays is affected greatly by the external factors both on the national and international level. The discussion of quality in higher education would be incomplete without touching on these aspects.

The environment in which the HEI operate is becoming more open to the increasing international influences and competition, thus creating more and more opportunities for partnerships across Europe and the rest of the world. This, in turn, leads to increasing opportunities for international studies. Rapidly changing environment increases the choice available to

students. Thus, HEI must embrace the internationalization of education and exploit it for the development and improvement of knowledge and well-being of each individual. The strategy of internationalization requires diversifying the study programmes available, attracting guest speakers and students, and involving students and academic staff in various international collaboration projects.

Internationalization strategy includes specific tasks and activities to attract students and foster international collaboration so as to attain the strategic goals of HEI and the common education space of Latvia and foster coherent actions of the parties involved. In order to attain the goals set for Latvia's education system and offer innovative education, each HEI should develop its own strategy and programme for international development (internationalization), including the following issues:

- develop study programmes, professional education and internationalization programmes;
- improve foreign students' experiences in Latvia and local students' international experiences and facilitate active exchange of students;
- develop and maintain international partnerships, create associations;
- develop skills of personnel and motivate employees to participate in internationalization.

Mutual agreements and contacts of HEI as well as activities in international recognition of education and academic achievements on EU level are gaining in importance. One of the main achievements over the last decade is development of bilateral and multilateral study programmes. EU-organized mobility programmes, such as *Erasmus* and *Socrates*, are also based on institutional recognition agreements. Since this type of academic mobility is becoming more and more widespread, we can predict growing need for agreements between HEI, especially in regard to mutual recognition of study periods. This factor will be substantial in recognition for academic purposes, yet it will play a role in recognizing the professional competencies as well.

It must be noted, however, that labour market as one of the driving forces of the content and quality of education attributes high value to international recognition of qualifications and education. Since labour market uses and applies the learning outcomes in real life, quality of education cannot exist separately from it. This is especially important with the free movement of labour in the open European space.

Thus, in order to embrace the internationalization and the demands of the external environment, and to develop a common understanding of the quality in higher education, such institutional agreements and best practice must be established within the existing common European system, e.g., Lisbon strategy or Bologna declaration.

The central role in Bologna process is dedicated to education mobility and recognition of qualifications. It seems fair to claim that mutual recognition of the qualification gained in other countries should be perceived as a bridge that allows people to transfer from one education system to another in the lifelong learning process without losing their „property" (i.e., the qualifications gained elsewhere) [14]. Bologna declaration speaks of the convergence of education systems, yet at the same time it does not insist on harmonization of all national systems, nor does it claim the implementation of the suggested system will solve all the related problems. The Bologna declaration envisages a common system as a framework that would facilitate mutual cross-border recognition of higher education while still allowing for differences within this common framework. The importance of retaining individual differences is also emphasized by management thought leaders, including USA scientist and practical management and leadership consultant I.Adidzes, who has said – „Management education of leaders of different countries should not be copied from a culture totally unlike their own. The education has to fit the needs of the country in which these leaders operate [1]."

The importance labour market puts on the recognition of higher education further emphasizes need for new tools for assessment and recognition of individual qualifications in the common European labour market.

EU member states have developed a framework of comparable and compatible qualifications for their higher education systems, which describes qualifications in terms of workload, level, learning outcomes, competencies and profile. EHEA, in turn, has developed an overarching framework of qualifications, comprising of three cycles (including the possibility of intermediate qualifications – according to national systems) and containing generic descriptions for each cycle based on learning outcomes and competences, and credit ranges in the first and second cycles.

EHEA ensures coherence between the overarching Framework for Qualifications of the EHEA and the broader Qualifications Framework for Lifelong Learning [17], encompassing general education as well as vocational education and training.

Development of national and European frameworks for qualifications is an opportunity to further embed lifelong learning in higher education system. This is achieved through recognition of prior learning including, where possible, non-formal learning providing access to, and acting as elements in, higher education programmes.

The decision of the European Parliament and the European Council on implementation of a common Community framework for the transparency of qualifications and competences (*Europass*) [6] is binding for Latvia as well. *Europass* system includes the following currently independent elements:

- Europass Curriculum Vitae;
- Europass Diploma Supplement – a diploma supplement for higher education;
- Europass Certificate Supplement. This document has not yet been introduced in Latvia;
- Europass Language Passport;
- Europass Mobility.

Introducing *Europass* in Latvia has created certain options for the providers of the education service offering and the labour market – including the international or at least the European one – to try speaking a common language. Success in making such documents comprehensible to the employer, especially if across the European space, and implementing those in real life would be a significant move towards sustainable long-term development of education system. However, as much as we would hate to admit, the educators and employers still speak different languages; they have different goals and expectations. Thus, there is still ample room for improvement.

Europass Certificate Supplement will also be introduced in Latvia. It does not replace the original documents of education and qualification, nor does it guarantee automatic recognition of the document. However, this Certificate Supplement creates a logical link to the profession standard and would thus make the professional qualifications awarded to the graduates of vocational secondary education and higher education in Latvia clear and easy to understand in the rest of Europe and possibly, across the world. It is meant to give a concise description of the major knowledge, skills and competencies gained during the study process. Thus, the development of the Certificate

supplement in Latvia must be closely related to the profession standard.

Evaluating the interaction between the education system and its services and the labour market, it is important to take into consideration the levels of education and the ability to change qualifications easily when transferring between two qualifications with minor differences in the competences required. The European Qualifications Framework for Lifelong Learning should serve as the basis for the purpose and professions (positions) should be classified according to the minimum essential levels of education required for performing the job, as well as by their main fields of activity, based on the main and sound long-term competences.

According to the European Qualifications Framework for Lifelong Learning (EQF), several definitions used in the education system require additional explanations [18]:

- *qualification* means a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards;
- *national qualifications system* means all aspects of a Member State's activity related to the recognition of learning and other mechanisms that link education and training to the labour market and civil society. This includes the development and implementation of institutional arrangements and processes relating to quality assurance, assessment and the award of qualifications. A national qualifications system may be composed of several subsystems and may include a national qualifications framework;
- *national qualifications framework* means an instrument for the classification of qualifications according to a set of criteria for specified levels of learning achieved, which aims to integrate and coordinate national qualifications subsystems and improve the transparency, access, progression and quality of qualifications in relation to the labour market and civil society;
- *learning outcomes* means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence.

Learning outcomes are one of the most important elements in the Bologna process. This lets us conclude that the documents certifying qualifications should be devised such as to be understood across borders.

The authors believe that it is possible to create a model of national qualifications framework in Latvia that is easily understood in the common education space of Europe. The scientists of University of Latvia and the researchers involved in the EU Structural Funds National Programme "Labour Market Research" have reached a similar conclusion [16].

The EQF has eight levels, four of which correspond to the European higher education qualifications framework – three of these are the cycles developed in the Bologna process (bachelor's, master's and doctor's) and the fourth – the short cycle programmes within the first cycle of Bologna process.

It becomes evident that the existing structure of professional qualification levels should be changed in Latvia. It seems only rational to reorganize it according to EQF levels; this way the structure of higher education would be built of three separate and different professional qualification levels, namely: level 6 for the award of Bachelor's degree, level 7 – for Master's degree and level 8 – for Doctor's degree. At the moment, however, the system is rather confusing since level 5 professional qualification is awarded both after graduating from Bachelor's as well as Master's professional study programmes.

In addition, the higher education system in Latvia is split into academic and professional education with two award systems – that of degrees and of qualifications. Such a complicated system creates additional confusion both in the general public, and also in the local and international labour market.

European qualifications framework covers the whole system of education and helps develop a common approach to lifelong learning. In 2005 a project on higher education qualifications framework in Latvia, proposing also the inclusion of the profession standards in the overall system, was presented. However, the implementation of this crucial project has not yet been completed.

The Action plan of the higher education and science reform in 2010-2012 envisages defining the learning outcomes in terms of knowledge and skills for every study programme and course, according to the unified qualifications framework (up to 2012), and assess the quality of study programmes, resource availability and sustainable international evaluation, applying adequately developed methodology (up to 2011). Therefore issues tackled in this article are important in Latvia today with regards to the higher education reform, which in authors' viewpoint, is a highly positive trend.

4. CONCLUSIONS

Even though significant progress has been made since the 2005 Bergen meeting of European education ministers, and our focus is now on reaching Europe 2020 goals, we are far from enjoying the results obtained in quality management in higher education. There is still no clear and unequivocal understanding of the terms like 'quality assurance', 'quality management' and similar amongst staff of HEI and civil servants. As mentioned in [10], it seems that quality has become "a play for ministries and agencies, quality on the shop-floor level and student learning experience certainly have not gained the centre stage of attention in this development".

The consequent lack of a shared linguistic understanding is one of the major stumbling blocks for the full development of the European Higher Education Area, at least in terms of shared values for quality assurance. If we are to achieve a common European, national and institutional level understanding on development of quality management system in higher education, agreement on the uniform use and understanding of the terminology is the most crucial first step.

The authors suggest adopting the most widespread four-step approach to QMS of business world for the HE environment as well. Additionally, understanding that *quality assurance*, which includes accreditation of study programmes or HEI, cannot be attained without introducing functional remaining components of QMS is of crucial importance.

QMS in HEI must be built as an integrated and dynamic system, considering all the factors influencing such a system – an appropriate internal quality management system model of HEI, requirements and recommendations of the national and European legislation, requirements of accreditation bodies and movement towards sustainable excellence in attaining the goals of education.

External environment influences, including globalization and labour market demands, put additional pressure on the HEI and quality management systems in HE. Increasing internationalization and student mobility forces HEI to not just reconsider and constantly improve their offering but also expand their international presence through partnerships with other HEI and hence, recognize the education obtained elsewhere. Labour market as the consumer of the products of

education system, in turn, demands a certain level and quality of learning outcomes as well as recognition of the qualifications across borders, which is important not just in the common European space, but across the globe. This brings quality, conformity with labour market as well as need for common or comparable standards and international recognition of education to the forefront of education systems.

Institutional agreements should be regarded as one of the ways of implementing a common process of diploma recognition. However, since these are bilateral or multilateral agreements between specific institutions, authors deem necessary a higher level overarching common process of diploma recognition across European space as a step towards convergence of education systems. Authors conclude that *Europass* system and also the EQF should be at the core of this.

It also seems that the European regions characterized by active and intense collaboration among universities, ministries, public organizations and entrepreneurs of different countries will be the first ones to attain the goals of Bologna declaration [4].

The authors come to conclusion that European Qualifications Framework allows comparing national standards and alleviates diploma recognition, mobility and cooperation in professional and higher education. Therefore, the methodology of development of profession standards, evaluation system and evaluation methodology as well as definition of competencies and labour market requirements should all be designed according to the common understanding of Bologna process requirements and conform with learning outcomes and forms of education. Following the latest European trends, the description of skills and knowledge as well as model of competencies could be devised around the eight qualification levels defined in EQF and correspond to the professional qualification levels assigned to lifelong learning. Thus, one of the primary tasks to attain the goals of Bologna process in implementing a common qualifications framework and competence transparency model in Latvia is harmonizing levels of national qualifications framework with the descriptors and levels of EQF.

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Collegiate Degree Value: A Global Perspective

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ABSTRACT

A nation's educational system is a key driver of its economic success. The US educational system, thus, can be viewed as one of a number of key ingredients in the economic success and stature of the United States on the world stage. Globalization of higher education, however, is changing the playing field somewhat and presents both risks and opportunities for both American domestic and international institutions. Nothing less than the long term economic success of nations rests on the success of educational institutions understanding, adapting to and prospering in these changing conditions.

Keywords: academic globalization, degree value, education system evaluation, education economics

1. INTRODUCTION

There are few products or services that are as prevalently consumed as education. While the level, standards and nature of this education varies from country-to-country, education is one of the most ubiquitous products worldwide. A nation's developmental progress and even global standing is, to some extent, measured by the sophistication of its educational system. Perhaps the most prevalent comparisons surround the nature and success of nations' collegiate education systems.

As educational systems are a critical component of having an effective workforce and strong national economy, there is clearly no shortage of controversy surrounding the topic. Some proffer that the US education system is the envy of the world while others suggest that US education has lost its way. The truth, however, is a combination of the two. To correctly place the US collegiate educational system in a global context, we must examine the prevalence and economic value of education in various countries as well as the similarities and differences in educational systems.

2. DISCUSSION OF IMPORTANCE OF EDUCATION TO SOCIETY

Higher education provides significant economic benefit to its recipients and society-at-large. Baum and Ma proffer that college graduates are likely to have higher earnings and are more likely to receive health and retirement benefits. Further, they identify other benefits such as improved health and increased prosperity for graduates' offspring. [3]

Society benefits from lower levels of poverty and unemployment. Baum and Ma also note that college graduates contribute more taxes than non-graduates and have a lower level of usage of various social services. The benefits extend to the non-college-educated, with a positive wage level effect for non-graduates caused by graduate workforce presence. College graduates, in general, also have healthier lifestyles, exhibit greater civic participation and are more likely to volunteer and vote. [3]

Collegiate education produces the scientists and engineers that advance production technologies improving living standards. It trains the doctors and researchers that increase public health. Literature and the arts are enhanced by the presence of college-trained artists and those with the understanding to critique, interpret and refine artistic works. Humanity's basic understanding of the world and universe is enhanced by scientific study in all disciplines. There can be no doubt that the contribution of education (particularly at the collegiate level) to society is tremendous.

3. TRENDS IN GLOBALIZATION IN HIGHER EDUCATION

Altbach, Reisberg and Rumbley suggest that academia has always been, to some extent globalized. They note that universities have operated within a global community for some time. However, a number of changes have occurred which have created enhanced interest in globalization. [1]

First, they note that the advent of English as a language of science and education is a significant development. They liken this to the way Latin was used in scientific circles in Europe during the medieval period. This standardization facilitates communication and the mobility of students, instructors, research papers and such. [1]

Second, the effect of telecommunications and the Internet must be considered. The immediacy of communication possible via these mechanisms allows forms of education (eg, distance and online programs) and collaboration not previously possible. [1]

Third, Altbach, Reisberg and Rumbley proffer that a massification of education has occurred. This phenomena, they

suggest, has resulted in lowered educational standards as more of the population seeks and obtains degrees. Globally, enrolment in post-secondary education by the relevant age population has increased from 19% in 2000 to 26% in 2007. However, participation and the increase in participation varies widely from country to country. For example, the same period saw only an increase from 5% to 7% in lower-income-level countries. [1]

Forth, international program expansion and cooperation has occurred. The Bologna Process and Lisbon Strategy have attempted to align European programs and create a European Higher Education Area. Countries including Singapore and the United Arab Emirates have encouraged foreign universities to set up campuses locally. Combined programs and a variety of other arrangements have also become commonplace. [1]

Finally, countries have adopted immigration policies designed to attract foreign students. Altbach, Reisberg and Rumbley note that in 2006, more than two-and-a-half million students studied outside their country of residence; they project this number increasing to seven million by 2020. Attracting foreign students is seen to provide host countries with financial and competitive benefits. [1]

While many things have changed, Altbach, Reisberg and Rumbley note that a great deal of inequity in access to education still exists, both at a national and personal level. An individual from a prosperous family in a developed nation, they note, has greater chances of educational attainment than an individual from a less well-to-do family or a developing region. [1]

4. OVERVIEW OF UNITED STATES COLLEGIATE EDUCATION

Eckel and King note that while the United States educational system has roots in both British and German educational formats, it is distinctly different from both. American colleges and universities compete fiercely for students and research funding and are somewhat protected from government influence (due to Jeffersonian ideals relating to free expression and limiting government). [7]

The United States higher education system consists of approximately 6,500 institutions including 4,200 degree-granting colleges and universities and 2,300 vocational institutions. These institutions provided instruction to 14 million undergraduate and 2 million graduate students in 2001 and issued over 2.4 million degrees. [7]

American post-secondary institutions include 1,165 community colleges which enrolled 6 million undergraduates in 2001. There are also 629 public colleges and universities which award bachelor's and higher level degrees. There are also 1,567 private not-for-profit four-year-degree institutions, 324 for-profit four-year-degree granting institutions and 779 for-profit two-year-degree granting institutions. [7]

Academic accountability is not administered by the government in the United States, but instead by regional and national accrediting agencies. These accrediting agencies provide minimum standards but do not, generally, dictate how those standards are met or provide any mechanism to compare performance of accredited institutions. [7]

The demographic of the American college attendee has changed dramatically with three out of four students (in 2001) being considered as having non-traditional characteristics. Forty percent of American students, for example, are over the age of 25. [7]

American students are comparatively mobile. Eckel and King proffer that the non-traditional characteristics of many students and the conflicting demands associated with this necessitates this mobility. Further, American students interact with institutions in a market environment where schools compete to attract top students and students compete to gain admission to top schools. [7]

5. OVERVIEW OF AUSTRALIAN COLLEGIATE EDUCATION

Australian higher education is conducted via a system of 39 universities. Thirty-seven of these are public universities and two are private. At the bachelor's level, three styles of degrees are offered. General bachelor's degrees require three years of study. Professional degrees require four years. Honours degrees require three to four years; an additional year can be undertaken to facilitate entry to post-graduate study. Graduate education includes coursework and research masters degrees and doctoral level degrees. [8]

Australia also has a vocational education system. This system grants associate degrees, diplomas and advanced diplomas. The Australian Qualifications Framework provides some level of alignment between university and vocational programs. Australian universities train a significant number of overseas students (26% of the student population originated from overseas in 2005). [8]

6. OVERVIEW OF NEW ZEALAND COLLEGIATE EDUCATION

Post-secondary education in New Zealand is provided by thirty-three public institutions which include eight universities, twenty institutes of technology and polytechnics, two colleges of education and three wānanga (Māori tertiary educational institutions). [10]

New Zealand has experienced a dramatic increase in post-secondary education participation and a demographic shift. From 1996 to 2006, the number of participates increased by 82% and during the 2001-2006 period, half of the growth was from individuals over forty years of age. This growth, however,

has mostly been at the certificate level (with 103% increase). Bachelor's degrees and post-bachelor's-level degrees have increased at rates of only 10% and 18% respectively. Like with Australia, a framework exists to provide some correlation between university and non-university education. [10]

7. OVERVIEW OF INDIAN COLLEGIATE EDUCATION

India's education system suffers from a great divide. On one side, technical and management institutions produce graduates that have been responsible for attracting software, engineering and other work from all over the world. Unfortunately, very few are able to benefit from this. Adult illiteracy in India was at 42% in 2006 and Cheney, Ruzzi and Muralidharan proffer that only 20% of Indians attend secondary schooling. As with many other areas, those from socially and economically advantaged families have significantly greater opportunity for educational attainment. [5]

In 2003, India had 272 universities, 16 institutions established nationally or by states and 13,150 colleges. Cheney, Ruzzi and Muralidharan suggest that the politicized nature of Indian educational institutions and teacher hiring and promotion results in poor quality. In fact, they note that the institutions may provide as much or more value from selection as from instruction. The technology institutes, for example, admitted just 1.5% of applicants. The selection process, they note, is relatively corruption-free. [5]

In India, 80% of undergraduate education is performed by colleges that are affiliated with a university. Under this arrangement, the university develops a program and sets the standards for student evaluation. The college instructors simply deliver the applicable material with little room for adaptation or modification. [5]

Indian programs are criticized for covering outdated content and focusing on memorization. A bachelor's degree, while a requirement for many jobs, has little intrinsic meaning due to the wide variation in degree and teaching standards. Many students, thus, pursue post-graduate or professional qualifications to increase their employability. [5]

A significant number of Indians attend overseas educational institutions. India had 110,000 students studying overseas in 2006; 80,000 of those studied in the United States. Of those studying in America, 56,000 were pursuing degrees in science or engineering. [5]

8. DISCUSSION OF DEGREE VALUE

There are many different ways to value a college degree. A typical model for degree valuation compares pre and post-degree earnings and computes the additional earnings value to degree holders (taking in to account the earnings forgone and tuition costs to obtain the degree). Many, however, would argue that this model is incomplete. A more complete model requires consideration of the experiential and social values of a degree as well as the economic ones.

Experiential value can be loosely defined as the value that accrues to a degree holder from the experiences that he or she has during the pursuit of the degree. This includes the intrinsic value of learning as well as the broadening-of-horizons that may occur due to academic breadth requirements. A degree program may help a student find a career path of interest and participation in shared interests forms friendships and builds contacts that can have economic and non-economic value to the student. Experiential value, thus, is undeniably present – and it may differ between particular degree programs, program types and national degree frameworks. It is, unfortunately, difficult to quantify.

Social value deals with the externality created by education. It is a recognition that others beyond the two parties involved in the education transaction (student and institution) benefit from educational attainment. Specifically, it is an understanding that an educated population has greater capability to deal with various social issues. Further, educated society members may be better informed voters and more concerned citizens. Again, these benefits may vary between academic pursuits and the locations that these pursuits are conducted. They are, also, difficult to specifically quantify.

9. SCARCITY AS A VALUE DRIVER

A rudimentary economic model would support the notion that scarcity creates value. Some have commented that the prevalence of colleges (including numerous ones that have no or extremely minimal entrance requirements) has diminished the value of a collegiate degree. In the United States, 24.4% of those aged 25 or older have at least a bachelor's degree. An additional 27.4% have an associate's degree or have taken some collegiate courses. In Australia, a similar 25.59% of those between 25 and 64 have a bachelor's degree or higher. Australia even more dramatically surpasses the United States in the 25-34 age group where 34.2% of Australian's have a bachelor's degree compared to 27.5% of Americans. New Zealand falls in the same neighborhood: 22% of those 25 to 64 have earned a bachelor's degree (29.3% of those between 25-34). The trend in both Australia and New Zealand is strongly towards higher levels of degree holders. Australia, for example, increased from 19% to 25.59% of the population between 25 and 64 holding a bachelor's degree over just ten years. However, both of these countries, in the author's experience, tend to hold collegiate degrees in higher esteem. The recent historic relative scarcity of degrees combined with the absence of perceived ultra-low-quality programs is perhaps responsible for the greater respect provided to degree holders. [2,4,9]

Furthering the notion that scarcity isn't strongly related to perceived value is the case of India. Only 7% to 13% of "young Indians" (not the population in general) are enrolled in collegiate study [6]. However, even with the relative scarcity (especially

compared to the United States, Australia and New Zealand), these degrees are not considered (generally) as valuable. For example, of those studying in the IT field, the NASSCOM industry association proffers that 50% are completely unemployable and an additional 25% would require "extensive further training" [6]. This is confirmed by this author's personal discussions with various hiring managers in India. Clearly, thus, program quality is highly relevant and scarcity's effects are less pronounced.

10. PROGRAM STRUCTURE AS A VALUE DRIVER

Another possible consideration is the nature of the degree program. Programs can be classified in to two quasi-distinct groups. Some programs (such as many in the UK, New Zealand, Australia and India) seek to impart only subject and subject related knowledge. Others (like most in the United States) seek to provide a well-rounded 'liberal arts' education incorporating studies in a major topic and other (in many cases unrelated or minimally related) topics. The subject-focused programs can be completed more quickly; however, there does not appear to be any strong correlation between either type of program structure and higher value.

11. IN-SITU OBSERVATIONS

The author's personal experience in the United States, Australia, New Zealand and India as well as procurement experience in Asia has provided significant exposure to the product of these areas' educational experience. While insufficient space exists to fully describe these observations in this paper, two key points of qualitative observation bear mentioning.

First, the relative prestige of bachelor's (and higher) degree holders is quite different in Australia and New Zealand as compared to the United States. Particularly in New Zealand (and to a lesser extent in Australia) possession of a bachelor's degree is prized and frequently advertised on business card and such. In the United States, on the other hand, a bachelor's degree is the basic price-of-admission for many jobs and, while listed on one's resume, is not promoted to the same extent. In India, bachelor's-level experience is looked at as having minimal benefit. These degrees infrequently provide complete preparation for entry in to the workforce. As an antidotal example, many managers in India are not at all surprised to find individuals with a technical bachelor's degree working in unskilled occupations such as working as a taxi driver.

Second, the perception of foreign degrees varies somewhat from country-to-country. In the United States, foreign degrees (particularly from many Asian and Indian universities) are not given much weight. Conversely, Australians and New Zealanders look favorably upon degrees from abroad – particularly from the United States and Europe. Overseas degrees are also viewed favorably in India – though many believe that Indian domestic degrees are gaining in stature. This difference in perception may be attributable to the perception of particular programs, in various particular instances. However, there are clearly differences in perception from country-to-country.

12. PROBLEMS FOR DEVELOPED ECONOMIES AND INSTITUTIONS THEREIN

If the skills that universities in developing economies are providing are approaching those provided by US and European institutions, it would seem reasonable to presume that wages will be pressured by market forces to rise in developing countries and fall in more developed ones until a parity is reached. There are, of course, factors that will prevent a complete equality such as the cost of transport and cost of living differences that are factored in to wages. However, given the fact that much knowledge-centric work is highly portable – or that individuals themselves have some level of mobility to areas where workers are in demand – it would seem that a dramatic shift is approaching. Those that stand to lose from this and seek to preserve the status quo would be well served to determine if there is some additional value that can be provided by educational institutions in developed countries that cannot be easily duplicated or leap-frogged by those in developing economies. Countries must justify their higher wage levels and institutions must justify their greater expense compared to their developing economy counterparts.

Whatever value higher-wage countries degrees may have, it is all but inevitable that this will erode over time. There are already signs of this. India, for example, boasts 5 top 400 schools. China now has a school in the top 50. This is particularly auspicious given that the ranking metrics are developed from a western perspective and may thus favor western schools. The fact that major corporations are shifting research and development activities to both countries is clearly a testament to their collegiate education systems as well. [13]

13. OPPORTUNITIES FOR DEVELOPING COUNTRY INSTITUTIONS

The increasing perceived-value of foreign degree programs presents significant opportunities for institutions located in low-cost areas. These institutions can benefit from their high-perceived-value and low costs in four ways. They can produce degree holders for employment in their local and international markets, they can offer on-their-site education to individuals from higher-cost markets, they can create e-learning and other distance programs to offer to students in higher-cost markets and they can provide instructional services (perhaps as part of a joint-initiative) for institutions in higher-cost areas.

A degree from a well-respected institution can ease the movement of a worker in to a foreign market. In some cases,

the degree may be required for or facilitate visa application. It also will likely be a key decision influencer for firms as part of their hiring process -- particularly for recent graduates. Foreign work experience, similarly, can be valuable.

Thus, individuals seeking lower-cost, high-quality education may choose to enroll at a degree program in a low-cost area. Not only does the individual benefit from reduced costs, he or she gains experience in the local culture. Many firms (particularly multinationals) view foreign experience as valuable and, thus, a degree from a high-perceived-value overseas program may have additional benefit.

The advent and dramatic growth of e-learning provides another opportunity for overseas providers. Institutions whose degrees are of high-perceived-value can offer online degree programs to students in higher-cost areas. Also, they may be able to offer single courses for transfer to other institutions.

Finally, an institution (or commercial provider) in a low-cost area may partner with a college or university in a high-cost area to provide instruction services. This instruction could be provided via e-learning mechanisms, video conferencing or other mediums [e.g., 11, 12]. The provider intuition (or company) is able to generate local employment (and potentially employment opportunities for local graduates of the institution) and revenue from the arrangement while the higher-cost-area institution benefits from reduced instruction costs. Further, the dramatically lower costs may facilitate lower class sizes and additional personalized attention for students.

14. AN ATTRITION MODEL FOR DEVELOPED NATIONS

Some suggest that globalization should not be feared by those in developed markets. Wildavsky, for example [see 14, 15], proffers that there is no limit on the amount of learning that can occur and thus educational gains in one country don't necessitate losses in others. In fact, gains by overseas educational institutions will likely be beneficial to students (who may benefit from lower prices driven by market competition and lower-cost instruction providers) and human knowledge in general.

However, market forces created by cost differentials will likely not be particularly beneficial to developed (higher-cost) nations. The foundations of an attrition model, thus, can be developed. This model must be considered at two levels: institutional and national.

Institutions risk declining student enrolments (particularly in e-learning programs where close proximity is of minimal benefit). They may lose some of their high-fee-paying overseas student base (who decide to obtain education in their own or an alternate market) and may also suffer cost pressures from and even the loss of domestic students to overseas institutions.

Research grants and other funding sources may also be impacted, if lower-cost institutions can capture them instead. These declining enrolments and research funds may diminish the reputation of the university over time, resulting in yet lower enrolments and research funds. This may create a downward spiral effect for the institution.

On the positive side, institutions may benefit from lower-cost labor available in developing economies. These institutions may decide to hire instructors to conduct classes remotely via telepresence (for on-campus courses) or various distance learning techniques. Further, this may have the effect of driving down educator wages in developed countries, further benefiting institutions.

From a national perspective, education is a key wage-level influencer. If high quality education is available in lower-cost regions, there will be little (other than existing deployed capital and transportation costs) to support the higher wages in developed countries. Companies will, in pursuit of their own best interests, locate their research and development facilities in locations where they can maximize benefit and minimize cost. If benefit is roughly equal (due to having access to similarly qualified staff) then the cost differential will be a key influencing factor. Over time, wages in developed countries may be forced downward by market effects.

15. COMBATING ATTRITION

There is no silver bullet for combatting the attrition previously discussed. Left completely unchecked, a basic market model would suggest that educational costs would decline as more and more low-cost entrants with quality programs enter the market. India, for example, had costs-to-student (inclusive of tuition, lodging, transportation and supplies) ranging from $810 to $1,487 for bachelor's degree students in 2001-02 – a small fraction of what students in a developed country like the United States would pay. If these programs (or even some of these programs) are of sufficient quality, students that might have studied in developed countries may choose to study in India instead. While they would incur transportation costs to and from India (perhaps even several times per year due to breaks and such), their total cost would be less than the costs of virtually all United States universities (absent a complete scholarship, significant cost-transference from living with parents, or such). Over time, once all of the low-cost entrants have entered and begun serving the market, costs would be expected to start to rise. This model, however, is overly simplistic. [5]

The model neglects, for example, the fact that a variety of factors are considered beyond costs in making a college selection decision. The first, and likely the most influential, is the fear and uncertainty factor. Many parents would not feel comfortable having their son or daughter studying in India or

other low-cost locations due to a lack of familiarity, distance and fears founded on the occasional terrorist attacks in these regions.

Second, the model fails to consider job placement. Presuming that the student hopes to seek employment in the developed country (and not the low cost location), a local university is likely better equipped to provide placement assistance.

Finally, differences in primary and secondary education systems may make it more difficult for students to transition to post-secondary institution in other countries. This may provide additional incentive to remain in one's home country.

In addition to the above, attrition can be combatted by the introduction of added-value by high-cost-location institutions. For example, these institutions can involve students in ground-breaking research and provide other opportunities that are not available in low-cost-region institutions.

16. CONCLUSION

The value of an institution's degree is clearly more than the economic benefit to its graduates. Educational institutions have an important role in personal advancement as well as in the advancement and comparative strength of nations. While the United States is currently a leader in collegiate education, there is no guarantee that this situation will persist. Educational advancements overseas may benefit humanity-in-general through advances in technology and science; however, this benefit may not extend directly to the United States economy and educational institutions.

For American institutions to remain strong and the American economy to recover, it is necessary for the US education system to provide value over-and-above education systems in developing countries. Some of this value already exists. It takes the form of placement competency in the local economy, a spirit of innovation and a tradition of research excellence. However, more value sources are needed to ensure the future prosperity of the American collegiate education system and the American economy at-large.

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Writing As Strategy: Transforming Authorship In The Design Classroom

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One very significant benefit of writing is that it requires shifts in perspective, which is an important skill in dealing with client-involved work. Unlike most self-generated projects, commercial work with clients requires a flexibility of thinking that is made agile by writing exercises of the types outlined at the end of this paper. The designer must see the body of visual work–and be able to analyze and change it–from multiple viewpoints. The designer must be her/his own critic, looking at the work as an outside agent. She/he must be able to see the work as the client involved, embodying that client's set of beliefs and expectations. The designer must see as the production artist, as author, audience, merchant. The ability to move around these roles, taking them on and returning to that of author, ultimately, to resolve external visual and interpersonal problems, is not an easy one to acquire, nor is it one that is mentioned very specifically in design courses. The designer has multiple actions to perform as author, and must evaluate and discuss the work with clarity of vision from a number of different perspectives.

We propose here that this agility can be strengthened through writing because the surprise of the unexpected is introduced (exercise parameters), the shift in perspective is pointed out and required, liminal space is opened in which "...there is little distinction between self and environment, between stimulus and response, or between past, present and future" (Csikszentmihalyi, 1975). Even before the illuminating results of the writing are read and implemented (and read almost as the critic, rather than agent, even for the author), the process has wrought important shifts, thereby making these very shifts familiar for use in the designer-client relationship.

In this paper, we examine some important theories that cross disciplines and are methodological models for a purposeful use of writing exercises in the design curriculum. Following these, we will share the contexts and analyses of several exercises utilized across the design curriculum and from our shared experiences teaching in several universities.

The undergraduate graphic design curriculum is expected to do many things. At the end of their coursework, students are meant to be creatively flexible, experts at the affairs of business, interpersonally gregarious, adept writers and skilled at complex visual communication. There are a lot of factors complicating the efficacy of a program built to provide these skills. Important among these factors are that different people learn differently; that design coursework appears in schools and programs with vastly different philosophies of design, including being located in critically different areas (art departments, technical schools, portfolio schools). For example, design curricula situated in an art department and/or within a school of the arts or of liberal arts may open more time for experimentation along the way to an end result, while more portfolio-based technical programs will eschew certain elements of process in order to produce more pieces of final work and sometimes using more time for elaborate software instruction. This paper focuses on work observed in undergraduate level writing in graphic design courses in the first case; areas of art in a university system where the proximity to liberal arts study as well as foundational requirements which use writing in core capacities makes writing paramount and focus on process an accepted use of time. However, it is the belief of the authors that the benefits of writing are truly universal. These benefits and their situation at the experiential and formal corners of graphic design, examined through philosophical and theoretical systems, are what make up the bulk of this paper.

Why We Assign Writing: Goals and Intentions

The reasons for assigning writing in the design curriculum are multifold, as are the styles of assignment and point of insertion on the continuum of the design process. Writing is assigned in order to

disrupt a static classroom environment. Writing can interrupt the flow of work, one that in design can be determined generally as: defining the problem, ideation, examination and refinement, analysis, selection, production. Writing opens up experimentation and brainstorming processes and loosens rigid attachments to solutions that have become standards and therefore immutable. Writing develops written, verbal and critical skills that are inherently necessary in becoming a working designer. Finally, writing, for the design student, makes ideas real and concrete. The ethereal existence of the unspoken/unwritten idea is made concrete which means it can be analyzed, edited, produced. In her discussion of structure, Andrea Marks parallels the processes of developing a larger piece of writing with that of making a designed piece (Marks, 2004). In the sense of writing as product rather than solely process, John Chris Jones speaks of writing as a way to gain a clearer understanding of the scope of a design problem.

The Space for Writing

It is certainly of import to recognize the variety of contexts or "venues" in/on which a writing exercise can take place. Here, by exercise, we mean a writing assignment of 1000 words or fewer that asks the student to answer a pointed question or asks for either directed or open reflection on visual or other written work. Venues may be a blog or wiki online written outside of class, in-class writing on paper or typing, and at-home typing. We have a few thoughts on the differences each of these venues make on process and product, but only as a means for recognizing that part of the educational architecture; this question of venue has many implications and can be developed in a separate inquiry. Also very important but representing another branch of study is the quality of the writing and how that fits into the process, style and fruit of writing exercises. Bloom's taxonomy of cognitive complexity can be a useful tool here. (Granello, 2001)

A course blog offers several distinct advantages over a university system. Primarily, second party vendor blogs offer the ability to bring in guests from outside the system. These guests are allowed full access to the content as well as the ability to become members of the community. A second, unexpected, outcome found in observing class work is that students seem to feel more at home outside the university system. They post additional information about design events, other blogs and even personal work. Finally, the lifecycle of an outside blog is infinite and can be revisited while most university systems are finite and rarely last beyond the scope of the class.

For a student, writing passages online for review is in process interior but in product exterior.

The visual and perceptual frame built into online work creates a liminal space for working that is disconnected. The benefits of this are that students attack the work without the fraught personal connection that comes from speaking aloud to peers or writing thoughts on paper. The work is that of a video game. The liminal space is activated only when the written work is posted, but again the visual framing (boxes within boxes–literal frames–and other visual noise) puts the work outside of itself and into a commercialized play zone. There is a fastness and ease to this writing. The charged moment happens after the act of writing has been completed.

Writing online either in a wiki or in a blog or the university's online system does add vigor to the process. It is possible that this liveliness is due to the game-like aspect of working online. The student may feel more comfortable with several modes of content running at the same time: music playing, internet open, blog open: there is a sense not only of the current moment which brings energy to the activity of writing online, but also the electricity of being seen, of being made public. Land and Bayne provide a clear and expressive vision of what educational work online means by citing Barnett:

'The last two decades have witnessed, as part of the wider phenomena of globalisation and 'supercomplexity' (Barnett, 2000), an inexorable shift in higher education from print-based culture to digital. This shifting emphasis has occasioned different ways of generating and engaging with knowledge. Print culture, in the form of the stable, bounded, individual and private text, has tended to operate within, and to reinforce, patterns of authority and individualized authorship. The digital, more protean and volatile, is concerned increasingly with image, openness, multimodality and collectivity.

...we now live in a world of radical contestation and challengeability, a world of uncertainty and unpredictability. In such a world, all such notions – as truth, fairness, accessibility and knowledge – come in for scrutiny. In such a process of continuing reflexivity, fundamental concepts do not dissolve but, on the contrary, become systematically elaborated. (Barnett 2005, p.789) (Land and Bayne, 2008)

Writing on paper is no longer preferred, seen by students as too limited, too quiet, too slow, and eschewed for the championed pastiche of digital options by faculty. Writing on paper has more limits. There are a lot of virtues to the perceived "limits" of pen and paper. When writing online, the work of expression can be multimodal; images and grabs from online sources can be seamlessly embedded in the

student's own final, layered and published piece. When writing on paper with a pen, or working strictly within word processing software with no access to the internet, the life of the thought, and its subsequent memorialization in permanence, is kept within a smaller realm. This thought, these ideas, are not less than those built from multimodal sources (Felten, 2008), but are challenged (in the best circumstances) to communicate even more within these tighter parameters. Rather than patching together already created information with only a few self-authored phrases or paragraphs, the student must develop an idea with depth rather than breadth. This difference is a compelling one, and one that makes variety in exercises so worthwhile.

Liminal Space and Dissonance In Writing Exercises

Writing in class is a ritualized activity. The student is in her/his body alongside peers, all working at the same time and physically together at the same time. The awareness of this, however subconscious, with the intimacy and quiet of pencil and paper, allow some challenging thoughts to puncture the writing process, but the cleared space in time and with literal and figurative quiet infuses the writing with a higher level of self-reflection. The charged moment occurs during the process of writing more so that in the case of online writing, which elicits its charge upon posting. A fascinating arm of the study of writing and experience can found in the works of Derrida, Husserl and Merleau-Ponty. Less important to our specific inquiry here are their thoughts on spoken versus written voice, which is often found in tandem with the more pertinent perspectives on truth, the ideal and the consciousness of time. (Dastur, 2006)

Critically reflective writing exercises make up the bulk of writing techniques that can charge the liminal space of process-oriented work time for the student. Shifting focus from evaluative inquiry to the issue of agency in critique allows a view into how writing develops understanding in undergraduate design education. We see cases of the student designer/author analyzing her/his own work; the designer analyzing her/his peer's work (empathy, constructive criticism, forming an argument using language and values that intersect with those of classmate); and the student designer analyzing the work of an established designer or one simply not personally known by the student (placing work into historical context and larger scale problems; addressing cultural, economic, age, gender, language differences). In each of these cases the writing has a different role.

Writing allows a sense of distance from the physical visual work while navigating the history of the making of the work. The student stops the process of working, of focused creation; this interrupts it. This interruption is one half of the benefit of the writing exercise. This is where awareness of the theory of cognitive dissonance is useful in understanding the flow of work and where writing enters that flow. The part of Festinger's theory that applies beautifully to the scope of investigation here is that of two cognitions: that there are two knowns that are dissonant. Either incoming dissonant information must undergo a shift in order to be assimilated into the existing belief or the reverse must happen; existing beliefs must shift in order to fit the new and mismatching information. Festinger writes:

"...what captures our attention are the exceptions to otherwise consistent behavior…"

1. The existence of dissonance, being psychologically uncomfortable, will motivate the person to try to reduce the dissonance and achieve consonance.

2. When dissonance is present, in addition to trying to reduce it, the person will actively avoid situations and information which would likely increase the dissonance.

(Dissonance is *"the existence of nonfitting relations among cognitions") "Cognitive dissonance can be seen as an antecedent condition which leads to activity oriented toward dissonance reduction..." (Festinger, 1957)*

Festinger goes on to investigate and elaborate on the opportunities for resolving dissonance. Our interest is in the moment, the pre-liminal moment, when dissonance occurs and becomes the catalyst for work toward causation of consonance.

Dissonance is forced by the writing assignment (and in different ways, as we will see) and liminal space opens. The liminal space, open, untethered, comes before edits are made, even before the focus on editing or change happens.

In Charlotte Bloch's paper "Flow: Beyond Fluidity and Rigidity. A Phenomenological Investigation," she opens a discussion on the term flow, found in the social sciences, which "refers to a particular type of experience characterized by feelings of fusion with an on-going activity, effortlessness, and fluidity." (Bloch, 2000) In her paper she criticizes prevailing theories regarding flow as stopping short of a requisite level of complexity, but for our needs, the general

understanding of flow as a phenomenon is useful. Bloch historicizes the theory of humanist psychologist Csikszentmihalyi and quotes him saying about flow:

…action follows upon action according to an internal logic which seems to need no conscious intervention on our part. We experience it as a unified flowing from on moment to the next, in which we feel in control of our actions, and in which there is little distinction between self and environment, between stimulus and response, or between past, present and future…the "flow experience":

* focused attention and complete involvement,
* the merger of action and awareness,
* freedom from worry about failure,
* the disappearance of self-consciousness,
* the distortion of a sense of time, and
* a reward in the experience itself ("auto-telic").

This series of experiences reflect very well the benefits of writing for the student. The finished product and conversations with colleagues and clients are measurable, concrete, and most importantly, only very marginally abstracted parts of the process of design. The opened out, abstracted, liminal arena writing creates in space and time is priceless and covered succinctly by Csikszentmihalyi in his writing about the theory of flow.

As mentioned previously, there are a number of factors affecting how the writing exercise affects student work, where it can fit into a class period, and how effective it is. A rich area of investigation is that of role and perspective. The student may be asked to engage in the critique of another's work as instigator, as continuator, as definer, as questioner. The exercise may require that the student write about her/his own skills (self-reflection), either in the first person, or sometimes in the third person, which enables displacement from observation to critique; into a shifted second voice with its objectivity.

At this point we provide a small sampling of exercises utilized in graphic design courses taught at the undergraduate level and which show some of the techniques and intentions opened out thus far.

Examples of Student Writing Exercises

Summary: One-sentence overall project summary
Venue: Writing "venue" (online, on paper in class, on paper outside of class)
Parameters: Assignment requirements and guidelines
Goal and outcome: Writing assignment a) goal and b) analysis of outcome

COURSE: GRAPHIC DESIGN I
Summary /
Develop a graphic translation of an object through observation and progressive visual studies.
Venue /
Online blog site created for class
Parameters /
75-150 word synopsis of student work shown in the post. Followed by 150-300 word critique of each of their classmates' work.
Goal and outcome /
Use blogs as a form of peer critique. Examples include critiques of class work on blogger. Also use the exchange of written criticism during class. Using critique of existing work in order to address basic design principles. Writing about peer work.

COURSE: GRAPHIC DESIGN I
Summary /
Read Chapter 5 in Type and Image, write on process from several points of view.
Venue /
Write or type list outside of class; discuss in next class period.
Parameters /
Read Chapter 5 in Type and Image, about design process. Research and find (in a interview or essay, etc.) what another designer's process is. How does it relate to the process described in Chapter 5 and how does it relate to your own? Write 250-500 words on this.
Goal and outcome /
The goal was to awaken students for the first time to their own process, to ask them to locate themselves in the design profession alongside others who have different ways of approaching a problem, reevaluate their own methods, start a larger conversation about how people work. Learn about previously unknown designers. It took some digging to find this sort of information, which asked more of each student researching than a quick skim of the internet. Comparison with other designers allowed students to discuss something relatively internal and untouched. Students learned from each other, which reinforces a healthy community-oriented methodology for future class periods.

Conclusion

Understanding the importance of perspectival shifts in the client-designer collaboration, wielding surprise and the richness of the liminal moment with purpose, and forcing dissonance are all facets of the view of writing we need in order to push our students to gain the level of cognitive and interpersonal agility necessary for being vibrant agents in the field of design. Writing is an asset as process, as product, as a tool for developing concepts and following ideas from word-map to established thesis. The written and the visual have interconnections that can be used fruitfully when educators develop and respect the venues, spaces, interior/exterior crossings and liminal moments of the act of writing.

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The Joint Academic Program Between Jacksonville State University and Taizhou University: From Inception to Implementation

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ABSTRACT

Jacksonville State University, located in Jacksonville, Alabama, is a state-supported, regional, coeducational institution. Three years ago, representatives from Jacksonville State University (JSU) began speaking with specific staff and faculty members from Taizhou University (TU) located in Linhai, China. Conversations involving possible university collaborations took place and resulted in a signed memorandum concerning a dual-degree computer science program. This paper describes some of the evolving collaborative undertakings with other Chinese universities as well as the on-going experiences and challenges encountered in the implementation of the dual-degree program with Taizhou University.

Keywords: global collaboration, academic joint programs, accreditation, Jacksonville State University, Taizhou University.

1. INTRODUCTION

Charlton and Andras describe globalization as some entity that refers to the increasing dominance of an international network of communications—especially in the economy, but also in social systems such as politics, the mass media, and science and technology [3]. In the same essay, they further argue for the need to standardize basic structures and the continuous specializations of advanced functions in science education.

Globalization has inevitably impacted the relationship between higher education and the economic growth of a country. The need for talented and skilled individuals managing businesses abroad gives higher education a major role in the supply of this resource. Higher education shapes and is being influenced by the configuration of regional trading blocs and is becoming similar across countries [4]. Colleges and universities face the dilemma of preserving the legitimacy of their national culture when entering the global market with various beliefs and behaviors [14].

Globalization is influencing the educational market and the situation is changing rapidly in the recent years. The theme of academic globalization is becoming more and more important for many universities around the world, as a process that helps the student graduation experience (by creating an expert with new characteristics that cannot be provided in their home university, or even in their country), and the university research programs (allowing professors and researchers from another university, even from another country, to collaborate or even to lead a research program) [1].

In recent years the global university system has been transformed by the new technology and political trends. The Internet and lower cost international travel have made it easier to collaborate with academic colleagues in other countries. In addition, the end of the Cold War has expanded the participants and the range of points of view in international academic conferences. As a result it is possible now to think in terms of a global network of universities with local nodes rather than in terms of separate institutions [16].

Three years ago, representatives from Jacksonville State University began speaking with specific staff and faculty members from Taizhou University (TU) located in Linhai, China. Conversations involving possible university collaborations took place and resulted in a signed memorandum concerning a joint degree program.

Beginning Fall 2010, JSU welcomed its first group of TU students to further their comprehension of the English language and their study in the field of computer science. The format of the program is called a 1-2-1, whereby Chinese students complete their first year of study at TU, come to JSU for two years of study, and complete their dual-degree in TU.

The first summer the Chinese students spend in Jacksonville will involve an intensive session of study at JSU's English Language Institute (ELI). The first group of Chinese students is set to arrive at the ELI in Summer 2010. After completion of the entire program's course of study, these students will have earned a Bachelor of Science in Computer Science from both TU and JSU.

In this paper, we will describe some of the developing academic partnerships with several Chinese universities and the experiences and challenges we have encountered in developing the dual-degree program with Taizhou University.

2. INSTITUTIONAL PROFILES

Jacksonville State University (JSU): JSU, located in Jacksonville, Alabama, is a state-supported, regional, coeducational institution. Drawing students primarily from Northeast Alabama, the University is committed to providing a wide variety of undergraduate programs to a diverse population that includes many first-generation college students. The enrollment at JSU during the past five years averages 8896. In 2005, roughly 24% of the student population was African American, Hispanic and American Indian and more than half (59%) were women. These enrollment figures put JSU in an excellent position to broaden and enable the participation of members of the underrepresented groups in the STEM disciplines. JSU is primarily a teaching university. It takes pride in its ability to produce quality graduates who undergo rigorous theoretical as well as practical mentoring. It is committed to providing appropriate instructional facilities and resources to assure that students have experience with the most recent technology.

Taizhou University (TU): TU is located in Taizhou city, the new coastal city in east China. TU is a comprehensive university. With a long history of running the school, TU started in 1907. During decades of practicing, the university is in possession of solid foundation and ample experience in terms of teaching and research. At present, there are more than 7,000 students and more than 800 faculty members. There are 13 departments or colleges at TU. The university has 9 branches of subjects, including literature, natural science, engineering, management, medical and education, etc, covering 38 Bachelor's Degree programs and 16 Associate-degree programs. TU has been active in carrying on international exchange and cooperation and has maintained friendly relationships with foreign universities, such as Lincoln University of New Zealand, Chodang University of the Republic of Korea, and Magdeburg-Stendal Applied Science & Technology University of Germany. Every year outstanding faculty members will be sent to overseas institutions as visiting scholars for further study and research, which will broaden their horizon [13].

Huaqiao University (HU): HU is a national university located in Quanzhou and Xiamen, Fujian province, China. HQU was founded in 1960, with support from the late Chinese premier and historical figure Zhou Enlai for students of overseas Chinese backgrounds (Hong Kong, Taiwan, Macau, Singapore) to pursue tertiary education in their ancestral homelands. This university is situated in a famous overseas Chinese hometown - Quanzhou city, in Fujian province. The university has two campuses, one is the main campus in Quanzhou and the other one is the new campus in Xiamen. Since the founding of the university 45 years ago, the University has graduated more than 76,000 students, of which 36,000 are from overseas. The University has now 24 000 full-time on-campus students, including 3,000 overseas students from 29 countries and regions such as Taiwan, Hong Kong, Macau, Malaysia, the Philippines, Indonesia, Thailand, Japan, United States and Argentina [9].

Zhejiang University of Media and Communication (ZUMC): ZUMC is a highly professional institution of higher education in China in the area of media and communications. The University was born 30 years ago when China reached out to embrace the world. The majority of their graduates would work for media organizations such as radio and TV, newspapers and magazines, advertising companies and film producers, etc. In recent years, strategic steps have been taken to open up international channels for academic activities such as teaching, researches, cross-continental conferences and jointly conducted programs. ZUMC has established firm and constructive relations with a number of overseas universities in the area of student degree programs, teacher training and degree programs and joint research projects. ZUMC will make constant endeavor to provide the best learning and teaching environment for both domestic and international students and scholars [18].

In April 2010, one of the authors of this paper visited Huaqiao University and Zhejiang University of Media and Communications. One of the many objectives of the visit is to explore the possibility of expanding the JSU-TU dual degree CS program to the two universities. A memorandum of understanding was exchanged with Huaqiao University and an exploratory talk was made with the Department of Information Technology at ZUMC. Also, in Summer 2010, a number of English

teachers from TU visited JSU for an intensive English proficiency workshop.

A graduate degree program in English, specifically for ZUMC students, is initiated at JSU during the 2010-2011 academic year. Furthermore, in August 2011, ZUMC visited JSU to explore JSU's graduate program in information technology. As a result, two graduate students from ZUMC will commence their studies at JSU in the Fall 2011 semester.

3. DESIGN CONSTRAINTS AND ACCREDITATION FACTORS

The design of the dual-degree computer science program is first described in our previous work [15] and we would like to reiterate it here for the sake of clarity. It is guided by Jacksonville State University's (JSU) accreditation constraints and the current University mission and department objectives. The two accreditations affected by this program are those from the Southern Association of Colleges and Schools (SACS) and the Accreditation Board for Engineering and Technology (ABET).

JSU's commitment to these two accreditation agencies requires that the following guidelines be satisfied:

1) A student in the program must pass the English Competency Exam (ECE) before the completion of his/her one-year residency at JSU. (SACS)
2) The Major Field Test (MFT) and the senior survey must be completed by each student in the program before graduation. (ABET)
3) Every course in the joint program must be taught by a qualified instructor who possess by a graduate degree in the field of study and stays current and active in the discipline. (SACS and ABET)
4) Students must be provided with access to adequately equipped computing laboratories and to the Internet. (ABET)
5) Faculty members and students must be provided with access to published reference materials in print and digital format to keep them abreast of current trends in the discipline. (SACS and ABET)
6) Students must be provided with a capstone experience that will give them a chance to apply their acquired skills and knowledge to solve a challenging problem. (ABET)
7) Students can complete the program in a reasonable amount of time by offering courses with sufficient frequency. (SACS and ABET)
8) The curriculum must adhere to the objective of preparing students for a professional career in modern society by combining technical requirements with general education requirements. (SACS and ABET)

- At least 40 semester hours of CS
- At least 15 semester hours of Math (discrete, differential and integral calculus, probability and statistics)
- At least 12 semester hours of science
- At least 30 semester hours of humanities, social sciences, arts, and other disciplines.
- Oral and written communication skills must be developed and applied.

4. THE ACADEMIC JOINT PROGRAMS

We investigated two forms of academic joint programs: a 1-2-1 joint program and a 2+2 joint program. The 1-2-1 joint program entails the completion of the first and last years of study at the home institution of the student. With the 2+2 program, the student starts his/her first two years of the program at the home institution and completes the degree program at JSU.

Concerns and issues pertaining to the 1-2-1 joint program include:

- the ease of getting a US visa due to the fact that the student needs to return home to complete the degree;
- the internship and senior thesis requirements by the home institution are addressed; and
- the language and cultural transitions may be difficult for the Chinese students.

Concerns and issues pertaining to the 2+2 joint program include:

- the availability of practical training period for foreign students becomes a great recruiting tool; and
- The internship and senior thesis requirements by the home institution may have to be waived.

We perused the curriculum of each partner institution and mapped their courses with the courses in our curriculum. The mapping of computer science courses is very straight-forward. The greatest difficulty is the mapping of their support courses to our core courses.

5. EXPERIENCES LEARNED and STIMULATING COLLABORATION

Higher education institutions operate in changing academic workplaces shaped by the demands of knowledge-driven marketplaces [5]. Universities have responded to these challenges by updating their curricula, formulating projects of practical relevance, partnering with businesses, government and individuals to fund research [4]. The influence of American corporations in Asian countries drives the presence of American higher education institutions in that region [7]. There is a correlation between the economic power of a country and the absorption of international students. The growing

presence of transnational educational institutions in Asia and Mid East stimulates the international exchange of faculty, administrators and students.

Due to the usage of the Internet and international travel students and academics can now participate in international projects. Although universities can be somewhat competitive in attracting students and faculty, the members of the academic community increasingly work on projects and co-author papers with colleagues on other campuses. As professor Umpleby stated: "In terms of communication there is now one global university" ([17]).

The inflow of international students to U.S. universities imply changes in infrastructure, programs, financial allocation, and culture [10]. Diversity must be integrated in classroom management and curriculum design to provide each discipline with a multicultural and global view.

The first group of students from Taizhou University started their junior year as computer science majors at Jacksonville State University in Fall 2010, after completing a session of study at the English Language Institute. During their first two years spent at TU, they learned the fundamental computing concepts and became proficient in at least three commonly used programming languages. The computer science faculty members expect them to be ready to work on complex projects.

Teaching methods can be very different in different countries. For example, most of the Chinese universities place more emphasis on the theoretical aspects of the computing discipline. At JSU, most of the upper-level courses in Computer Science are project-based. It took the Chinese students a considerable time to adjust. Even when they are told several times what is expected, sometimes it seems they do not believe what the instructor has said. We believe that the communication gap and culture shock are predominantly the causes of the problem. Although they are technically proficient, the students have a major difficulty in grasping some of the instructional materials.

We strongly encourage the new Chinese students to collaborate with their American colleagues, to engage in conversations, to exchange ideas and to be active participants in the class discussions. In order to benefit from the opportunity to study at JSU, they need to fully immerse in various activities that take place on JSU's campus.

We will impart this critical information to our counterparts at TU so they can better prepare the students whose intent is to join the dual degree program in the future.

The 2+2 dual degree program, rather than the 1-2-1 program, appears more attractive to the Chinese students. This is due, in most part, to the great opportunity to do practical training in the USA before going back home to China. In addition, it would be more beneficial to the Chinese students to take more English language courses before embarking on a study-abroad program such as what JSU has to offer.

Our efforts have been very well supported by the JSU administration. Despite the economic downturn, the faculty exchange program with Wuhan University remains active and fully funded. Plans for a similar faculty exchange program are currently being drawn with ZUMC.

6. CONCLUSION AND FUTURE PLANS

The College of Arts and Sciences at JSU continues to expand its outreach for college students worldwide. As the new era of education turns to globalization, we will continue to explore new initiatives and collaborations with other institutions of higher learning around the globe.

Jacksonville State University continues to develop and expand its academic partnerships with several Chinese universities. Emerging academic collaborations with Wuhan University, ZUMC, HU, and TU will be actively explored and nurtured. The possibility of expanding research partnership opportunities are also in our future plans.

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Critical Success Factors for Pedagogy 2.0

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Abstract
This research is exploring Web 2.0 adoption and success in education. Web 2.0 technological innovation is introduced and defined highlighting different tools and applications. This research develops a framework to govern Web 2.0 introduction in teaching and learning made of different factors. It was suggested here that the adoption and hence, the assimilation of Web 2.0 in teaching and learning is not a straight-forward process and hence needs careful consideration of different Web 2.0 issues in relation to pedagogy with technology is being looked at as a conduit to deliver more effective educational services. Web 2.0 has many advantages, disadvantages and at the same time, posits different implications and challenges for educators, professionals and policymakers.

1. Introduction

Advancement in technology has revolutionized and reshaped teaching and learning in unprecedented way. This argument is so impending that many researchers questioned the efficacy of existing assessment techniques and accused them of being as shallow and as less reflective to the contemporary needs of both technological society students and academic staff. More specifically, they fail to assess critical learning issues such as problem solving, critical thinking, collaboration, innovation and creativity (Smith & Peck, 2010). As a result, they called for the introduction of more appropriate approaches such as blended learning which contains different types of education techniques and technologies, e.g., face to face education and online learning activities (Köse, 2010). In a nutshell, there is a need to create more effective pedagogical approaches to better equip students for the professional life (Augustsson, 2010; Grosseck, 2009). Wu and Hsu (2009) highlighted that although traditional education with a technology assistant is the trend in current educational practices, emerging technologies provide opportunities for not only instructor-student, but also student-student, real-time, and/or time-delayed collaboration. In higher education, Internet technology has evolved from being a vehicle to distribute course materials, communicate (e-learning) and evaluate, to enhancing educational processes that support collaborative student learning (Maloney, 2007).

Recently, latest technological variants namely Web 2.0 emerged as powerful enablers to support and enhance in-class teaching and learning in higher education (Baltaci-Goktalaya & Ozdilek, 2010; Grosseck, 2009). Wu and Hsu (2009) highlighted that Web 2.0 tools have shaken every field including education. This is so looming that Web 2.0 is considered by many educators to be the next thing in education and the one that will attract the attention of students who viewed current educational practices negatively and accused them of being as stagnant and as not evolving to meet contemporary learning needs (Wikipedia, 2011).

Web 2.0

The term Web 2.0 first emerged in January 1999 by Darcy DiNucci, a consultant on electronic information design but the real Web 2.0 that we know it nowadays resurfaced in 2003 (Wikipedia, 2011). There are many definitions for Web 2.0 but almost all definitions agree on defining it as the social use of the Web which allow people to collaborate, to get actively involved in creating content, to generate knowledge and to share information online (Grosseck, 2009). The term Web 2.0 is associated with Web applications that facilitate participatory information sharing, interoperability, user-centered design, and collaboration on the World Wide Web (Wikipedia, 2011).

Unlike Web 1 (read only), Web 2.0 (read/write) propelled by social-sharing capabilities, is introduced as the new technological buzz in education to support teaching and learning. In online social networks, collaborations amongst students is highly emphasized and hence, evaluating the adaptation of Web based systems with Web 2.0 features is important as Web 2.0 in addition to introducing new types of Web content, it brings a new level of interface design in Web development (Sabouri & Jalali, 2009). It also entails cumulative changes in the ways software developers and end-users use the Web (Wikipedia, 2011). Thus, Web 2.0 provides users with more user-friendly interface, software and storage facilities which enable them to add value to the application they are using. Hence, Web 2.0 allows users create, describe, post, search, collaborate, share and communicate online content in various forms (Tripathim & Kumar, 2010), e.g., music, bookmarks, photographs, documents, commenting, tagging, and ratings.

Web 2.0 features

O'Reilly (2006) provided the following characteristics of Web 2.0:

a. user as contributor.
b. Participation not publishing
c. Lightweight programming models
d. Trust and collaboration
e. Software above the level of any single device
f. A rich user experience

Web 2.0 draws together the capabilities of client- and server-side software, content syndication and the use of network protocols. Standards-oriented web browsers may use plug-ins and software extensions to handle the content and the user interactions.

Web 2.0 components

Thus, Web 2.0 can be described in three parts which are as follows (Wikipedia, 2011):

a. Rich Internet application (RIA) on the browser side from a graphical or usability point of view, e.g., using Ajax and Flash.
b. Service-oriented architecture (SOA)— defines how Web 2.0 applications expose its functionality to other applications to integrate with providing a set of much richer applications, e.g., Feeds, RSS, Web Services, Mash-ups.
c. Social Web — It defines how Web 2.0 integrates and interacts much more with the end user.

Web 2.0 tools

Web 2.0 includes blogs (Blogger, WordPress), micro-blogs, wikis (Seedwiki, Wikipedia), syndication of content through RSS, tag-based folksonomies, media sharing, social networking (Facebook, YouTube, MySpace), social bookmarking (Digg, de.licio.us), Instant messaging (MSN Messenger), Internet Telephony (Skype), Audio/Video Conferencing (NetMeeting), hosted services, web applications, and mashups. Other Web 2.0 applications such as Voice-Thread allows the use of different types of media (images, documents and video) where individuals or groups could use their voice to comment (with a microphone or telephone) in different ways: text, audio file or video (with a webcam) (Augustsson, 2010). The latest generation of Web 2.0 technologies are becoming more ubiquitous, offering many unique and powerful information, sharing and collaboration features. Grosseck (2009) provided examples of using Web 2.0 technologies in education, e.g., prepare and collect materials, evaluating and analyzing the progress made by students, putting together informative and formative presentations, time management, planning the timetable and the calendar of activities, developing projects in collaboration, digital storytelling, students' e-portfolios, etc.

Web 2.0 Implications

At the outset, researchers viewed Web 2.0 tools as having a pervasive impact on society (Tripathim & Kumar, 2010). Teachers viewed using Web 2.0 technologies as supporting their courses positively and as improving learning and interaction among learners and teachers (Baltaci-Goktalaya & Ozdilek, 2010). Web 2.0 integration into the classroom learning environment can be effective at increasing students' satisfaction with the course, improve their learning and their writing ability, and increase student interaction with other students and faculty; thus changing the students' role from passive to active learners, allowing them to better create and retain knowledge (Ajjan & Hartshorne, 2008). On the other hand, Augustsson (2010) found Web 2.0.0 technology useful as a valuable supplement in a campus course where other teaching takes place in time and space. In contrast, other researchers accused Web 2.0 of being a marketing gambit which will eventually vanish like its predecessors of overhyped technologies (Dilger, 2010). Similarly, Tripathim and Kumar (2010) found the literature pointing to Web 2.0 as a hype, an attitude and does not represent any advancement in technology and that it's a mere a technological change. Other critics called the Web 2.0 as a piece of jargon, difficult to understand and it cannot possible be right. While Web 2.0 may provide rational debate and collaboration, it may also lead to the possibility for "spamming" and "trolling" by less rational users which may force rational members opt-out from contributing – this requires radical trust by the management of the website (Wikipedia, 2011). Wikipedia (2011) also raised the possibility of Web 2.0 undermining the value of expertise by allowing anybody from anywhere to cast their own opinions and post any kind of content regardless of their backgrounds, knowledge, credentials, biases or possible hidden agendas.

Between proponents and opponents, there is no doubt that Web 2.0 is gaining new grounds every day in different areas including education. It is clear however that for this conjuncture to stand, many implications needs to be resolved first. This research is interested to explore the importance of using the Web 2.0 in education highlighting different constituents and impacting factors in both learning and teaching. Thus, this research is interested in finding answers to the following research question: *How can we use Web 2.0 more effectively in learning and teaching*.

In the following, the research progress a guiding theoretical framework and attempt to link it to Web 2.0 factors. The research ends with a discussion and conclusion section.

2. Reference Theory

In search for appropriate framework to guide this research endeavor identify potential determinants of technology adoption the Technological Innovation Theories (TOT) appeared to be more prevalent amongst researchers. The adoption and diffusion of information technologies by individuals and organizations is part of the process of information systems implementation (Kwon & Zmud, 1987; Moore & Benbasat, 1991, 1996). Innovation diffusion refers to the spread of innovations through a community of firms over time whilst adoption refers to the decision (adopt/reject) within a firm to make full use of a new idea as the best course of action (Rogers, 1983, 1995). Rogers (1983, 1995) reviewed several thousand innovation studies and developed a framework that envisions a simple innovation diffusion sequence. The sequence leads from knowledge acquisition to persuasion of interest, followed by the adoption or rejection decision itself, implementation, and finally the confirmation stage of evaluating the actual outcomes compared with expectations. In view of the technological innovation theories, Rogers' (1995) model appeared to be the most widely accepted model by researchers in identifying 'perceived' critical characteristics for innovations in IS research (Kaplan 1999; Karahanna et al. 1999; Moore & Benbasat 1991, 1996). Rogers (1995) identified five significant characteristics of the innovation which influences its adoption:

a. Relative advantage: the degree to which an innovation is perceived as being better than its precursor;
b. Compatibility: the degree to which an innovation is perceived as being consistent with the existing values, needs and past experiences of potential adopters;
c. Complexity: the degree to which an innovation is perceived as being difficult to use;
d. Trialability: The degree to which an innovation may be experimented with before adoption.
e. Observability: the degree to which the results of an innovation are observable by others.

In their review of adoption literature Premkumar and Roberts (1999), Thong (1999) and Tornatzky and Klein (1982) endorsed Rogers' (1995) innovation characteristics and found the first three factors consistently associated with innovation adoption. However, past studies found that facilitation factors vary according to the innovation type (Swanson, 1994). Thus, extending or adapting contexts and factors developed in earlier IS research on Web 2.0 adoption is not a straightforward process, simply because Web 2.0 introduces features of its own. Accordingly, this research will examine these three factors but from within the ICT/IWBT pedagogy literature in order to develop the guiding theoretical framework. In emphasizing the importance of this framework, Ajjan and Hartshorne (2008) argued that for Web 2.0 to succeed among educators, more effort is needed to improve the perceived usefulness, ease of use, and compatibility (with current practices) of Web 2.0 applications and faculty's self-efficacy. They further emphasized the need to provide "best practices" models to further facilitate the adoption of Web 2.0 in higher education. In the following, the above framework is discussed from within Web 2.0 pedagogical literature.

3. Web 2.0 advantages

Web 2.0 technologies like YouTube stimulate (student work is open to peer review) and satisfy (enjoyment, contemporary, building self-confidence) the learning needs of both graduate and undergraduate students and allow for more active participation and engagement (i.e., improves visual literacy) from students (Smith & Peck, 2010). Thus, Web 2.0 technology is well suited for collaborative learning, collective knowledge building, knowledge management, social networking and social interaction, which means that both course participants and teachers become more active and personally involved (Maloney, 2007). By using Web 2.0, teachers are giving students the freedom to learn for themselves and share that learning with their peers (Wikipedia, 2011) and hence, teachers are given more time to effectively facilitate the teaching and learning process. In a review of the literature concerning Web 2.0 support for collaborative learning and reflections, Augustsson (2010) found that Web 2.0:

a. provides support for students' reflections on their own thoughts and reflections about emotions
b. enhances identification and collaboration between students
c. according to (i&ii) Web 2.0 supports the development of students' self-awareness in demarcated contexts, for example when they collaborates towards specific goals. Thus, it supports individual students and integrates them into a work group
d. develops students' identification and awareness in relation to self, a task and others.

Grosseck (2009) emphasized that teachers can foster collaborative work not only among their own students but with colleagues, students, and community members from around the world – and provided the following Web 2.0 advantages for higher education:

a. reduction of costs
b. flexibility
c. easier and faster access to information, when and where it is needed
d. the integration of a variety of Web 2.0.0 technologies in the teaching-learning activities;
e. extensive opportunities of information and collaboration by the agency of social bookmarking services
f. possibility to control access to resources by authenticating users
g. sharing accumulated experiences (blogs, microblogs, wikis, Flickr, YouTube) and resources
h. independence from the platform
i. compatibility with the elements of the educational field and the existing contextual dynamics
j. the low level of complexity needed for use
k. reliability in continuous usage, over an extended period of time
l. redistribution of effort, so that less and less time and energy are spent during search and information management
m. (del.icio.us, RSS)
n. the increase in number of modalities of use and the heterogeneity of didactic practices and of types of formation
o. due to the diversity of the new technologies
p. the possibility to test the existing didactic practices, without great changes in the current modus operandi;
q. the major focus on didactic (educational) innovation, and not on the technology per se
r. creating digital content (especially media, podcasting, videocasting)

4. Web 2.0 compatibility & Complexity

However, the pace on which such technologies develop imposes tremendous challenges on both students and teachers. Hence, the implications here are threefold.

Initially, to many educators Web 2.0 is largely unknown where more research is needed to explore the efficacy of Web 2.0 in teaching and learning and more focused training programs are needed to up-skill teachers' knowledge with Web 2.0-pedagogy (Grosseck, 2009). For example, while some teachers feel that some Web 2.0 technologies could improve students' learning, their interaction with faculty and with other peers, their writing abilities, and their satisfaction with the course; few choose to use them in the classroom (Ajjan & Hartshorne, 2008). Further the attitude and hence, the impact of Web 2.0 in education varies amongst educators (Grosseck, 2009):

a. Producing a short circuit in the reflection and debate on the impact this new technological trend has on education;
b. Rejecting the new by saying that we shouldn't tolerate „the vassalage to American culture";
c. Technological immaturity, wrecked by indifference and by the absence of openness towards new ideas and didactic experiences;
d. Intellectual and academic dogmatism;
e. The hardening of scientific thought;
f. The erosion of creativity;
g. Taking up an opportunistic attitude and acquiring the ambiguous identity of an information cool/groovy;

h. Limiting oneself to the periphery of intellectual work methodologies (in the context of proliferating Web 2.0.0 without being sufficiently informed, we risk offering the students a precarious training);
i. Annoyed reactions from "basement communities" which can, many times, be tempted to consider introducing Web2.0 technologies in their institutions as mere whims;
j. Tensioning work relations and creating notoriety complexes as far as the colleagues who have adopted the new wave of the Web are concerned, etc.
k. Under these circumstances, we believe it is necessary to reconsider the role of educators. Thus, we need to:
   - Assume a new attitude (without going to extremes);
   - Set ourselves up as innovators in education, by promoting new pedagogical objects: courses under an audio/video form (podcasts, videocasts), books/manuals in the shape of a wiki, communicating with our students through blogs etc.;
   - Try to bring arguments in favor of a taking a correct stand when faced with these realities;
   - Plead in favor of renewing our psycho-pedagogical tools;
   - Enjoy the pleasure offered by the act of knowledge;
   - Assume responsibility for our own formation
   - work a lot, spend a great amount of time for self-training, sometimes to the detriment of spending time with the family or of relaxing.

Secondly, technology savvy students may ridicule the use of existing and traditional teaching and learning approaches (Smith & Peck, 2010). Those students are already raised on new media technologies, participate at a global level and receive better online feedback (Wikipedia, 2011). Such students are no longer satisfied with retrieving information from the Web only but need to be involved in the process by creating and sharing content. For Web 2.0 to succeed in education, students need to prove (Grosseck, 2009):

a. initiative and responsibility,
b. curiosity and imagination,
c. the ability to explore
d. creativity,
e. to work cooperatively and constructively,
f. to communicate and collaborate distinctly with each other,
g. to be open towards identifying and solving problems.
h. to carry a fruitful dialogue, on both educational and social issues.

Finally, the use of advanced technologies and approaches to enrich the student learning experience means bringing the whole student audience to an equal footing in terms of comprehending the technological tool itself let alone liking it in the first place and above all, to accept using it. This is important as Wu and Hsu (2009) reported an enhancement in student performance when using Web 2.0 but younger participants showed more interest in Web 2.0. Further, this enhancement was significantly different between male and female with the later reporting having more positive attitudes toward Web 2.0. Above all, educators need to master such technologies in the first place to be able to design effective assessment tools as stated earlier.

Interestingly, Smith and Peck (2010) warned that failing to consider the complexities introduced by technology may position the student as the digital victim (engaged in learning about the tool itself and not the task) and the teacher as the digital perpetrator (in their attempt to use Web 2.0 in designing a task for students). They highlighted the need to work towards more collaborative outcomes for both student and academic to bridge the (generational) gap between what students see as assistive to learning and what the teacher sees as helpful to assessment. In the same vein, Grosseck (2009) supported the need to properly introduce the new Web 2.0 technologies in the curriculum and to make students more responsible about their learning to become effective partners in the teaching-learning process and warned that abusing Web 2.0 can block or annihilate information processing, and can decrease the quality of learning. Grosseck (2009) provided other Web 2.0 challenges for higher education:

a. an Internet connection is required (especially a broadband connection);
b. it hides behind it a sum of technologies and concepts which are still insufficiently defined;
c. it is based on Ajax, which depends on JavaScript and, therefore, a user without activated JavaScript, won't be able to use the respective page;
d. it determines variations of interpretation between types of browsers;
e. it offers free things, in open-source structures, with a rather vague significance;
f. it leads to a low quality of the actual content, with sites which struggle in deep informational mediocrity;
g. it promotes amateurishness by invaluable contents generated by users;
h. it gives everyone the opportunity to complain, thus creating a community without rules;
i. it has monetary quantification (the Internet as a business - Google);
j. it is a kind of second-hand Web, a medium for persons with low digital abilities;
k. it has limited security;
l. the speed of programs is incomparably lower than the one of desktop programs;
m. it doesn't mean anything per se, it is just electronic junk;
n. the extremely diversified offer of technologies which can be used and which exist on the market at the moment, make the actual selection process difficult;
o. time and knowledge invested in the Web 2.0.0 technologies.

Sabouri and Jalali (2009) emphasized that although both online social networks and online collaboration sites have the collaboration aspect in common but they differ in the types of collaboration. While the former tends to be limited to sharing of information, comments, and media the later demonstrates much stronger user collaboration.

5. Discussion and conclusion

It is clear that the success of learning and teaching is fully dependent upon the efficient integration and alignment of such technology with learning and teaching processes. It is emphasized here that this should be done from a pedagogical perspective (Grosseck, 2009) and student's centered. This calls for rethinking the efficacy of existing teaching methods, demanding curriculum (full of theoretical concepts), other extremes which claims to offer intellectual flexibility curriculum and considering programs which involve those competencies which are useful to the future graduate in finding a job (Grosseck, 2009). Students use Web 2.0 tools in their social lives but in education, careful consideration is needed to attract such student use Web 2.0 in their learning.

This research endeavored to explore the multi-faceted perspectives of Web 2.0 technology in education by defining it and highlighting its different tools and their use in pedagogy. The research then proposed a guiding theoretical framework based on the technological innovation literature as a reference theory. The research then attempted to link the framework with Web 2.0 advantages and disadvantages raising different theoretical and professional implications. In the next phase of this research, an attempt will be made to investigate Web 2.0 penetration in education, namely in teaching and learning by faculty and students. Most importantly, there is a need to develop more accurate measures as Tripathim and Kumar (2010) asserted the scant availability of complete set of parameters or standards for evaluating Web 2.0 tools.

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A second order cybernetic model of scientific conceptual understanding: The case of kinematics

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ABSTRACT

Even if difficulties of the pupils in sciences are diversified, most seem linked to deficiencies in their understanding of basic concepts. Since about twenty years, different researches tried to bring solutions in this problem, favouring the multiplication of directives that can be applied to science education. To integrate their results, we offer a second order cybernetic model of scientific conceptual understanding which allows, not only to describe all the paths learners took to understand, but also to choose instructional strategies of education appropriate to do so.

Keywords: Learning model; Scientific understanding; Conceptual network; Cognitive schema; Instructional strategy

1. INTRODUCTION

At the dawn of the XXIth century, it has become essential for young people to undergo basic scientific training, either to favour their integration in a society more and more dominated by science and technology or as part of their studies in a scientific or technical domain. High schools, principally responsible for the acquisition of basic scientific learning and the training of new scientists, attains these purposes only partly as many young people leave school without completion of their high school diploma and others choose not to continue studying in a scientific or technical domain [1]. In this respect, difficulties students experience throughout their scientific studies seem to be connected to deficiencies in their understanding of basic concepts which remain, even after having completed several courses in a specific scientific domain [1,2]. In reference to these issues, a question arises: Is there a model of the process of understanding scientific concepts which would account of various difficulties in science learning experienced by high school students? To answer this question, our research of a theoretical nature analyses and synthetizes the results of researches on conceptual scientific understanding. To integrate the results of these researches, we propose a model constituted by the main dimensions of understanding and their reciprocal relations.

2. METHODOLOGY

The theoretical perspective of this research aims at clarify what is general in the various aspects of the conceptual scientific understanding, to highlight variables linked to this understanding and their reciprocal relations, and to formulate them in the form of laws or principles, by trying to abstract it from individual characteristics of learners and from contexts [3]. Moreover, to give a better account of the complex character of the phenomenon of conceptual scientific understanding, we adopted a systemic method where variables are interrelated in the form of a organised whole, represented in form of a modelling schema [4].

To elaborate the model of scientific conceptual understanding, our research method consisted of performing, in an iterative way, the analysis and the synthesis of literature in this domain [5]. We briefly introduce the main steps of this research method:

1) The identification of the corpus of texts to be analysed concerning conceptual scientific understanding
   Fundamental topics and texts concerning conceptual scientific understanding were chosen according to this topic. We therefore questioned two educational databases. The first one contains texts which are written in both French and English (FRANCIS). The second database contains texts that are only written in English (ERIC). This first selection of texts was made using the descriptor COMPRÉHENSION or its English equivalents UNDERSTANDING and COMPREHENSION, and by limiting articles and monographs chosen in the education and scientific domain.
2) The segmentation of texts in analysis units
   The constituted corpus of texts was later segmented in units of analysis. In an analysis of documents, the unit of analysis is defined as a segment of information which relates to a category [5]. The length of the units of analysis does not coincide with the linguistic segmentation of the text (sentence or paragraph) but rather tries to capture a main idea concerning the understanding of scientific concepts [6].
3) The location and coding of analysis units
   Every unit of analysis is described with the aid of one or of several keywords which characterises the information contained in unit. Using keywords allows one to condense content, and makes it easier to find and compare the research results of the different authors with

respect to a topic or a sub-topic of scientific conceptual understanding. To this end, keywords have to be expressed in a way that is general enough to allow comparison (and synthesis) and specific enough to facilitate their location and the treatment of information during the analysis [5].

4) The structuring of results obtained in a modelling schema of the scientific conceptual understanding

Once the thesaurus for scientific conceptual understanding had been constituted, we calculated the frequencies of the keywords appearance and the associations between keywords in the units of analysis [6]. The analysis of these frequencies allowed us to identify the important keywords and to connect them in the form of a schema [7].

5) Validation of the model of scientific conceptual understanding

The modelling schema is later subjected to a technique of validation based on the clarification of paradoxes identified in the studied texts. Indeed, the highlighting of a paradox allows the modification of the conceptual structure of a theoretical schema and the clarification of this paradox allows the refinement of this schema by specifying the limits of the studied concepts [8].

Finally, in spite of the linear character of the steps of the research method described above, the analysis and the synthesis of the content contains feedback loops at every step which allow the process to converge on a "prototype" of the model of scientific conceptual understanding [5]. Given the theoretical character of our research, we did not undertake an empirical validation of this model so that this validation will have to be completed in subsequent research.

3. RESULTS

Presentation of the model of scientific conceptual understanding

Steps of the model

We specify now the different steps of the model of scientific conceptual understanding and its structure. This model can be conceived as a cognitive system which interacts with its environment by collecting information and producing answers. During the elaboration of one's understanding, the learner's conceptual structure, semantic in nature and constituted by schemas, acts as a cognitive tool which, not only chooses and stores information from its environment, but also transforms it to produce better adapted schemas. As a result, schemas mobilised by the learner when he interacts with the phenomenon are changed during treatment process to gain a more adequate understanding of the phenomenon [4]. As a learning approach, understanding becomes divided into three parts: the conditions of understanding, process of understanding and product of understanding (see fig 1).

Conditions describe the requirements at the entry of the system, which contains two components: the initial state of understanding of the learner and the scientific concepts to be understood. Process describes the way the interaction between the leaner and the scientific concepts takes place. The product specifies the characteristics of the final state of understanding [9].

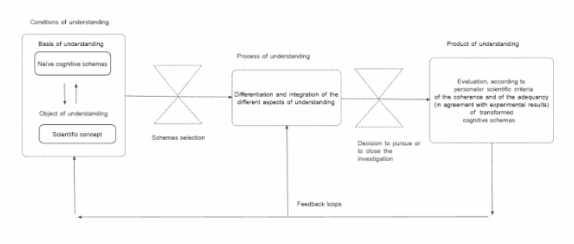


Fig. 1 Schema of the model of scientific conceptual understanding

Main sense of information transfer

The main sense of the information transfer of information is directed from conditions to the product by way of the process [9]. This transfer can be influenced by the choices or decisions of the learner (see fig 1). Indeed, from conditions to process, learner's schemas adapted to the study of the scientific concept are chosen among all of the available schemas according to the characteristics of the concept. From process to product, the learner chooses to continue or to close the activity of understanding if he judges that his state of understanding is satisfactory [10]. The information transfer form conditions to process and form process to product can also be influenced by emotional or social factors. For example, it seems that beginners prefer schemas having a high degree of correspondence with the structure of the studied concept. This preference limits the level at which the beginners can treat information later [11].

Feedback loops

We have described up to now the information transfer from conditions to process and finally to product. However, the information transfer can also take place in the reverse sense. This inverse transfer is called feedback and allows one to reinvest the results of every step at a previous step, constituting feedback loops [12, 13]. The first feedback loop, going from conditions to process and conversely from process to conditions, means that the learner turns his attention to the object of study (concept, phenomenon, law, principle), that some of his cognitive schemas are activated to treat the information coming from this object, and that meanwhile some understanding difficulties appear (see fig 1).

The second feedback loop, going from process to the product and reciprocally from product to the process, means that the new organisation of knowledge changes the understanding process (see fig 1). For example, new links established between some elements of the representation of the learner can lead him to search additional information, to incorporate some contributions of his peers toward the development of a more general schema, etc.

The third feedback loop consists of the use of the products of this approach as new "entry" in the system, which launches a new understanding cycle (see fig 1). This cycle allows one to open the way to new learning: generalization of the new concepts, their use in the resolution

of problems, and their application in daily life [12,14]. The repeated use of the understanding cycle allows learner to provisionally occupy a series of states of understanding of increasing complexity [15]. These states distinguish themselves by their degree of organisation of knowledge and the new operations which this organisation allows. The series of states of understanding defines all of the levels of understanding of increasing complexity [4].

External influence on the approach of understanding

Moreover, the approach of understanding is opened to external influence of emotional or social nature. Knowledge which the pupil uses often comes from interactions with daily objects. As such, learner's conception of science, the value he grants in scientific activities and the competence he recognizes in the accomplishment of these activities were influenced by an extended contact with the school environment [16].

Viewing the whole approach of understanding

By viewing the whole approach of understanding in sciences, we first notice that it is initiated when the cognitive schemas of the learner are mobilised for representing the object and its properties 17]. This representation includes two distinct processes: the identification of various aspects of the object (differentiation) and the synthesis of these aspects in a consistent conceptual structure to fulfil different scientific functions (integration) [5]. The higher or lower ability of the learner to differentiate and to include the various aspects of the object (that it is a phenomenon, a concept or a scientific law) results into the acquisition of more or less efficient cognitive schemas to predict and to explain this phenomenon [15]. These cognitive schemas constitute new entries during the launch of a new understanding cycle. Therefore these new schemas can contribute to the study of various situations that are similar or different from the initial situation, favouring generalization and knowledge transfer. Understanding is therefore iterative, continuing until learner is satisfied [10].

Regulation of the approach of understanding

Finally, the presence of explicit regulation mechanisms in the schema of the approach of understanding results in several important consequences for learning: 1) they partly explain the gap between qualitatively different conceptual structures, 2) they lead to the organisation of a hierarchy of acquired knowledge. Indeed, the reinvestment of the products of understanding as new entries does not only increase the knowledge of the learner, it transforms the way information is treated since schemas are the conceptual tools with which the learner interprets and organises his environment [4,14]. Moreover, this reinvestment facilitates self-regulation, i.e. when the learner regulates his or her learning. More precisely, learners having good self-regulation skills generate feedback for themselves providing information about what learning objectives have been mastered and what it is necessary for them to do in order to pursue new objectives, while in comparison, learners not having such skills rely on external feedback, given by the teacher or the school textbook [16].

4. PEDAGOGICAL APPLICATIONS: THE CASE OF KINEMATICS

Description of the pupil's evolution of understanding

If the schema of approach aims at describing factors which influence understanding and their organisation, at least in its main lines, the choice of instructional strategies to favour understanding depends on the particular characteristics of pedagogical situation [5]. As a result, to go from the description of the way understanding evolves to the choice of activities allowing to favour this understanding, one first needs to specify the evolution of the understanding of learning and secondly to specify requirements relating to each step of the approach of understanding by taking into account characteristics of the pedagogical situations found in sciences. We aim in this section to satisfy the first requirement and in the next section to satisfy the second.

In this respect, to describe the evolution of the understanding of learning, our approach consists in simulating what would be an approach of ideal understanding when it is carried out according to steps and by respecting relations between its elements [18]. In that way, by applying this approach repeatedly, it is possible to explain the various progressions of the learner's understanding. Indeed, if conditions and products of understanding define the points of departure and of the arrival of approach, the process of understanding allows to link these two states. And yet, the process of understanding in sciences is constituted of two operations: the identification of pertinent factors of a concept and the formulation of a rule which allows to link those factors to produce a new concept [17].

These operations act on two types of variables: on one hand, all the concepts of domain, say kinematics, and on the other hand, all of the learners' representations. Moreover, this approach is applied whatever is the learner's actual level of understanding and is therefore independent of the specific understanding cycle (see section 3). As a result, this approach ramifies by iteration into various paths according to the state of understanding (partial or complete) of different concepts of the aimed domain. The set of all these paths constitutes what we call a network of understanding [19]. An example of such network is given in the face 2 with respect to the speed concept [17].

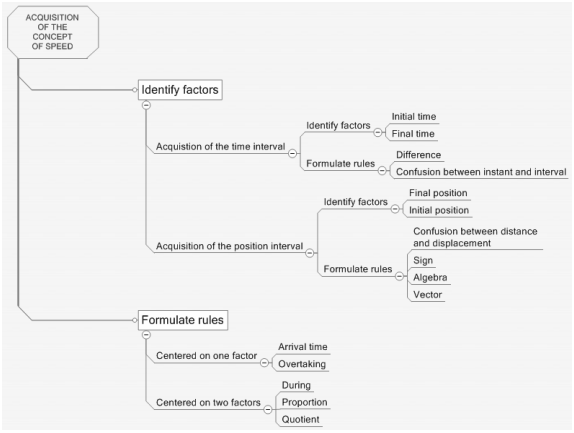


Fig. 2 Understanding network of speed

Instructional strategies fostering scientific conceptual understanding

To formulate instructional directives, it is necessary for us to first specify the frame in which these are going to be inserted. Our approach, centered on significant learning, aims at studying the development of the understanding of the pupil in the educational contexts which it influences [17]. In regards to the approach of understanding, we aim to show the complementarity of instructional strategies intended to guide the pupil in their approach of understanding by respecting the systematic character of this approach [20, 21]. It is from this perspective that we suggest the following instructional strategies of education for each of the steps of the approach of understanding: 1) establish the conditions of understanding; 2) favour the process of understanding; 3) favour the evaluation of understanding by the pupil; 4) favour the self-regulation of the approach of understanding.

Establish the conditions of understanding

Above all, conditions allowing interaction between the cognitive schemas of the pupil and aimed scientific concepts must be set up. On one hand, this interaction required that the activities (either to explain a scientific phenomenon or to resolve a problem) allow pupils to mobilise their current cognitive schemas and, on the other hand, that these schemas, once activated, could be made public and explicit in order to be studied, either by the pupil (metacognition), or by the teacher (diagnosis of previous knowledge).

Favour the process of understanding

To fill up the gap between the aimed concepts and the previous knowledge of the pupil, two approaches have been offered [14,22,23]:

- Assuming the naïve schemas of the pupil and scientific concepts are irreconcilable, the first approach plans to replace these naïve schemas with scientific concepts by fulfilling some conditions.
- Assuming the naïve schemas of the pupil and scientific concepts share common points, the second approach aims at the gradual modification of the naïve schemas first into scientific concepts by giving the pupil support and adapted guidance.

These two approaches led to the development of distinct instructional strategies. In the first approach, the replacement of the pupil's cognitive schemas by scientific concepts is made by stressing the conflict between the two and by persuading the pupil of the necessity to replace the first with the second. To this end, it is necessary to lead the pupils to express their schemas in relation to the aimed concept (represented by a scientific phenomenon), then to lead the pupils to become aware of the insufficiencies of their schemas to explain properties of the selected phenomena. It is then a matter of introducing the scientific concept as a credible, comprehensible and fruitful alternative [10,23].

The second approach consists in favouring the progress of the pupil towards a better understanding of scientific concepts from what he understood already, by offering structured activities which guide the pupil's approach [22]. In this respect, we listed two types of intervention. The first type aims at leading the pupil to progressively model a group of phenomena associated the same concept or principle, allowing the pupil to identify important factors and to formulate the rules which explain the observed properties [24,25]. The second type encourages the pupil to compare its schemas directly with the scientific schemas, for example by offering analogies or conceptual models allowing the pupil to choose pertinent information, to organise it and to connect it with its previous knowledge [26,27].

Favour the evaluation of understanding by the pupil

To make sure that the product of understanding, that it is a concept or a model, answers scientific criteria, the pupil can review the concept or model in a retrospective way. This is done by critically examining the approach undertaken to acquire this concept or this model or in a prospective way by proving that the concept or model allows the fulfillment of various scientific functions (prediction, explanation, etc.) [28,29]. In the first case, evaluation allows to reconsider the characteristics of the approach of resolution of scientific problem to show possible variations and to foresee directions of investigation allowing to generalize the schema or the acquired model. In this respect, it is important to teach the pupil not only how to work out models of a given domain, but also to teach the way of reviewing them while leading him to reflect on their nature and their role [25].

In the second case, it is a question of first determining if the constructed schemas can be applied to similar situations or favour the acquisition of new knowledge as well as to specify the limits of the solutions found and their application field [30].

Favour the self-regulation of the approach of understanding

When the instructional approach is constituted of very structured activities, it limits the opportunities offered to the pupils to choose, and its implementation is then regulated by the teacher who must make sure that its various interventions are in agreement with the present state of understanding of the pupil. Yet, considering the diversity of experiments and knowledge of the pupils, it is unlikely that such an instructional approach is suitable for all pupils and as a result allows an optimum regulation of their approach of understanding [31].

That is why an approach favouring the self-regulation of the approach of understanding by the pupils should include instructional strategies that encourage them to take control of their own learning. To this end, this approach should include various dispositions to encourage the pupils to mobilize and combine their cognitive strategies (such as metacognition and motivation) in order to identify their knowledge and skills, to plan their approach and to reflect on the results obtained in order to possibly change their cognitive strategies and give them a higher efficiency [16]. In this respect, the following strategies proved to be efficient to develop the metacognition and the self-regulation of the pupils:

1) Strategies combining the modelling of phenomena, the evaluation of models produced by the pupils according to some criteria and debate between pupils on the role and the utility of models [25];
2) The environments which, while giving challenges adapted at the level of the pupils, guide them in their approach by giving them different supports

such as various information sources, feedbacks and simulation [32].

5. DISCUSSION

In this article, we argued for a systemic approach to study scientific conceptual understanding. Hence, the model of understanding proposed here can be defined as a cognitive system composed of elements in interaction. One of main characteristics of this model consists of its regulation mechanisms that guide the learner toward his goals, which makes it a cybernetic mechanism [33]. This regulation can be made in an external way, for example by the teacher, or in an internal way, by the learner himself, who then takes charge of his own learning processes, i.e., reflecting on his actions, assessing them and planning according with he has learnt, while using his auto-regulated skills.

In such a case, the model of scientific conceptual understanding can be classified as a second order cybernetic mechanism [34]. Its essential characteristics are similarity between cycles of understanding and auto-reference throughout each cycle. Indeed, by going through the different paths of the understanding network, (see fig. 2 for the speed), we can observe that relations between neighbouring concepts are governed by two processes (identification of factors and integration of these factors into a new entity) which repeated themselves from the left (most basic concepts) to the right of the network (acquisition of the speed concept).

The self-reference generates the paradoxes that have been mentioned earlier (see section 2). For example, one such paradox is the learning of autonomy in an educational situation. Indeed, one can wonder how it is possible to teach a pupil how to take care of his own understanding. Let say for example that we succeed in this teaching, and as a result the pupil has acquired a greater autonomy. Obviously, a direct teaching approach would not be the appropriate teaching strategy, since one can hardly imagine a student acquiring autonomy simply by being told, and explained, how to be autonomous. But even in the case of more active situations where the pupil, for example, learns to model the properties of chosen phenomena, can we say that he has acquired autonomy?

Research has shown that it is not the case. As such, using or developing models to predict and explain scientific phenomena may not be enough for students to use these skills in other contexts. In fact, it may impede the construction of the models itself. Schwarz and White [25] have shown that it may be necessary, in addition to activities of modelling and inquiry, to include knowledge about the use of models as well, i.e. meta-modeling knowledge. Referring to the model of scientific understanding described here, their activities would include the second feed-back loop, developing models of scientific phenomena and reflecting and evaluating their nature, purpose, and utility in predicting and explaining properties of these phenomena.

6. CONCLUSION

Difficulties experienced by pupils during scientific learning find their origin partially in misunderstandings which manifest themselves in a manifold way in different domains while sharing some similarities. To explain these difficulties and to plan efficient interventions intended to favour pupils' understanding, it is important to explain the way scientific conceptual understanding takes place. In this respect, our model of scientific conceptual understanding accomplishes this objective with two conceptual tools: 1) a network of understanding, which allows for the description of different paths of learning when a pupil advances in understanding; 2) a schema of the approach of understanding, which describes the organisation of different stages of understanding so that it is possible to choose strategies of education most adequate to each of the stages of approach.

In regards to the limits of our research, the method of contents analysis using keywords tends to rigidify the collection and analysis of data. Indeed, the keywords that appear from the analysis do not allow one to give an account of the nuances brought by the authors. In addition, by classifying units of analysis with the aid of keywords, the coding method does not take into account the evolution of terms used in the field of the understanding of concepts in sciences [35]. Moreover, the accent put in this research on the identification of variables and their interrelations cannot give an account of the wealth of other perspectives, some for example more centered on specific characters of context or of individuals [36].

Despite these limits, the integration of the results of research on understanding in a scientific conceptual model can enrich pedagogic practices linked to understanding and to point out new research avenues. Above all, the approach suggested here to favour understanding allows the teacher to choose according to the learner's actual state of understanding the instructional strategies most adapted to guide its progress.

Finally, it is important to include the emotional and social aspects in the model which would aim at the entire development of the pupil. More precisely, the influence of emotional and social factors in the development of understanding should be explained more. For example, we can assume that dispositions provoking interest would allow to engage pupils in the understanding process. Inversely, factors of emotional nature as a weak tolerance for ambiguity (for example when a pupil in transition between two levels of understanding is confronted with contradictions between his schemas and new knowledge) can unsettle the development of his understanding [37]. It is also important to identify factors allowing for the support of motivation throughout the approach of understanding if we want as educators to withdraw all of benefits of our interventions [38].

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A Personalized Recommender System to Support SMT-based Product Development

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Abstract

Shape Memory Technology (SMT) opens up a variety of new approaches to actuators and sensors but there are two major issues, which hinder a broader application of SMT: Industrial users lack the necessary knowledge to use SMT in their products and there is a lack of simplified tools for scientific authors to publish their research findings. This engineering knowledge required by industrial users has been collected in the Special Research Project SFB459 – "Shape Memory Technology" and published in the "Knowledge and Method base for Shape Memory Alloys" (abbreviated as KandMSMA). It has been proven that actual state of the KandMSMA is inappropriate for practical use. Several deficits led to a rejection of the KandMSMA.

To solve this problem, a recommendation-based assistance system has been integrated into the KandMSMA. It supports scientific authors on the publishing process and industrial users on finding necessary information. The assistance system combines different approaches to generate recommendations. This article explains the problems in providing engineering knowledge for SMT-based products as well as the approach to the recommendation-based assistance system which provides methodical assistance along product development process of SMT-based products.

Keywords: Shape Memory Technology, Product development, Knowledge provision

1. INTRODUCTION

SMT represents an innovative, but heretofore sparsely used approach to developing novel actuators and sensors. In this way SMA are, for instance, employed in unlocking actuators as described in [1]. However, there are two crucial problems to a broader employment in diverse products. For one thing, the material properties and effects entail higher demands as to the skills of the product developers. For another thing, developers lack exactly the knowledge that is necessary for a useful integration of SMT into their products. As described in [2], the required knowledge comprises information on effects and material properties of different SMA and especially information that supports the SMT-specific product development process as described methodically in [1] and [3]. Within the interdisciplinary SFB459, various research findings in the field of materials science and a methodology for the development of SMT-based products have been generated. These research findings were then edited for industrial transfer and were made available online in the wiki-based KandMSMA. The acquired research results stem from diverse fields of materials science, mechanical science and product development.

In order to face the issue of the lack of information and to enable an optimal transfer of the research results in industry, an approach for an improved information provision has to pursue two goals: The first goal consists in the development of a recommendation-based assistance system for the support of scientific authors and industrial users, which will enable a simplified documentation of research results and their provision in the KandMSMA. Here, easy to operate and supportive software tools keep the effort for the insertion of and search for information low, so that an improved exchange of information between industrial users, especially product developers and scientists is facilitated. The second goal is to integrate methodical support which is oriented on existing process models for methodical product development into the assistance system to be developed. This methodical support has to provide information adapted to the developers' progress in the product development process.

Initial Situation

In the course of the research in SFB459, the wiki-based KandMSMA has been implemented in several iteration stages (cf. [4]). The KandMSMA already includes a major part of the research findings in the form of articles on different groups of themes. Therefore, the KandMSMA is a central tool for the documentation and provision of interdisciplinary research findings and for the support of the development process of SMT-based products. The contents of the KandMSMA essentially stem from three topic areas as they are depicted in sum in TABLE1: fundamental principles of SMT, methodical guideline for product development with SMT as well as manufacturing and processing of SMA pre-products and SMA components.

TABLE1. CONTENTS OF THE KANDMSMA (EXTRACT).

Basic knowledge of SMT	Guidelines for product development	Manufacturing and processing of SMA

▪ Effects
▪ Material characteristics
  ▪ Alloys
  ▪ Polymers
▪ Characteristics in use
  ▪ Corrosion
  ▪ Wear
  ▪ …
	▪ Process model for SMT
	▪ Methods for
	  ▪ Dimensioning
	  ▪ Standardization
	  ▪ …
	▪ Application samples
	▪ …
		▪ Processing
		  ▪ Master forming
		  ▪ Forming
		  ▪ Finishing
		  ▪ …
		▪ Processing tools
		  ▪ Laser melting
		  ▪ …

The first area comprises basic knowledge on shape memory materials and effects. The information included in this area describes the material properties of SMA as well the corresponding experiments. The micro structural composition of SMA and the characteristic of the phase transformation stages are elaborated on in particular. The second area comprises information on a methodical guideline for product development with SMT. Here the individual steps and the methods used in them are described for a product development process that is adapted to the development of SMT-based products.

Furthermore, examples of the employment of SMT in diverse products are to be found in this area. The third area finally deals with aspects of the manufacturing process of different shape memory alloys and on the other hand, there is also information on the manufacturing and processing of SMA-based components.

Objectives of the KandMSMA and the Assistance System

A major task of the KandMSMA that has already been accomplished to date is the collection and provision of the information on SMT generated in SFB459. In contrast to conventional databases and wiki systems and due to the future implementation of an assistance system, the efficient and targeted provision of the contents stored in the KandMSMA is to be to the fore. The usage of the KandMSMA and the integrated assistance system supports developers in the development of SMT-based products along the entire product development process and allows them to access the required information faster. The focal point of the information contained in the KandMSMA is the support of a developer in the early phases of product development, i.e. planning, conception and design.

An intended further task of the assistance system in the KandMSMA is the support of developers on the qualitative inspection of the results generated in the product engineering process with appropriate tools. Besides classic check lists or to do lists, which a developer can use in individual steps during product development, simple interactive tools, e.g. for dimensioning are supposed to be available, too. In addition to this, the user is to be enabled through appropriate contents to use other supportive tools for the development with SMT, for instance in the way described in [5].

Target Group for Support via an Assistance System

The support via the assistance system primarily addresses industrial users. However, it is also necessary to address the circle of scientific authors with this support. The profiles and goals in the addressed groups of people from research and industry are heterogeneous. They differ in their way of usage as well as in their standard of knowledge. Both in industry and in research the knowledge standard on SMT appears to be very differently distinctive, so that differently experienced users or user groups have to be considered for the development of the assistance system. Since the KandMSMA and the assistance system are available online, the differing experience of the users with online media and online publications also have to be considered. The essential user groups can therefore be characterized by means of the following criteria: knowledge standard in the domain of SMT, experience with publication in and use of online media, manner of use of the KandMSMA, frequency of usage of the KandMSMA and demand for support on the use of the KandMSMA and on SMT.

The following reference groups and implication scenarios are therefore taken as a starting point for the development of the assistance system. Development and evaluation of the assistance system is not limited to these groups.

Science (I): SMT-experienced material scientists who are sufficiently experienced in dealing with online media and who are planning to publish their research findings in the KandMSMA. It is expected that theses users have sufficient experience in their area of studies. Still, due to the scope and complexity of the information in the KandMSMA, they are not able to integrate their research findings sufficiently well into the structure of the KandMSMA. These users are to be supported primarily in the integration of these contents into the KandMSMA.

Science (II): SMT-experienced material scientists who want to inform themselves of the latest research findings on different SMA and to integrate their own findings into the KandMSMA. Just as user group Science (I), they have sufficient experience in their own area of studies. By contrast, they have only inadequate experience in dealing with online media. Due to the scope and complexity of the information in the KandMSMA, they are also unable to integrate their research findings sufficiently well into the structure of the KandMSMA. On the one hand, the user group is to be assisted in integrating their research findings into the existing contents of the KandMSMA at a lesser effort. On the other hand, they are to be enabled to navigate to the contents that are interesting to them by means of simple and intuitive tools.

Industry (I): Product developers who want to implement SMT in their products and therefore need information on the development of SMT-based products. The developers lack the necessary basic knowledge and methodical knowledge for the development of SMT-based products. Consequently, support for the developers has to be given in two ways. For one thing, the developers are to be lead through the development process methodically. For another thing, they are to receive the information necessary for their current step in the development process.

Industry (II): SMT-inexperienced prospective customers, who want to inform themselves essentially of SMT and its uses. This exemplary user group is particularly interested in sample applications and information on the different effects that are presented to them in a targeted fashion.

In accord with the aforementioned goals, the emphases in the development of the assistance system are on the support of the developers (Industry I) and the scientific authors (Science I and II). Besides this, the various user roles during the use of the KandMSMA are to be taken into account: A group for the integration of information (editors on differing permission levels for publication), the group of the assistance system users (readers) and finally a group for system administration and system maintenance (administrators).

Challenges during the Provision of Information

In the existing KandMSMA, groups of themes and articles come under an evolved hierarchical structure as depicted as a section in FIGURE1. This structure leads to difficulties with the integration and finding of information in the KandMSMA, both for the scientific authors and for the industrial users. This deficit is now to be remedied by the assistance system which is integrated into the KandMSMA.

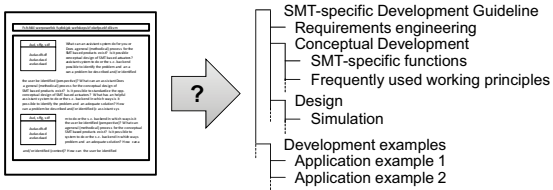


FIGURE1. EXCERPT OF THE PRESENT STRUCTURE.

Two essential problems with the integration and finding of contents emerge from the present wiki system of the KandMSMA: The first problem consists in the basic possibility to assign articles to several groups of themes and thereby to different positions in the hierarchical structure. For example, it is possible to class an article on the manufacturing of an SMA both with the area of manufacturing and with the area of SMA. This problem can be further subdivided into three sub problems:

1. While articles are integrated, the structure can be complemented with user-individual substructures, mostly without using existing suitable substructures. This leads to several thematically identical parallel structures within the KandMSMA.
2. New articles are integrated into inappropriate substructures, which lead to an intermingling of different groups of themes and exacerbate the subsequent location of contents.
3. New articles are not classed within the hierarchy profoundly enough and thereby not unambiguously, so that articles on different groups of themes are located at the same place in the hierarchy. Owing to the low hierarchy level, these articles are indeed correctly classed, but are insufficiently easy to find within the bulk of articles located in this place.

This situation emphasizes a second problem. Due to their varying standards of knowledge, users of the KandMSMA can only with difficulty class articles in the complex and scientifically oriented hierarchical structure of the KandMSMA. Furthermore, the structure of the articles allows for different interpretations by users from diverse disciplines and with various standards of knowledge. As a consequence, less adept users, who do not know this structure sufficiently will have difficulty finding articles they are looking for. This aspect is especially applicable to industrial development engineers who want to inform themselves of SMT and integrate it into their products. In addition to this, the existing system is characterized by an only static provision of information to the user and by a requirement of substantial human resources for changing and annotating articles.

2. APPROACH TO THE ASSISTANCE SYSTEM

In order to meet the problems in the existing KandMSMA, a new approach has been developed to assisted users with a sophisticated assistance system. The approach is based on two basic functions as described in the following subchapters. On the one hand, recommendations are made for the annotation of contents, so that these can be integrated into the KandMSMA in a most simple way. On the other hand, suitable recommendations of contents are generated in a personalized way, based on these annotations, for individual users, in particular product developers. Here the users are offered two kinds of recommendations. The first kind comprises recommendations that are similar or contextually related to the contents viewed by the user. The second kind of recommendation is a series of articles, in which the individual contents are ordered in a sequence suitable for reading and processing. This second kind of recommendation is especially suitable for the stepwise support of a product development process. The implementation of these two functions facilitates a detailed and more efficient provision of information, so that published research findings can be made available to the developers in an easy fashion. By means of this, a reduction of the time that a user needs for finding information in the KandMSMA is also to be achieved by means of a personalized provision of information.

Recommendation of Annotations for Newly-added Contents

A new approach to solution, the basis of which is a semi-automated annotation of articles, has been developed for the publishing of new contents in articles. In this context, the term *semi-automated* refers to the fact that the assistance system recommends seemingly suitable annotations by means of a combination of content-based and rule-based methods. Users can accept, alter and also reject these annotations for their articles. In this approach, the complex hierarchical arrangement of articles in the KandMSMA is replaced by a list of acceptable key words and categories, from which the annotations and thereby the relations between articles are created. Contrary to the solution in being, articles are thus available in a non-hierarchical structure and are therefore non-redundant in the hierarchy. Individual users who want to integrate and annotate new articles are not necessarily meant to know the entire amount of available key words and categories, but can confine themselves to the subareas that are relevant to them. Moreover, by recommending possible annotations, users are to be induced to rather use existing keywords and categories than to integrate keywords and categories of their own. Finally, the semi-automated annotation is supposed to minimize the formation of parallel content structures and competing annotations, which exacerbates the subsequent location of contents. In this way, the time and the number of actions required to insert new contents into the structure of the KandMSMA is reduced through the semi-automated annotation of the contents.

Personalized Recommendation of Contents

As a second basic function of the assistance system, by means of the recommender system [6], users are recommended a subset of the contents of the KandMSMA that is relevant in a context, e.g. the information necessary for development. The context comprises the user profile, the totality of the contents of the KandMSMA and the situation in which the user is situated together with the assistance system. The user profile itself is composed of various explicit, i.e. indicated by the user, and implicit properties, which were deduced from the user behavior. Examples of explicit information are contact data and personal data as well as information on the industrial or scientific background of the users, their research fields or professions. There is also the option for a user to state preferences for different topics which the assistance system has to consider for recommendations. Topic preferences are also deduced from the users' behavior as implicit properties. Since the assistance system is to accomplish an accompanying support of the developers along the development process, the progress in the development process has to be recorded additionally in the user profile. After all, a situation describes further influencing variables, which can be considered by the system during the generation of a recommendation. Examples of this are the system deployed by the user or the protocol of the current browser session. During the development of the assistance system, the consideration of the situation only plays a minor role.

On the whole, the information used by the assistance system can be subdivided into three main categories [7]. In the first category, information on the user for whom the recommendation is generated is collected. This information is contained in the user profile as mentioned above. The second category describes information that can be deduced from the

collective behavior of all users. The contents, for example that have been searched and viewed successively as well as the annotations assigned by the individual users are especially part of this behavior. Furthermore, evaluations and opinions can also be included in the recommendation generation. The third and therefore last group observe information in the articles of the KandMSMA, themselves. The properties, for example annotations, of these articles serve as a primary basis for this.

Content-based and collaborative approaches as well as combinations of these are used for processing the available information. At the same time, further supportive approaches such as e.g. editorially created rule –based systems can be deployed. There is a variety of approaches as illustrated e.g. in [7] and [8]. Content-based approaches determine recommendations on the basis of the similarity of contents. In this way, contents are compared e.g. by reference to the occurring terms or the annotations used for them. This means that contents which are similar to the contents that have already been viewed or defined as preferences are recommended in the user profile. For the content-based approaches, the initial step is to compile a text statistic, which is then the starting point for different mathematical algorithms. Collaborative approaches by contrast neglect the actual contents and their properties. Instead, they use statistics on the behavior of users during the employment of the KandMSMA and search for similarities in the user behavior. Here sequences and coherences in which the contents of the KandMSMA are called and employed by users are of particular interest. Both content-based and collaborative approaches make use of mathematical algorithms such as e.g. Term Frequency-Inverse Document Frequency (TF-IDF, cf. [7] and [8]), Latent Semantic Analysis (LSA, as in [9] or [10]) or Latent Direchlett Allocation (LDA, [11] and [12]) in order to determine the relevance of a recommended content. A more detailed explanation of these algorithms is not to be a subject of this paper.

The process for the recommendation is a continual cycle of user observation and recommendation generation as it is depicted in the following FIGURE2. First, the user is identified by the system. Then a profile and a context are created by gathering data and observing behavior or, in the case of established user profiles, are actualized accordingly. With the aid of the user profile, recommendations are subsequently generated and presented to the user in a next step. The user then reacts to the recommendation by e.g. reading the recommended contents or by ignoring them and selecting different contents, respectively. The system reacts by further processing the selection and/or by gathering further data on the user. At the same time, the user profile is modified. According to an analysis of the modified user profile, a renewed recommendation is then created.

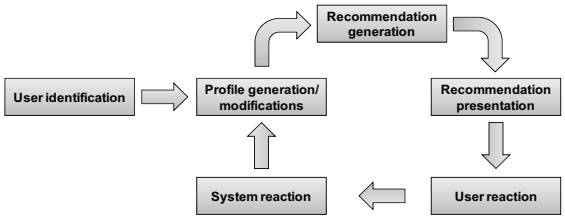


FIGURE2. INTERACTION BETWEEN ASSISTANCE SYSTEM AND USER.

Challenges in Recommendation Generation

Two significant problems have emerged especially in the realization of the semi-automated annotation. The first one consists in the finding of appropriate approaches that are suitable for a support of the annotation of new contents. As already described, these are based on user-individual or social/collaborative information or on the contents to be annotated. Even though all of these approaches would be generally suitable to recommend annotations, in this special case of publishing new contents they are utilizable only under specific conditions. Thus if the author is not the only one who has access to these contents, collaborative approaches are utilizable after the publication of the contents in the KandMSMA only. Therefore, they are not suitable for recommending annotations for new content. Contrary to this, annotations for new contents can already be recommended when using content-based and user-individual approaches. The second crucial problem with semi-automated annotation consists in the fact that these approaches have to draw on a sufficiently large reference corpus in order to be able to recommend appropriate annotations for new contents. By contrast with the recommender systems and databases applied elsewhere, only a rather small text corpus is available to the present KandMSMA (cf. e.g. [7] and [8]). Hence a concept for an assistance system that solves all of the problems mentioned above by a combination of the different approaches has been developed specifically for SMT as described in the following.

3. CONCEPT FOR THE ASSISTANCE SYSTEM

The development is aiming at the creation of an assistance system that is integrated into the already existing KandMSMA, which on the one hand effectively provides the user with personalized information from the KandMSMA and on the other hand enables a simplified publication of new information. The KandMSMA itself is a central component, which provides the entirety of the engineering knowledge as well as the data basis for the generation of profiles and recommendations. To the outside, it offers a user interface for scientific authors and developers. Both are integrated into the web frontend of the wiki-based KandMSMA.

The major part of the assistance system is situated in the stages between the user interface and the KandMSMA. On the one hand, the contents to be newly integrated are analyzed by individual methodical components of the assistance system, so that a recommendation for an annotation can be generated. In this process, the aforementioned content-based approaches are employed in combination with editorially generated rules. Editorial parts are of particular importance to the recommendation of annotations. In this manner, e.g. in the text corpus of the KandMSMA at hand, improvements in the annotation could be achieved and recommended series of articles could be generated by using editorial rules. For the recommendation of articles from the KandMSMA on the other hand, collaborative methods are used in addition to the content-based and editorial methods.

Processes of Recommending Annotations and Contents

In order to recommend annotations on new contents, the author first integrates the content into the KandMSMA. The content which is thus forwarded to the assistance system is then examined along with the user profile via a text and profile analysis. In a second step, a comparison between the new content and the existing content is drawn. By means of this, it is to be rendered possible e.g. to class a new article with the topic requirement determination in the planning phase according to

the terms used. Editorially created association rules utilize the terms used in an article in order to recommend additional annotations.

In the profile analysis, interests and actions that are saved in the user profile are matched with the new contents. It is then determined in how far a user has already been active in a subject area. This allows for e.g. the information of experts in this subject area on new contents in cases of no accordance. The individual annotation recommendations from these sub-approaches are subsequently arranged in a general annotation in a rule-based way. The rules here applied consider the relevance of the individual suggestions and arrange them in a rank order. The user can now accept or alter the suggested annotations.

On the analogy of the recommendation of annotations on new contents, user profiles and actions are used as a basis for the recommendation of existing contents. For this, the user is observed by the assistance system when he makes use of the KandMSMA. This observation is to determine especially his interests and context, which can be deduced from e.g. the annotations of the articles read. These annotations are employed by three groups of methods for recommendation generation. In the behavior-based group, the user profile is matched with the profiles of other users and contents that other users have viewed in the same context or with the same interest are selected. The editorially rule-based recommendation group deduces further recommendations for potentially relevant contents and series of articles from the viewed articles. Content-based methods are finally used as last group, which generates a recommendation of articles that are similar in content to the articles viewed. With adaptations, the described mathematical algorithms for the recommendation of annotations can also be used. On the analogy of the recommendation of annotations, the individual recommendations are finally merged with a control system to a general recommendation.

4. SUPPORT IN THE DEVELOPMENT PROCESS

The assistance system described in the previous chapters has the central task of supporting the product developer in various tasks along the product development process. In the course of this, the recommendation of contents occurs in two different manners. This is on the one hand the recommendation of articles based on the recently viewed contents. For example, if a user reads an article on requirement determination, the assistance system will recommend further articles on the group of themes on “requirement”. As already mentioned in the introduction, the recommendation of series of articles, which lead users to their self-defined goals, constitutes a crucial functionality of the assistance system. In contrast to a simple recommendation of similar or contextually connected topics, the developers gain a direct overview of the steps representing different articles, which are necessary to reach their self-defined goal. Still, the recommendation of series of articles doesn’t only restrict itself to the guidance of a developer through the development process of SMT-based products. On-topic series of articles can also be recommended. Examples of this are the guidance through domain-specific articles such as on medical engineering or series of articles for the information of users who want to inform themselves generally of SMT and its applications. The support of a developer in the development process is shown hereafter in some excerpts. In the KandMSMA German is used as the main language, so the content of the following figures is in German. FIGURE3 illustrates exemplarily the process model that was taken as a basis for the development process.

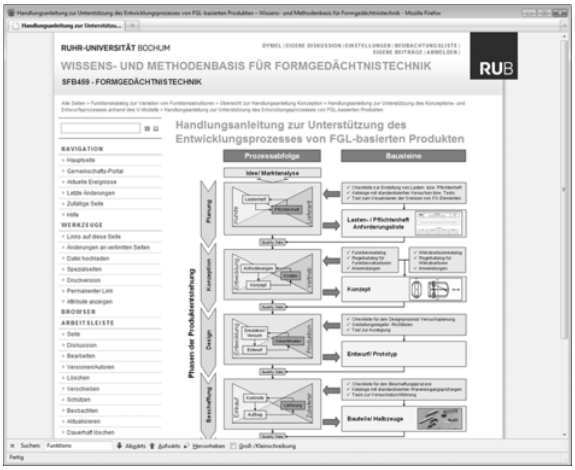


FIGURE3. SMT-ORIENTED PROCESS MODEL FOR THE DEVELOPMENT OF SMT-BASED PRODUCTS.

Initially, steps similar to those in other process models are gone through, e.g. VDI2221 [13]. The steps that are to be processed during the succession of the phases are depicted in detail in the assistance system. Methods and tools, for instance are to be elucidated and made available in the corresponding articles as early as during the planning phase. Check lists, explanatory articles and also simple software tools are available to the developers. An example of a tool of that kind is depicted in FIGURE4. This tool enables the conduction of a coarse dimensioning of wire actuators. The tool itself is embedded into an article which describes the fundamental principles and calculations for dimensioning an SMA wire actuator. As a result, developers have the option to first inform themselves of the necessary input variables and calculations of a wire actuator and can then have the calculations done in a restricted scope by a tool. In this way, developers can either check their own knowledge or precipitate their normal pace by using the tool.



FIGURE4. TOOL FOR DIMENSIONING SMA WIRE ACTUATOR.

Even though an extensive catalogue of applicable solution exists, the examples included in the KandMSMA show only a limited selection of options for the application of SMT elements in a system. The examples are therefore to serve developers primarily as starting points for their own developments. Thus the support of the developers occurs via a targeted provision of the information and tools contained in the KandMSMA and are guided by the assistance system. As a result, the assistance system is to gradually lead developers from the information provided in the articles through the development process and also to instruct them to proceed in a methodical way. This support is given by a recommendation of the KandMSMA articles relevant to the respective developer on the basis of the personalized user profiles and statistics on the use of the KandMSMA by other users.

To this end, user profiles which describe the interests and focus areas as well as the usage history of a user are generated by the system. This means that the system can attempt to classify developers into a phase of the product development according to the articles they have viewed. In consequence of this classification, the assistance system then recommends suitable series to the developers. As shown in FIGURE5, the recommended series are depicted in the form of a graph. In the middle of the graph is the process step. The process steps leading to this process step are shown on the left, the further ones on the right. The assistance system calculates the potential further steps by reference to the state of processing of the current process step and the previous process steps and also displays them in the graph. The steps that can and cannot be applied in the actual state of processing are depicted differently.

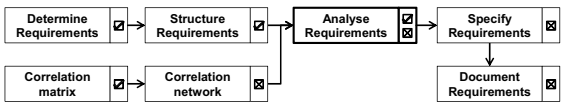


FIGURE5. ARTICLE SERIES FOR DETERMINING SMT-SPECIFIC REQUIEREMENTS (EXCERPT).

5. SUMMARY AND OUTLOOK

The introduced approach to the support of the development of SMT-based products is able to support the developers in diverse tasks along the product development process and to instruct the developers to proceed in a methodical way. Depending on the identified user context, contents of the KandMSMA are compiled as personalized recommendations and are then presented to the user. In addition to that, the assistance system offers support on the publication of new contents by enabling a semi-automated integration of these contents into the KandMSMA on the basis of recommendation of suitable annotations. The assistance system which provides support along the product development process makes use of the existing KandMSMA and is directly integrated along with the available interfaces into its web frontend. Moreover, this enables the use of the assistance system by every web-enabled computer with a standard browser.

With advancing development, the functionality of the assistance system has to be evaluated. For this purpose, objective evaluation criteria and scenarios, which depict the expected users of the KandMSMA representatively in their respective contexts have to be developed systematically. Therefore the completion of the assistance system software as well as the development of the evaluation criteria and scenarios has priority. Eventually, the assistance system is to be evaluated by developers and industrial partners.

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An Analytical study of the impact of gate-bias on the scattering parameters of a symmetric tied-gate InAlAs/InGaAs DG-HEMT

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***Abstract*—The paper presents a comprehensive analytical study of the impact of gate-bias on the scattering parameters and hence in-turn on the RF performance of a symmetric tied-gate InAlAs/InGaAs DG-HEMT. Such an analysis is important in order to predict the microwave performance of the device. The scattering parameters are derived from the intrinsic y-parameters obtained in terms of the small-signal equivalent circuit parameters. The gate-bias is shown to have a greater effect on the S_{21} (forward transmission coefficient) and S_{12} (reverse transmission coefficient) than on S_{11} (input reflection coefficient) and S_{22} (output reflection coefficient).**

Keywords- HEMT; double-gate;scattering parameters; microwave; RF; tied-gate; symmetric

I. INTRODUCTION

The excellent dynamic and noise performance reported by Vasallo et.al. [1-2] for the trenched gate InAlAs/InGaAs DG-HEMT fabricated via the transferred substrate technique has led to extensive research in order to explore its potential for future ultra-high frequency applications. Therefore, the need of the hour is to develop an accurate and a comprehensive analytical approach for the scattering parameter based RF modeling of this device which can form the basis for modeling of its noise performance.

The authors had proposed a charge control based model for the symmetric tied-gate $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ DG-HEMT for the analysis of the microwave performance of the device in terms of its current density, transconductance and the gate capacitances for gate-length ranging from 100nm down to 50nm [3]. The proposed analytical model established the enhanced microwave performance of the DG-HEMT vis-à-vis its single-gate counterpart in terms of its cut-off frequency (f_T). In this paper the impact of the gate-bias on the scattering parameters and hence on the RF performance of a symmetric tied-gate InAlAs/InGaAs DG-HEMT is studied which is essential for designing of the circuits for the low-noise amplifier applications. The computation of the s-parameters of the device forms a very vital part of the ac modeling, in terms of which the various gains of the device can be obtained, useful for predicting the microwave performance of the device. The analysis comprises of obtaining the various intrinsic small-signal parameters of the device that include transconductance, drain conductance and the gate-capacitances which leads to its small-signal equivalent circuit (SSEC) description. The intrinsic short circuit admittance y parameters are then obtained in terms of the computed small-signal parameters which are then further converted to obtain the intrinsic scattering – parameters.

The importance of the evaluation of the scattering parameters of the device lies in the fact that it is in terms of these parameters that the various figure of merits for the microwave performance evaluation, i.e., Unilateral Power Gain (G_u), Maximum frequency of oscillation (f_{max}) and Maximum Stable Gain (G_{ms}) are computed. The present work deals with studying the effect of gate bias on the various scattering parameters of the device. Such an analysis is essential when studying the device performance in the microwave frequency range.

II. THE INTRINSIC SSEC MODEL FORMULATION

A symmetric tied gate $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ DG-HEMT is shown in fig. 1 in which the doping profile, doping concentration, nature of the schottky-barrier and the dimensions of various layers in both the heterostructures is assumed to be the same for simplicity. The gates are tied together so that the voltage applied to both the gates become equal, thus, enabling the reduction of the equivalent 3-port network of a DG-HEMT to a simplified 2-port equivalent circuit which is then mathematically analyzed for the extraction of the various intrinsic elements of its SSEC including transconductance, drain conductance and the gate

capacitances using the charge control model proposed by the authors for the tied-gate geometry DG-HEMT.

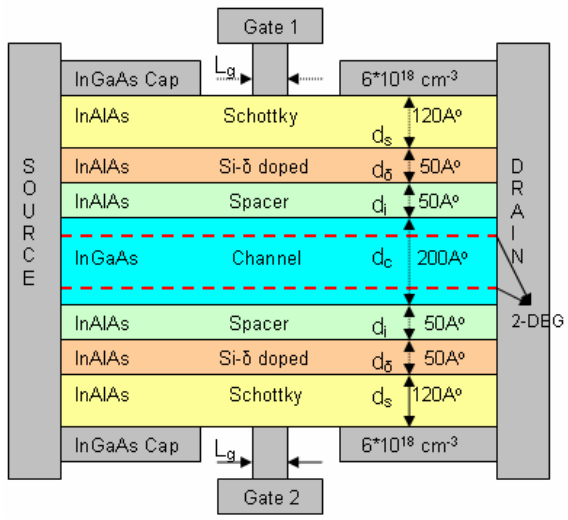


Fig. 1 Schematic of symmetric InAlAs/InGaAs DG-HEMT

TABLE I
VARIOUS STRUCTURAL AND ELECTRICAL PARAMETERS USED

Parameter	Symbol	Units	Value
Schottky-Barrier Height	φ_b	eV	0.56
Conduction-Band Discontinuity	ΔE_c	eV	0.52
Absolute permittivity of free space	ε_o	F/m	$8.85*10^{-12}$
Permittivity of $In_{0.52}Al_{0.48}As$	ε_d	F/m	12.47 ε_o
Saturation velocity	v_{sat}	m/s	$2.63*10^5$
Electron mobility	μ_o	m^2/V-s	0.83
Boltzmann constant	k	J/K	$1.38*10^{-23}$
Electron Charge	q	C	$1.6*10^{-19}$

The sheet carrier concentration in the 2DEG is given as [4]:

$$n_s(x) = n_{so}\left\{\alpha + (1-\alpha)\tanh\left[\frac{(V_{gs}-V_{gm}-V_c(x))}{V_1}\right]\right\} \quad (1)$$

and the maximum 2DEG concentration is:

$$n_{so} = \left[\left(\frac{2\varepsilon N_d}{q}\right)\left(\Delta E_c - \Delta E_f + \Delta E_{f1} + \frac{k\cdot T}{q}\right) + N_d^2(d+\Delta d)^2\right]^{\frac{1}{2}} - N_d(d+\Delta d) \quad (2)$$

The various structural and electrical parameters used in the analysis are given in table I. The dimensions of various layers are shown in figure 1 with gate-length L_g=100 nm, channel width Z=100 um and donor-layer doping $N_d \sim 0.25*10^{25}$ m^{-3}. $V_c(x)$ is the potential in the channel with α (~0.5) , V_{gm}, V_1 as the three fitting parameters The drain to source current in the symmetric tied gate $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ DG-HEMT comprising of the two charge accumulation regions in the two 2-DEGs is given as [3]:

$$I_{ds} = \frac{\frac{2\cdot q\cdot Z\cdot n_{so}\cdot \mu_o}{L_g}[X]}{1+\frac{\mu_o\cdot V_{ds}}{L_g\cdot v_{sat}}} \quad (3)$$

where,

$$X = \frac{(1-\alpha)\cdot V_1}{2}(X_1 - X_o) \quad (4)$$

$$X_o = \ln(y_o^2 - 2\cdot\alpha\cdot y_o + (2\cdot\alpha - 1)) + \frac{\alpha}{(1-\alpha)}\ln\left(\frac{y_o - 1}{y_o - 2\cdot\alpha + 1}\right) \quad (5)$$

$$X_1 = \ln(y_1^2 - 2\cdot\alpha\cdot y_1 + (2\cdot\alpha - 1)) + \frac{\alpha}{(1-\alpha)}\ln\left(\frac{y_1 - 1}{y_1 - 2\cdot\alpha + 1}\right) \quad (6)$$

$$y_o = \left[\alpha + (1-\alpha)\tanh\left(\frac{V_{gs}-V_{gm}}{V_1}\right)\right] \quad (7)$$

$$y_1 = \left[\alpha + (1-\alpha)\tanh\left(\frac{V_{gs}-V_{gm}-V_{ds}}{V_1}\right)\right] \quad (8)$$

The intrinsic small signal equivalent circuit for the tied – gate $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ DG-HEMT is shown in fig. 2.

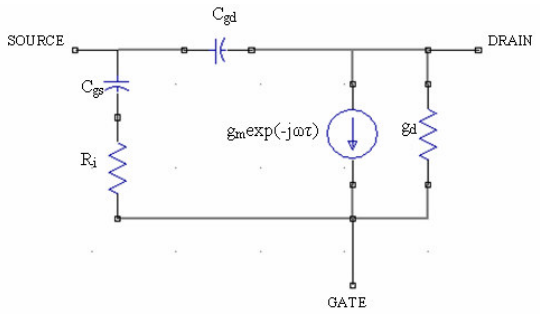


Fig. 2 Intrinsic SSEC

The *transconductance (g_m) and drain Conductance (g_d)* which govern the intrinsic gain of the device (g_m/g_d) are obtained using (3) as the incremental change in the drain current with the gate-to-source voltage at fixed drain-to-source voltage and the incremental change in the drain current with the drain-to-source voltage at fixed gate-to-source voltage respectively. The gate-capacitances including *gate-source capacitance (C_{gs}) and gate-drain capacitance (C_{gd})* are obtained using (1) as the change in the total charge in the 2DEGs with the change in the gate voltage and drain-source voltage respectively. In terms of g_m and the gate capacitances C_{gs} and C_{gd}, the cut-off frequency f_T and the transit time τ which determines the ultimate speed of the device is obtained as:

$$f_T = \frac{g_m}{2\pi(C_{gs}+C_{gd})} \text{ and } \tau = \frac{1}{2\pi f_T} \quad (9)$$

For short channel devices we can approximate the time constant $R_i \cdot C_{gs}$ as the transit time of the carriers across the gate-length $\frac{L_g}{v_{sat}}$. Thus, we can define the intrinsic channel resistance as $R_i = \frac{L_g}{v_{sat}C_{gs}}$ (10)

The SSEC description of the device is followed by evaluation of the short circuit admittance (y) parameters as illustrated in the next section.

III. The Intrinsic Scattering Parameters

The intrinsic short circuit admittance (y) parameters for the symmetric tied-gate $In_{0.48}Al_{0.52}As/In_{0.47}Ga_{0.53}As$ DG-HEMT are given as [5]:

$$y_{11} = \frac{\omega^2 \cdot C_{gs}{}^2 \cdot R_i}{D} + j\omega\left(\frac{C_{gs}}{D} + C_{gd}\right) \quad (11)$$

$$y_{12} = -j\omega \cdot C_{gd} \quad (12)$$

$$y_{21} = \frac{g_m \cdot \exp(-j\omega\tau)}{1 + j\omega C_{gs} R_i} - j\omega C_{gd} \quad (13)$$

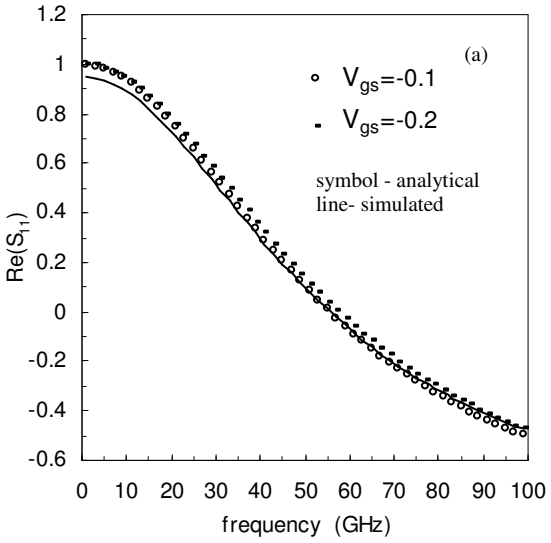
$$y_{22} = g_d + j\omega C_{gd} \quad (14)$$

where, $D = 1 + \omega^2 \cdot C_{gs}{}^2 \cdot R_i^2$ (15)

The intrinsic y-parameters thus obtained are converted to obtain the intrinsic scattering (S)-parameters [6]. The next section analyses the importance of modeling of the gate-bias dependence of the S- parameters in the designing of the microwave amplifier circuits.

IV. Results and Discussion

Fig. 3(a) and 3(b) show the frequency variation of real and imaginary part of S_{11} at V_{gs}=-0.1 and V_{gs}=-0.2. The frequency variation of S_{11} at V_{gs}=-0.1 obtained through ATLAS device simulation [7] is also plotted which is shown to agree well the analytical curve. It is observed that gate bias does not have a very significant effect on the input reflection coefficient (S_{11}). Since S_{11} is directly related to the level of matching or mismatching of the input circuit of an amplifier, it implies that the gate bias does not affect the matching of the source impedance with the input of a microwave amplifier.



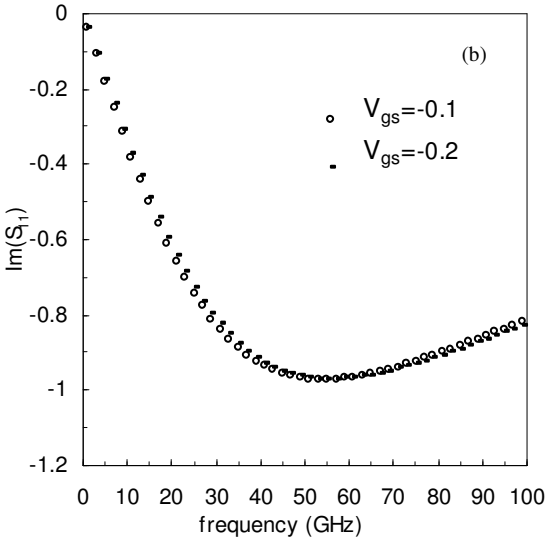


Fig. 3 (a) Real part (b) Imaginary part of Input Reflection Coefficient (S_{11}); symbol: model; line: simulated (V_{gs}=-0.1); V_{ds}=0.1

Fig. 4(a) and 4(b) show the frequency variation plot of the real and imaginary part of reverse transmission coefficient (S_{12}) for V_{gs}=-0.1 and V_{gs}=-0.2. It is observed that for a higher gate bias of V_{gs}=-0.2, the real part of S_{12} has a higher value especially at higher frequencies greater than 50 GHz. A similar trend is observed for the imaginary part of S_{12}.However, the increase in the value of $Im(S_{12})$ for greater gate bias at high frequencies is much more than that for the $Re(S_{12})$. Although S_{12} is not directly related to the power gain of the microwave amplifier circuit, the modeling of its gate-bias dependence is important since it indicates the level of isolation between the input and the output ports. For a perfectly isolated port S_{12} or the reverse isolation parameter is zero. Therefore, lower is the value of S_{12}, better is the isolation between the input and the output port.

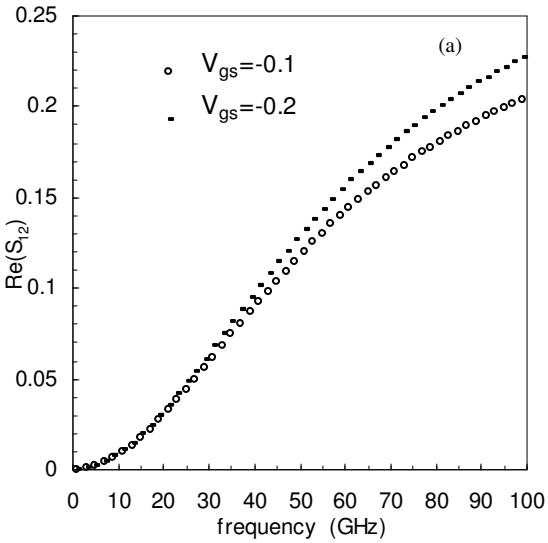


Fig. 4 (a) Real part of Reverse Transmission Coefficient (S_{12}); V_{ds}=0.1

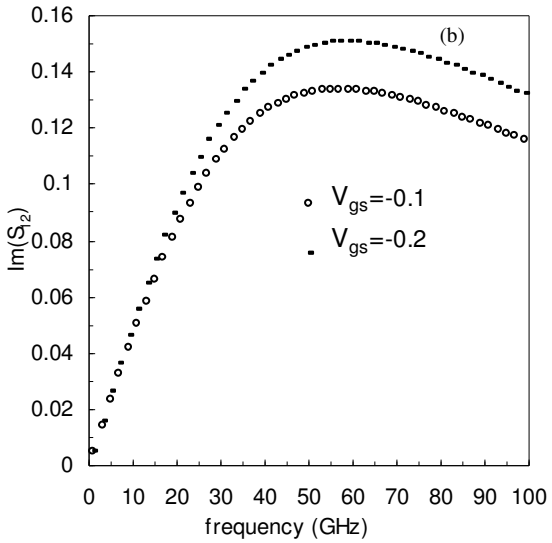


Fig. 4 (b) Imaginary part of Reverse Transmission Coefficient (S_{12}); V_{ds}=0.1

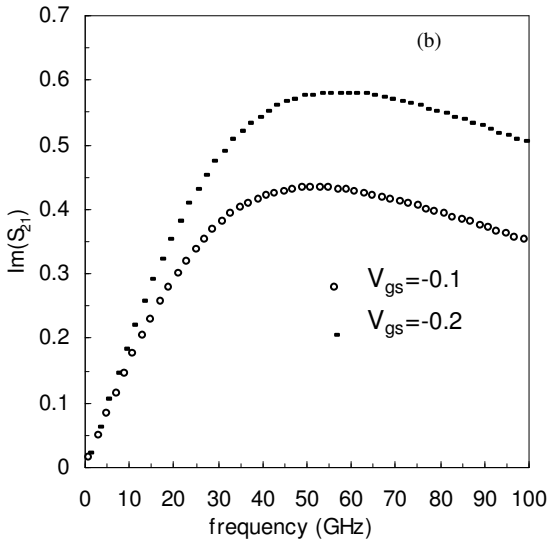
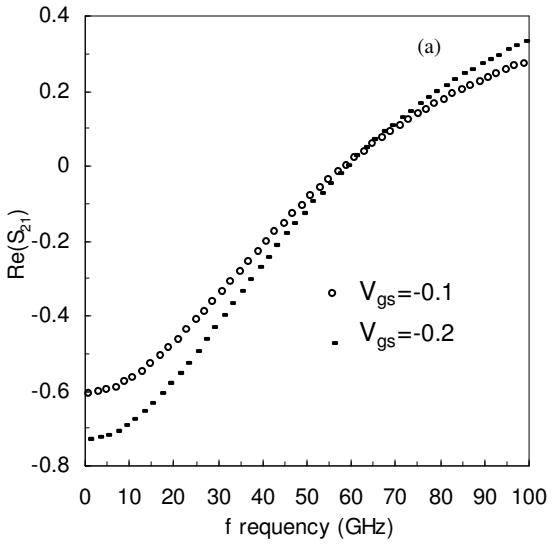


Fig. 5 (a) Real part (b) Imaginary part of Forward Transmission Coefficient (S_{21}); V_{ds}=0.1

Fig. 5(a) and 5(b) show the frequency variation plot of the real and imaginary part of the Forward Transmission Coefficient (S_{21}) for V_{gs}=-0.1 and V_{gs}=-0.2. It is considered to be the most important of the four scattering parameters of the two port equivalent circuit as it indicates the maximum achievable power gain of a microwave amplifier. Higher is the value of S_{21}, greater is the power gain of the active device of the amplifier circuit. It is observed that higher is the value of gate bias, higher is the value of S_{21} with greater effect of gate bias on the imaginary part of S_{21}.However as shown in Fig. 4, a higher gate-bias also leads to a greater value of S_{12} which indicates degradation of the isolation between the input and the output circuit of a microwave amplifier Therefore, proper modeling of the gate-bias dependence of S_{12} and S_{21} has to done simultaneously for achieving the maximum possible power gain from a microwave amplifier circuit.

Fig. 6(a) and 6(b) show the frequency variation plot of the real and imaginary part of the output reflection coefficient (S_{22}) for V_{gs}=-0.1 and V_{gs}=-0.2. It can be observed that the impact of gate bias on S_{22} is much less significant than that for S_{12} and S_{21}. But since it indicates the degree of mismatching of the output circuit, it is an important parameter in terms of designing a microwave amplifier. The effect of gate-bias on S_{22} is however, observed to be a little more than on S_{11}. At higher value of gate-bias the real part of S_{22} shows a lower value for lower range of frequencies, while the imaginary part of S_{22} shows a higher value at higher gate-bias especially at a higher range of frequencies. The net magnitude of S_{22} can however be shown to have a higher value for a greater value of gate-bias especially for higher range of frequencies.



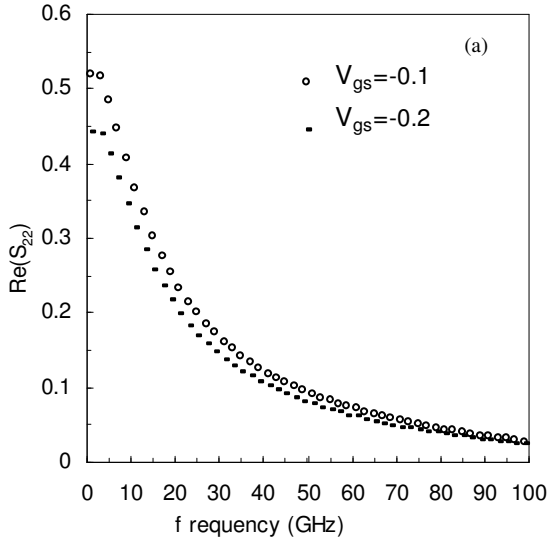


Fig. 6 (a) Real part of Output Reflection Coefficient (S_{22}); V_{ds}=0.1

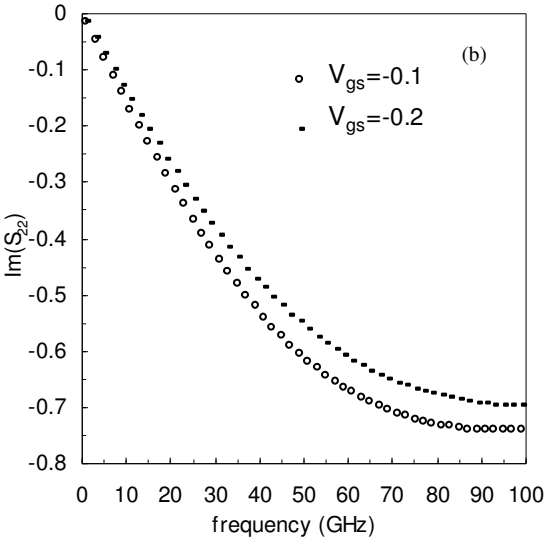


Fig. 6 (b) Imaginary part of Output Reflection Coefficient (S_{22}); V_{ds}=0.1

V. CONCLUSION

The gate-bias dependence of the scattering parameters of a tied-gate symmetric InAlAs/InGaAs DG-HEMT derived from the small-signal parameters of its two-port equivalent circuit has been studied. It can be concluded from the results obtained that the effect of gate-bias is more prominent for both the Forward Transmission Coefficient (S_{21}) as well as the Reverse Transmission Coefficient (S_{12}).A higher magnitude of S_{21} at higher gate bias indicates a higher maximum achievable power gain, while, a higher magnitude of S_{12} at an equally higher gate bias on the other hand indicates a degraded isolation and hence a greater feedback level between the input and the output circuits. Therefore, in order to obtain the maximum possible power gain from the microwave amplifier circuit, the modeling of the gate-bias dependence of both the above parameters have to done simultaneously Although, the input reflection coefficient (S_{11}) and the output reflection coefficient (S_{22}) do not show a significant dependence on the gate-bias, they are important with respect to designing of the microwave amplifier circuits as they affect the level of matching and mismatching of the input and output circuits. The analytical results obtained have been compared with the ATLAS-3D device simulation results and found to agree well which validates our proposed analytical model

VI. ACKNOWLEGEMENT

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Fuzzy logic: A link for behavioral computer simulations of collaboration in emergency management

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ABSTRACT

Emergencies are events that vary in complexity and dynamically shift along different phases of evolution, requiring different types of participants. Emergency management is an interdisciplinary field that involves multiple organizations holding different mandates and structural chains of command. This poses a challenge for collaboration in the way strategic problems are solved at each stage of the emergency, given that they may not follow the traditional normative linear patterns of decision making. To address this query, this work explores the application of fuzzy logic to characterize the problem solving approach used – coordination, cooperation, or collaboration -, with the level of complexity of the emergency and the type of inter-organizational interaction. Of special interest here is the capacity offered by fuzzy logic to operationalize experiences and perceptions of expert emergency managers. Fuzzy logic provides the framework to model these elements under flexible patterns of interaction. In addition, fuzzy logic allows connecting diverse epistemological fields such as behavioural cognitive psychology and management, and linking them to computer sciences and systems engineering. Hence, the results from this paper presents fuzzy logic from a modeling perspective that aims to contribute to achieve an efficient inter organizational emergency management response along the different phases of the crisis, by rendering fuzzy logic models of inter organizational coordination, cooperation and collaboration, which can then be applied to develop behavioral computer simulations. The expected contribution of this document is to facilitate the interaction within and across diverse fields of study involved in emergency management, by translating and interpreting their individual contributions into fuzzy logic models that can inform and complement the interdisciplinary effort.

Keywords: Fuzzy logic, Emergency Management, Collaboration, simulation, multi-organizational problem solving, model, complexity.

INTRODUCTION

Emergencies are events that vary in complexity and dynamically shift along different phases of evolution, requiring different types of participants. Emergency management is an interdisciplinary field that involves multiple organizations holding different mandates and and structural chains of command. This poses a challenge for collaboration in the way strategic problems are solved at each stage of the emergency, given that they may not follow the traditional normative linear patterns of decision making. To address this query, this work explores the application of fuzzy logic to characterize the problem solving approach used –coordination, cooperation, collaboration -, with the level of complexity of the emergency.

Emergency management approaches

There are different approaches to classify emergency management, one of them is a categorization based on the time of the occurrence of the emergency events. In these terms, crisis management studies the onset of an emergency whereas consequence management is responsible for the recovery period [1]. The activities entailed are also different; crisis management is focused on the response of the emergency and it is considered to be reactive, while consequence management deals with the effects in the aftermath of the event [2]. Risk management on the other hand, covers all the stages of the disaster (see Fig. 1), and the control of the crisis is a continuous task [3]. However, each approach possesses strengths and weaknesses.

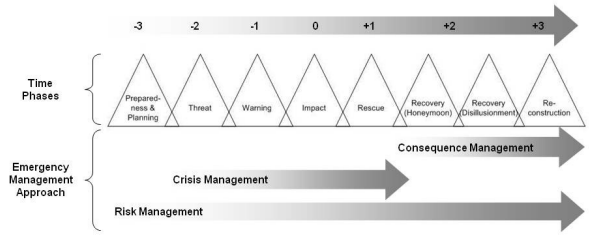


Fig.1. Emergency management approaches by time phase [3]

Event timeline

Emergencies evolve along different phases (Fig.1), each one holding different temporal characteristics [3]. Lemyre et al, [3] characterized each one of this phases as follows: *Preparedness and planning*, focuses on planning and implementing measures to reduce vulnerability. *Threat*, refers to the period previous to an extreme event when there is awareness that such an event may occur. The main activities are focused on information collection and authentication. The *warning* stage is the period previous to an extreme event when the threat is imminent and just about to occur. *Impact*, this phase starts at the moment

the emergency is detected. The *Rescue* phase starts after the emergency has been detected and until the authorities declare the end of it; main tasks include rescuing of victims, first aid and evacuation. *Recovery*, during this phase the reestablishment of essential services and cleanout is made. During the *Reconstruction* phase the construction and repairing of infrastructural damages is performed.

Lemyre et al. [4] explain there is an intrinsic dynamical relationship within the activities encompassed along each phase of the crisis, where the only two constants are "*change and movement*". To understand the dynamic evolution of these tasks, Lemyre et al [4], developed a model for problem solving of extreme events, based on two main components: "*situational complexity (complex, complicated or simple)"* and "*inter organizational problem solving approach (collaboration, coordination or cooperation)*", each one of them being modify by multiple factors, such as "*assets (information, resources and power)"* and "*time (stage of crisis)"*.

Interorganizational problem-solving approach

Along the continuum of approaches to problem solving, three different strategies relative to the differential use of information, resources and power had been categorized [4]: *coordination, cooperation* and *collaboration.* In *coordination* the priority is to make an efficient use of resources by avoiding task overlapping, each organization may take decisions independently, and they may only share information. In *cooperation* organizations not only make an efficient use of assets, but also share activities and information. Therefore they have a mild interdependent relationship at different stages of the problem solving cycle. Whereas in *collaboration,* besides of sharing resources, information and activities, organizations may also share power. Therefore the interdependence level is higher, thus both responsibilities and credit are shared.

Situation Complexity

Although the complexity of an event could shift dynamically, there is a continuum ranging from simple to complicated, to complex [4]. In a *simple situation* solutions are known, and each organization can solve it mostly independently. In a *complicated* situation, solutions are also known but the scope of the solution is further than the individual organization's capacity. Whereas in a *complex* situation the solution is mostly unknown, therefore organizations do not have certainty on which actions are more effective to solve the emergency.

Similarly, Scholtens [5] found that as the global complexity of the crisis increases the organizations involved in the response tend to collaborate to solve the manifold challenges faced. In these terms, Lemyre et al [4] in their model pointed out that at every stage of the emergency, there are "*kernels of coordination, cooperation and collaboration*", as well as "*kernels of complexity"* involving "*situations simple, complicated and complex*". This description can be captured by Zadeh's [6, p.310] definition of fuzzy information granulation, where he stated that: "*fuzzy information granulation may be viewed as a human way of employing data compression for reasoning and, more particularly, making rational decisions in an environment of imprecision, uncertainty and partial truth"*. Therefore fuzzy logic offers the possibility to characterize the problem solving approaches for interorganizational emergency response, in terms of the situation complexity along the different phases of evolution of the event.

Fuzzy Logic

Along his "*quest for better models of reality"*, Zadeh [7, p.2774] developed the theoretical basis for fuzzy logic in 1965, where the traditional binary logic was replaced by a multi-valued logic that reflects more closely the human capability of process perception based information, where language and qualitative statements plays a major role [8]. Zadeh [9] explains, that the behavior of very complex or "wicked" systems does not easily admit precise mathematical analysis and this effect increases as the complexity of the system increases. However, an approximate description can be successfully achieved based on linguistic variables and fuzzy algorithms. He envisioned the application of fuzzy logic in research fields where the main roles are played by "*animated systems constituents*", such as psychology, management, medicine, biology and artificial intelligence.

Fuzzy logic and emergency management

The usefulness of fuzzy logic applications is especially well suited to assist in the solution of social problems; of special interest for emergency management is the intricate process of inter-organizational problem solving. In this context, Fedrizzi et al. [10] explained that most of the decision making activities are performed within and across actors, groups or organizations with differing "*value systems"* along the different problem solving stages. For this reason they developed a decision support system to reach consensus based on fuzzy logic principles. Similarly Kacprzyk [11] developed algorithms to represent fuzzy majorities in group decision making contexts. Therefore fuzzy logic has the potential to assist decision makers to deal with complex problems within an environment of uncertainty, and decision support systems based on fuzzy logic can assist in this task [12].

Given the close fit between the interdisciplinary needs and requirements in the emergency management field, and the theoretical and applied capabilities fuzzy logic has to offer, this paper, proposes the use of fuzzy logic in the field of emergency management, to characterize the problem solving approaches for inter-organizational emergency response, in terms of the situation complexity along the different phases of evolution of the event. Although fuzzy logic is not a new theory, the multiple benefits and attributes it provides, have not yet been exploited nor applied in the inter-disciplinary field of emergency management but in a few cases to address information security management problems [13].

Fuzzy logic as a modeling language

Fuzzy Logic is a powerful tool to deal with imprecision and uncertainty, which offers instruments to solve real-world problems. According to Zadeh [7], one of the main legacies of fuzzy logic is its remarkable capability of "*precisiation"* that is the reason why it is highly reliable to represent different models of reality. Another important feature of fuzzy logic is that it can deal with uncertainty "*in terms of imprecision, nonspecific, vagueness and inconsistency*" [14, p. 226]. Likewise Carlssson, Feddrizzi and Fuller [15] pointed out that fuzzy logic can manipulate data and information with unknown statistical uncertainties. In fuzzy modeling, the arithmetic used for inference is based on "*if then rules"*, fuzzy reasoning is an inexact reasoning anchored in partial knowledge [16]. Consequently, fuzzy reasoning is rather qualitative than quantitative [17].

In addition, fuzzy logic offers inference mechanisms that make possible human cognitive processes capabilities to be translated into knowledge based systems [14][8]. Thus in general, the aim of fuzzy logic reasoning is to achieve conclusions from incomplete facts which are produced from experts; Bouchon-Meunier [18] described this as an "*approximation of standard evidence*". As a result, fuzzy linguistic models (FLM) are qualitative descriptions of systems behaviors, sustained on the fuzzy reasoning theory, which is a foundation for the

development of expert systems [19]. In this kind of models, traditional equations and numerical symbols are not needed [16].

Moreover, Sugeno and Yasukawa [16] described an expert system as a model build on conclusions obtained from "*observable features"* of the situation under analysis, obtained from experts' qualitative knowledge and experience. Therefore they explain that the design procedure is to build the linguistic rules, to then adapt the fuzzy parameters that bound the linguistic terms involved. The authors mentioned as one possible source of information and data for fuzzy qualitative modeling, observations based on knowledge and /or experience and linguistic data.

Likewise, Chartuvedi [14] describes two methods to outline fuzzy membership functions, classified as direct and indirect methods. In the direct method an expert intuitively designate a membership rating what in his perception portrays more meaningfully the linguistic terms under design. Whereas in the indirect methods, several experts are asked to respond plain probes that indirectly describe the membership function under construction. The answers are then processed via interpolation, curve fitting or through artificial neural networks methods.

Membership function features

In order to understand the designs presented in the results section, a brief explanation of the main characteristics of a membership function developed by Chartuvedi [14] is provided. He indicates that a membership function is a plot that describes how each point from a given *input space* is mapped to a *membership value* (or *degree of membership*) between 0 and 1. The *core* of a membership function is the area of the fuzzy set where there is a complete membership value (see Fig. 2). Meanwhile, the area of a membership function that has any value different from zero is called *support* (Fig. 2). Whereas the *boundaries* are the parts of the membership function that neither have a full membership value nor a zero one (Fig. 2).

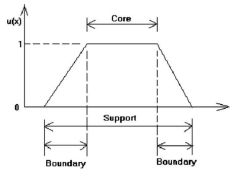


Fig. 2 Core, support and boundaries of a membership function [14, p.251]

A *generalized membership function* [14], is a concept to design membership functions with different shapes. Each generalized membership function has at least four segments of different dimensions holding different positions which can be customized to the design under construction (Fig. 3).

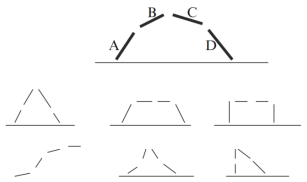


Fig. 3 Generalized membership function, [14, p.252]

Another concept to describe the features of the fuzzy sets is *normality* [14]. A fuzzy set is named as *normal,* if the maximum value of its corresponding membership function is 1, and *subnormal* in any other case.

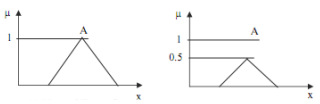


Fig. 4 Normality of a fuzzy set, [14, p.244]

Given the low likelihood of occurrence of emergencies and extreme events, retrospective data collection methods such as interviews, case studies, and other documental sources such as, governmental reports, newspapers, social media feeds and magazines are used to reconstruct the events of major crisis and emergencies. These elements have been recollected and analyzed by several researchers to develop the theoretical foundations for the emergency management field. Within these, outlines for a theory on inter organizational problem solving and decision making during emergencies are still under development and lack empirical evidence., The underlying theoretical logic is not yet fully developed. Nevertheless, there is already enough theoretical elements and material to develop an outline of a fuzzy logic model that enable an approximate representation of the phenomenon.

METHOD

Data collection and materials

The qualitative data to populate the fuzzy logic models was obtained from a series of research articles and reports that portrayed the expert observations and lived experiences from several first responders, governmental authorities, nongovernmental organizations and researchers who had experienced a major crisis, emergency or extreme event. The inclusion criteria for articles were: a multi-organizational environment and an observed effort to achieve collaboration between the organizations involved. After the selection process, three key articles were chosen to design the fuzzy logic models [4] [5] [20].

Membership function design

Within the literature reviewed, preconditions to enable collaboration between organizations during emergencies and extreme events were found. These findings were then related to the phase of the event where they were observed or reported. The design of each membership function aims to characterize the response observed or reported along the different phases of the emergency. The timeline characterization applied is based on Lemyre et al [3], and conform the input space (horizontal axis) within the membership function depiction. The degree of membership values relate the level of interaction experienced by response organizations (vertical axis). Therefore the membership function plot aims to characterize the patterns of problem solving approach used along the different phases of the emergency. This characterization was then classified to the theoretical levels of complexity of the event [4]. Each of the elements were interpreted as linguistic modifiers and outlined as a fuzzy membership function and its corresponding fuzzy sets. Each fuzzy set was setup in a Microsoft Excel spreadsheet as tables of membership values, which enabled the plotting of each membership function using an area type chart. Using these methods we look to acquire a proxy of the general outlines for inter organizational approach to problem solving applied during the different stages of the crisis along the different levels of complexity.

RESULTS

This section shows the design of fuzzy membership functions classified by level of crisis complexity, based on the experience and expert knowledge described in the literature reviewed. First a brief summary of the major literature findings is provided, followed by the set of corresponding fuzzy rules, complemented with a description of the membership values showed in table format, and finally each membership function is graphically presented and discussed.

Simple Crisis

According to the analyses presented by Lemyre et al. [4] from a series of Canadian case studies, within an emergency or major

event, there are tasks that can be performed by organizations individually without any interaction with other organizations responding to that particular event. Due to organizations being able to solve the crisis under their own availability of resources, information and mandate. Therefore the pattern observed was a mild coordinated effort mainly around the impact phase of the crisis. Translating these results into a fuzzy logic rule, this can be expressed as:

Rule 1. IF Situational complexity is low, THEN Inter-organizational approach used is LOW COORDINATION.

Table 1 show the membership values during a simple crisis, where a value of 0.3 is assigned to represent a low level of inter organizational coordination in the impact and rescue phases. In a simple crisis the membership values for cooperation and collaboration were set to zero along all the crisis phases.

Table 1. Inter-organizational interaction membership values: Simple crisis.

		Approach to problem solving		
		Collaboration	Cooperation	Coordination
Time phase	Preparedness & planning	0	0	0
	Threat	0	0	0
	Warning	0	0	0
	Impact	0	0	0.3
	Rescue	0	0	0.3
	Recovery	0	0	0
	Reconstruction	0	0	0

The corresponding fuzzy membership function is shown in Fig.5. In this graph, the vertical axis shows the membership function values of inter-organizational interaction (Table 1), and the horizontal axis shows an approximate depiction of the evolution of the timeline of the event. It is worth mentioning that the scale used in the timeline axis, is just an approximation and in any other event it may have different proportions, in other words, each one of the phases of the event may not have the same length and may overlap, this statement is valid for all the membership functions presented in the results section. The membership function shown in Fig. 5 is rendered as a subnormal plot to capture the low level of inter-organizational interaction, given that in a simple crisis the expected level of coordination is low.

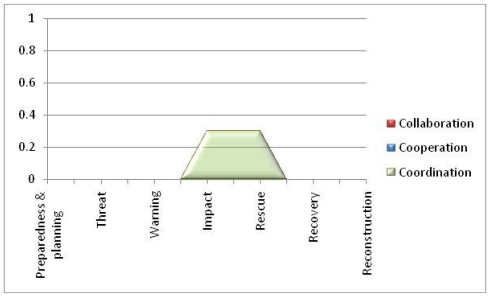


Fig. 5. Membership function for the three levels of problem solving approaches during a simple crisis.

Complicated Crisis

Berlin and Carlstrom [20] found during emergency exercises and simulations in Sweden, four different kinds of inter organizational approaches for emergency response. Parallelism is described as a similar concept to coordination; where each organization works independently from the activities of other response organizations. First initiative, on the other hand, can be classified as inter organizational cooperation, because resources and/or information were shared. Switching is described as another level of cooperation, characterized by a shifting of organizational mandates. Collaboration was barely observed between the response actors. Therefore in their experience, the most frequent pattern of interaction was coordination, followed by cooperation and the less observed pattern was collaboration. However the dynamic interplay of the patterns observed were "*kernels*" of medium coordination and low cooperation around and after the impact stage of the crisis. Translating these results into fuzzy logic rules, these results can be expressed as:

Rule 1. IF Situational complexity is medium, THEN inter organizational approach used is MEDIUM COORDINATION.

Rule 2. IF Situational complexity is medium, THEN Inter organizational approach used is LOW COOPERATION.

In this case, Table 2 shows the inter-organizational interaction membership values during a complicated crisis, where a value of 0.5 is assigned to represent a medium level of inter organizational coordination, and a value of 0.3 to characterize a low level of cooperation, both approaches were identified during the impact and rescue phases. In a complicated crisis the truth values for collaboration were set to zero along all the crisis phases.

Table 2. Inter-organizational interaction membership values: Complicated crisis.

		Approach to problem solving		
		Collaboration	Cooperation	Coordination
Time phase	Preparedness & planning	0	0	0
	Threat	0	0	0
	Warning	0	0	0
	Impact	0	0.5	0.3
	Rescue	0	0.5	0.3
	Recovery	0	0	0
	Reconstruction	0	0	0

The corresponding fuzzy membership functions are shown in Fig. 6. In this graph, the vertical axis shows the inter-organizational interaction membership function values (Table 2), and the horizontal axis shows an approximate depiction of the evolution of the timeline of the event. The membership functions shown in Fig. 6 are rendered as subnormal plots to capture the low and medium levels of inter-organizational interaction, given that in a complicated crisis the level of coordination expected is medium, and a low level of cooperation. In this case, coordination is represented as a precondition to enable cooperation, which in turn may overlap with some coordination activities that may require resource, information and authority sharing between organizations.

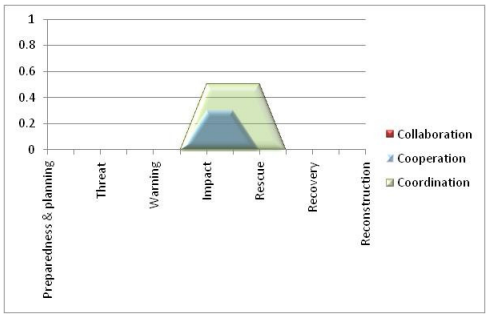


Fig. 6 Membership functions for the three levels of problem solving approaches during complicated crisis.

Complex crisis

In the Netherlands, Scholtens [5] based on field and documental studies for inter organizational emergency response; found that collaboration was only observable when life of people was in danger. That was the only key moment when organizations, had to work jointly and shared resources, information and authority. After this short period of time, the organizations return to work preferably independently. These findings coincide with the observations made by Berlin and Carlstrom [20]. The authors

hypothesized that collaboration is not the prefer pattern of interaction, due to the high efforts and costs involved in deploying this kind of response. In this case as well, dynamic interplays or *"kernels"* of coordination, cooperation and collaboration were observed. Translating these results into fuzzy logic rules, these results can be expressed as:

Rule 1. IF Situational complexity is high, THEN inter organizational approach used is MEDIUM COORDINATION.

Rule 2. IF Situational complexity is high, THEN Inter organizational approach used is FAIRLY HIGH COOPERATION.

Rule 3. IF Situational complexity is high, THEN Inter organizational approach used is HIGH COLLABORATION.

For complex crisis, Table 3 shows the membership values of inter-organizational interactions interpreted from the literature descriptions. Inter organizational coordination was set up to a value of 0.5 to represent a medium level. Cooperation was assigned a value of 0.7 to characterize a fairly high level of inter-organizational interaction; both approaches were identified during the impact and rescue phases. On the other hand, collaboration was set up to a value of 1, to represent the high level of inter organizational interaction needed during the life-danger period of the impact phase of a complex crisis.

Table 3. Inter-organizational interaction membership values: Complex crisis.

		Approach to problem solving		
		Collaboration	Cooperation	Coordination
Time phase	Preparedness & planning	0	0	0
	Threat	0	0	0
	Warning	0	0	0
	Impact	1	0.7	0.5
	Rescue	0	0.7	0.5
	Recovery	0	0	0
	Reconstruction	0	0	0

The corresponding fuzzy membership functions are shown in Fig. 7. In this graph, the vertical axis shows the inter-organizational interaction membership functions values (Table 3), and the horizontal axis shows an approximate depiction of the evolution of the timeline of the event. The coordination and cooperation membership functions shown in Fig. 7 are rendered as subnormal plots to capture the medium and fairly high levels of inter-organizational interaction. Notice that the pattern described for collaboration is a normal triangular membership function, with slopes so steep that its shape recalls a Dirac's function. As in the former case, both coordination and cooperation are represented as preconditions to enable collaboration. In the impact phase of the crisis patterns of dynamic interplays between collaboration, coordination and cooperation are shown.

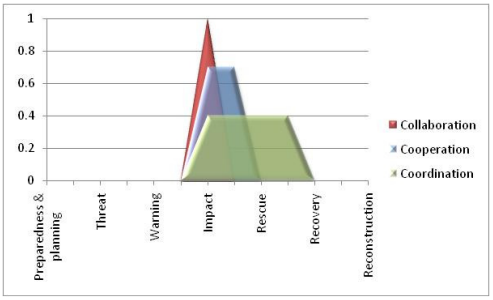


Fig. 7 Membership functions for the three levels of problem solving approaches during complex crisis.

Very Complex Crisis

In the analysis presented by Lemyre et al [4] from a series of case studies of international major events and disasters, the 2003 SARS case stands out, due to the high level of international collaboration involved to overcome the extreme complex challenges faced. In this case as well, the main danger was the lost of hundreds of lives related to the high power of viral transmission, and the uncertainty related with its treatment and prevention. Therefore collaboration was observed over an extended period, because the impact phase was geographically extended as well.Translating these results into fuzzy logic rules, these results can be expressed as:

Rule 1. IF Situational complexity is very high, THEN inter organizational approach used is MEDIUM COORDINATION.

Rule 2. IF Situational complexity is very high, THEN Inter organizational approach used is FAIRLY HIGH COOPERATION.

Rule 3. IF Situational complexity is very high, THEN Inter organizational approach used is HIGH COLLABORATION EXTENDED.

For very complex crisis, Table 4 shows the inter-organizational interaction membership values interpreted from the literature descriptions. Inter organizational coordination was set up to a value of 0.5 to represent a medium level along the impact, rescue and part of the recovery phases. Cooperation was assigned a value of 0.7 to characterize a fairly high level of inter-organizational interaction during the impact and rescue stages. Finally, collaboration was set up to a value of 1, to represent the high level of inter organizational interaction needed during the extended life-danger period of the impact phase of a very complex crisis.

Table 4. Inter-organizational interaction membership values: Very Complex crisis.

		Approach to problem solving		
		Collaboration	Cooperation	Coordination
Time phase	Preparedness & planning	0	0	0
	Threat	0	0	0
	Warning	0	0	0
	Impact	1	0.7	0.5
	Rescue	1	0.7	0.5
	Recovery	0	0	0.5
	Reconstruction	0	0	0

The corresponding fuzzy membership functions are shown in Fig. 8. In this graph, the vertical axis shows the membership functions values (Table 4), and the horizontal axis shows an approximate depiction of the evolution of the timeline of the event. The coordination and cooperation membership functions shown in Fig. 8 are rendered as subnormal plots to capture the medium and fairly high levels of inter-organizational interaction. Collaboration, on the other hand, is portrayed as a normal trapezoidal membership function. And as in the former complex case, both coordination and cooperation are represented as preconditions to enable collaboration. During the extended impact phase of the crisis, patterns of dynamic interplays between collaboration, coordination and cooperation are shown.

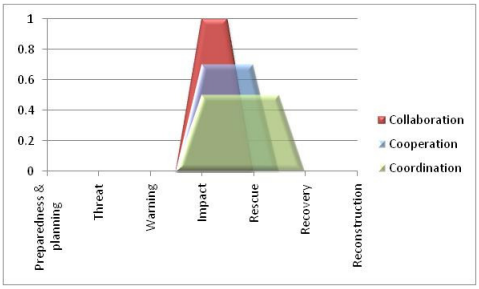


Fig. 8 Membership functions for the three levels of problem solving approaches during very complex crisis.

DICUSSION

The fuzzy logic models presented here are first attempts to characterize inter-organizational patterns of interaction and response during emergencies based on fuzzy rules. The characterization presented explored the inter-organizational approach for problem solving – coordination, cooperation, collaboration -, and related it to the level of inter-organizational interaction experienced by organizations in the response of the event along the different phases of the disaster, according to the level of complexity of the emergency. Of special interest here is the capacity offered by fuzzy logic, to operationalize experiences and perceptions of expert emergency managers. These fuzzy logic models can eventually help to populate expert knowledge data for computer behavioural simulations and expert systems, by offering basic low cost instructions to build on more complex algorithms. The fuzzy logic models can also be applied in situations where experimentation is a challenge for data collection. Although neither optimal nor comprehensive, the models portrayed provide an approximate description of inter-organizational problem solving patterns along different levels of crisis complexity. These models provide a graphical depiction of the literature results descriptions, which potentially could bring forth more precise or complete models that fit better the phenomena based on qualitative analogies.

Next steps will include refining, tuning up and validation of the fuzzy models to assess their external validity. Future steps will also include the development of fuzzy models of variables such as inter-organizational sharing of information, resources and power; inter-organizational inter-dependencies along the different phases of evolution of disasters and featuring of organizational resilience by organizational background. All of these models could eventually provide outlines to develop expert systems to assist in the field of emergency management. The first step is presented here using fuzzy logic as a mediator linking epistemologically differing fields, such as social and computer sciences by enabling the representation of degrees of human rationality bounded by vagueness.

ACKNOWLEDGEMENT

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Measurement of design feasibility for sustainability

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ABSTRACT

The paper presents the feasibility measurement of design for sustainability. Major feasibility considerations for sustainable design have been enunciated. It is proposed that present day design must include the environmental considerations in design of part or systems.

Keywords: Feasibility, design phase, sustainability, reuse, recycling, design methodology

1. INTRODUCTION

The purpose of this paper is to present a methodology for measurement of feasibility of design in engineering and sciences. The paper states the generic synergic relationships among various design parameters which affects the feasibility of design for sustainability. There has been increasing concern for environmentally friendly product and system in the market. Government world-wide have been tightening environmental regulations for products and systems. The reasons for this development are many but specially running out of fossil fuel, global warming, depletions of natural resources, and such other related factors.

But we in academic engineering world have not taken notice of these factors in our design process and so the engineers graduating from engineering schools have no concern for these developments. It is an attempt to make this awareness felt among future engineers. It is advocated in this paper that technological requirements for green design be espoused at early stage of engineering education. Concerns for energy consumption, material selection, manufacturability, recycling, reusing, including packaging should be taught in engineering design. Green design basically is a multidisciplinary approach for reducing energy and material consumption. It is estimated that in USA about 25% is recycling and 15% is waste combustion and rest 60% goes to landfill. It is time to bring these problems to class rooms of future engineers. The objective of design should also be to restrict use of hazardous materials in design which have adverse effects on human health as well as on environment. No where we teach in design class end-of-life aspects of the product i.e. state of disposal. A paradigm shift in our approach to achieving sustainable design is needed by including life cycle thinking in design. We can call it Life Cycle Assessment (LCA), or Design for Environment (DFE), or Green Design but concept and approach should always be based on life-cycle aspect of the product [1, 2]. Later in the paper I have enunciated feasibility measurement for sustainable design.

It is generally known that any final design adopted started with several design hypothesis. However good and robust design shared a small numbers of common characteristics to make the design adoptable. This paper studies the impact of such multiple views and representations and how it could be accommodated. Large scale design project involve many different disciplines each with their own area of concern and expertise. At various stages of design designers from different disciplines will represent an abstraction (a model) of the current design according to their views. The different models will initially be incomplete and inconsistent but through collaboration they will undergo changes as inconstancies are removed and details are added and eventually a constituent representation emerges. Hence, it is proposed that the essence of feasible design could be captured. It is recognized by designers that no amount of parameter tuning can markedly improve the feasibility of design if it is not grounded with fundamental theories of natural sciences. It also discusses resources issues that are traditionally discovered so late in design process like materials, manufacturability, weight, functionability, cost, and sustainability. For a feasible and good design customer attributes should match with functional requirements. And then functional requirements must be incorporated in design parameters to make it feasible. Feasibility may be of the following types.

1) Short term feasibility: The ability to immediately satisfy the needs.
2) Medium term Feasibility: the ability of the system to work at the maximum levels of productivity when use of the systems is varied.
3) Long term feasibility: the possibility to adapt the system to new types of use other than intended purpose.

The sustainable design requires a holistic view, from designing products that use machines and processes that produce them to optimizing the layout of the facility itself.

2. DESIGN CRITERION

However, as we know in the engineering world the designers sometimes misses the process parameters and manufacturability requirements of the product. In particular good design must be theory grounded: Good and feasible design must reflect the theory which is being investigated. We know that sometimes the designer is not able to visualize the force or load or a combination of them acting on the part. This simple analytical process would start the designer on good footing. We should also be able to analyze if the load will cause fatigue or the load is dynamic in nature.

It should also be noted that good design should not be situational as it limits its universability in the days of global economy. We all well know that engineering parts and products are designed in country X and manufactured in country Y and assembled in country Z and shipped to country N. To make the part or product internationally acceptable it has to follow standards and codes acceptable globally not country specific.

However the most important feature of feasible design means it should be implementable, i.e. it should be manufacturable. The sequence and timing of manufacturing steps should carefully be

thought about during design to weed out the potential problems during manufacturing process. Sometimes in the design of a system the redundancy should be built in as we can visualize its need in space shuttle, aircraft and such other systems. Often this flexibility results from duplication of essential design features. Good design strikes a balance between redundancy and tendency to over design. In engineering design sciences, it is called factor of safety. It is used to improve the safety of the part. However, as we try to improve safety by increasing FOS, it increases the material requirement of the part and the system. This in turn makes the part or system heavy and more costly and less profitable. The factor of safety is greater than 1 i.e. $1 < FOS \leq n$, where n is any number greater than 1. As we notice making the system more safe means increasing the material consumption. So to make the product or system safer means increasing the weight of the part or system and it is not sustainable. We should reduce the weight of the system but it may become less safe. We can appreciate the dilemma of aircraft design engineers. Heavier system would affect the performance of the entire system. The figure 1 below shows the effect of factor of safety (FOS) on materials, cost of manufacturing and total cost of a system.

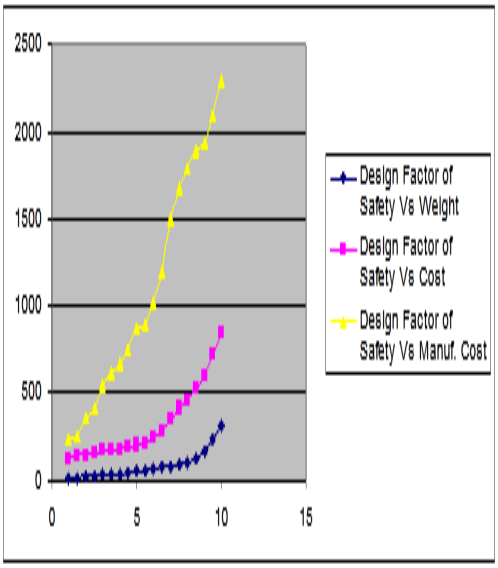


Figure 1: FOS VS Weight, Manufacturing Cost, Cost

As we consume more material it can affect the profit of the manufacturing company. We know
Profit/part = Sales Price/part - Cost/part
As we can see as FOS increases the profit will decrease and this situation is not sustainable. So the design engineers will have to account for all the consequences in the downstream of the design and manufacturing. Sometimes less FOS can affect the material selection and that in turn will affect the manufacturing process. For example, if you select cast iron to manufacture, say, flywheel you need foundry process, or if you select steel you need material removal process or sometimes with aluminum you may need forging press. All these downstream manufacturing processes are depended on the material selected and on FOS assigned in the design process. With less FOS sometimes you may be forced to select more expensive material. The quality control process would be entirely different for different manufacturing process and a good designer must bear this in mind while designing a part or system. With all the above contradictory factors described above, it is best to adopt an optimization technique to design the part. In optimal design process, an objective function needs to be formulated like minimization of cost, or minimization of weight, or maximization of profit. These objectives can also be combined together to make multi-objective function. Then we have to recognize the constraints on the objective function to make the solution more feasible and sustainable.

The paper tries to present a comprehensive methodology for a good, feasible and sustainable design. Developing new products involves ideation, which involves failure- not something that processes like to embrace. Many ideas are generated and discarded in the hope that the best idea will eventually be found [5]. History reveals that well-known ideas were often born when product functions were combined with new applications. The following adaptations are known the world over.

1) The gramophones was initially designed as a voice recorder, but then used to play music.
2) Adapting tea packages for easier preparation led to the innovation of tea bag.
3) Blotting paper in brass pot with drilled holes led to the coffee filter.

A conscious or not, using a product in a different way than its purpose is the seed of creating new applications, if not innovation. Adopting a product to a new need or situation relates to what is known by context awareness; human factors related context is structured into three categories.
a) The user's tasks and needs (e.g.… spontaneous activity, engaged tasks, generate goals).
b) The user's environment (e.g., location interaction with others).

The feasibility can be expressed in terms of capability and capacity of the part being measured. The capability can be measured as the number of different types of applications that a part can perform, while capacity is defined by cost and time required to configure a part for different types of operations. Therefore feasibility of a part can be expresses as a function of the set of operations, time and cost for reconfiguration. That is
Features=function of (capability, Capacity),
Capability=function of (Range of Operations)
Capacity=function of (Time, Cost)

Therefore, Feasibility=function of (Range of operation, Time, Cost)

3. DESIGN METHODOLOGY

Engineering Design Methodology (DM) is a formal approach to design, its aim is to provide a theory to the engineer with which he can systematically generate and evaluate solutions to a design problem in an objective and effective manner. DM tries to make design teach and learnable, and to ensure that engineer arrive at optimal solutions not by chance but by methods. DM provides methods and structure for design and divides the design process into the following phases [3]. Figure 2 shows the phases described here.
a) Task clarification: The design process starts out with the clarification of task. During this phase information about the requirements to be met are collected. Up to recent the design engineers used to think that requirement just means functioning

of the component or system. With the onset of sustainability concept the factors like safe (non-hazardous) material for the entire life time of the product has become essential along with cost and quality. The detailed requirements must include safety, cost, and quality along with the functioning of the system/product. The requirements list is basically a description of the ideal object.

b) Conceptual design: From the description of the ideal object, functions that object has to realize are derived, and a function structure is generated for sustainability. The detailed description of these phases is shown in figure 2 below. By combining these solutions a vast amount of concept ideas are generated. In order to decide which one of these concept variants should be developed further a realistic evaluation has to be made. For this purpose the ideas that do not meet the requirements in terms of cost, quality, and long term safety requirements are eliminated and rest are examined further [4].

Figure 2:Design Phases

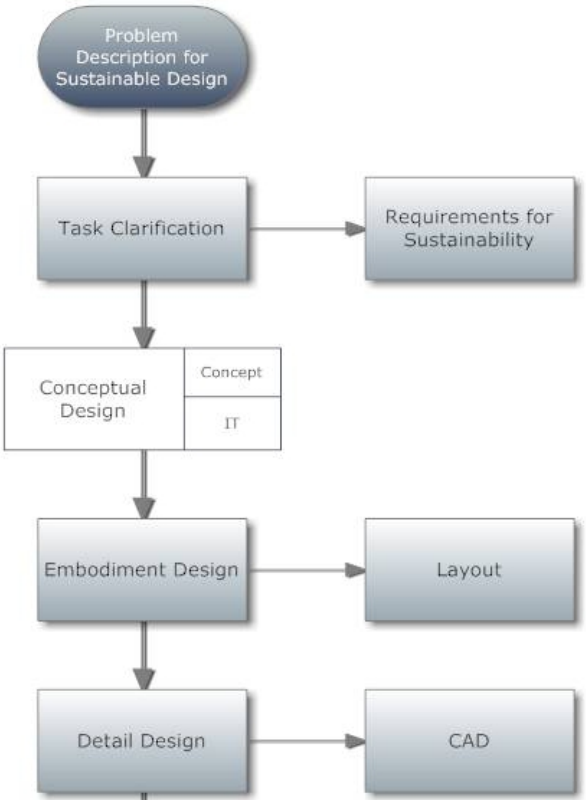


Figure 2: Design phases

c) Optimal design: In this phase the engineer refines the concept and determines the shape, size and geometry of the object in accordance with requirements for sustainability and real world constraints. The dimensions and surface properties of all parts and system are optimized, checked against constraints and fixed.

d) Detail design: In this phase the design is finalized and detail drawings, parts list, and 3-D models are generated by a CAD software. Although this engineering design methodology seems different but a similar variant of ideas are used by design engineers are used more regularly and are described in most of the design textbook. This is presented in Figure 3 below.

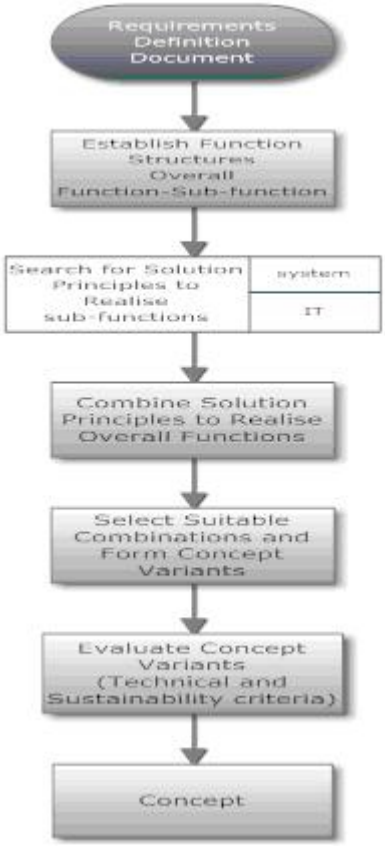


Figure 3: Phases of conceptual design

4. COGNITIVE CONCEPT NEEDED FOR DESIGN ENGINEER

Experience in engineering and design is important for designers. It is the knowledge a designer gained through seeing things and doing [6]. But it may not so literally. If for example a designer in space agencies has to design a vehicle for traveling on Mars, we can confidently say no designer has seen the vehicle on Mars. The 'doing' part is guided by design of vehicle on earth or some one may have some knowledge of designing moon vehicle. So we say some times when designing an object or system the experience is just inferential. The mental concept in human being is formed by the following models:

i) Classical model: In classical model a mental concept is defined by a set of necessary and, together, sufficient features. Mental concepts are organized hierarchically and all features are of structural nature.

ii) Probabilistic model: In the probabilistic model the mental concept is still defined by a set of features, but these need not be defining but only be typical. Each feature has a measure of typicality attached to it and classification of an object is done on a probabilistic basis.

iii) Exemplar model: Exemplar models do not have a set of defining features but instead a set of defining exemplars. An object is classified according to its similarity to the exemplars of the mental concept.

iv) Hybrid models: Hybrid models mix the defining-feature based and exemplar based models to form a system where both defining features and a set of exemplars exist.

v) Microtheory models: Microtheory models, on the other hand, use the rules governing the classification of the

object as the core of the mental concept model.

The experience of design engineers plays a central role throughout the design process. Transferring the problem at hand into tasks to which solutions can be found is a process that is based on the ability of engineers to relate to the problem to his prior experiences and his domain of knowledge. It may not be out of place here to mention that in mechanical engineering, the designer store a description of what technical object does and its basic properties, along with some examples and counterexamples as concepts.

5. THE FRAMEWORK OF FEASIBILITY MEASUREMENT IN DESIGN FOR SUSTAINABILITY

The paper presents the following feasibility criterion for sustainable design [7].

1. Choose non-toxic, sustainably provided or recycled materials.
2. Energy Efficiency: Use manufacturing process and produce products which require less energy.
3. Quality and durability: Longer-lasting and better-functioning products will have to be replaced less frequently, reducing the materials requirements in future.
4. Design for reuse and recycling: Product processes and systems should be designed for performance in a commercial "after life".
5. Design impact measures for total carbon footprint and life cycle assessment for any resources used are necessary. Available measures are complex but some give quick and accurate whole-earth estimate of impacts. One measure estimates any spending as consuming an average share of global energy use of 8,000 BTU (8,400 kJ) per dollar and producing CO_2 at the average rate of 0.57 kg of CO_2 per dollar.
6. Biomimicry: Redesigning an industrial system on biological lines- enabling constant reuse of materials in continuous closed cycle. At this stage of engineering design, we don't see any biomimicry being used in design. However it is certainly a useful idea.
7 .Service substitution: Shifting the mode of consumption from personal ownership of products to provision of services which provides similar functions e.g. from a private automobiles to a sharing service. Such a system promotes minimal resources use per unit of consumption.
8. Renewability: Material should come from nearby, sustainably managed renewable service that can be composted when their usefulness has been exhausted.
9. Robust eco-design: Robust design principles are applied to the design of pollution sources.

6. CONCLUSION

The paper has tried to present the measurement of long term feasibility considerations for sustainability in artificial and natural sciences. It has been pointed out that present engineering education in particular doesn't emphasize on the environmental considerations. The long term feasibility considerations have been clearly enunciated to make the sustainable.

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Research, Design and their Mutual Interactions

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ABSTRACT

Research and design are two complementary human activities that from the dawn of history have improved upon civilizations. New discoveries and research were made possible by former technological innovations. Many areas of research mutually upgrade and improve themselves in a positive feedback loop. A different kind of a symbiotic research-design relationship is in mathematical proofs.

Keywords: Research, Design, Basic Theory, Symbiosis**,** Government Regulations.

1. INTRODUCTION

This article schematically analyzes various types of science-technology relatoinships, giving examples from different fields for both the science and technology components.

2. DEPENDENCE: SCIENCE AND TECHNOLOGY

The mutual co-dependence between science and technology is schematically represented in **Figs**. 1 and 2. Technology may contribute to science (**Fig**. 2 (a)) science can contribute to technology (**Fig**. 2 (b)), or they can mutually reinforce each other (**Fig**. 2 (c)). These relationships are analogous to the relationships among organisms, namely symbiosis**,** synergism and commensalism. Symbiosis is defined as a mutually beneficial relationship between two organisms. Synergism is defined as two components having a combined effect which is greater than the cumulative effect of each component by itself.

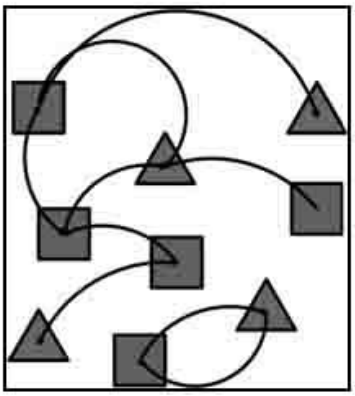


Fig. 1 Science-technology general view of the space graph (illustration) of human creation's elements (research, technological inventions) types using the following legend:



Commensalism is defined as a relationship between two organisms where one organism benefits and the other organism doesn't gain anything and doesn't lose anything.

We will discuss in the following sections milestones in science-technology developments, emphasizing the types of each of the mentioned relationships.

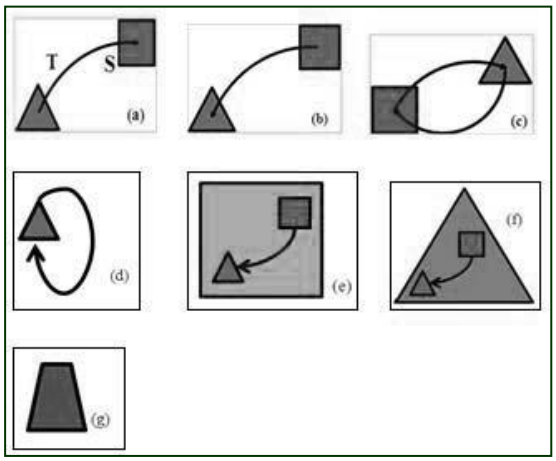


Fig. 2 Seven types of science – technology relationships:
(a) Technology supports science; (b) Science supports technology; (c) mutual reinforcement; (d) self reinforcement; (e), (f) Aggregation (Scientific, ot technological dominance, respectively) of one of the previous relationships or other relationship, containing other components; (g) Duality of techno-scientific domain – mixing shapes (square and triangle) and colors (blue and green) of the original shapes.

3. PYTHAGORAS THEOREM

An example of research that was helpful in the design of many useful objects (i.e. science supporting technology – **Fig**. 2 (a)) is the Pythagorean Theorem [1] (**Figs**. 3 and 4).

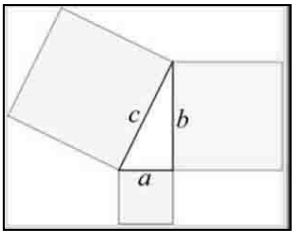


Fig. 3: Pythagorean theorem: a visual presentation: of the formula $c^2=a^2+b^2$, i.e. the sum of the areas of the two squares on the legs (*a* and *b*) equals the area of the square on the hypotenuse (*c*).

The application of that theorem has been used in measuring geodesies, navigation, prediction of celestial configurations and calendar determination.

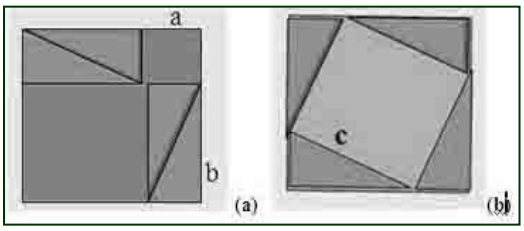


Fig. 4: Four triangles ordered in a square demonstrate the Pythagorean Theorem: The surface of the inner square (b) equals the sum of surfaces of the inner squares, where as the surface of the triangles remain the same in both sub-Figures (a) and (b), comparing the corresponding squares surfaces, the famous formula $a^2+b^2=c^2$ is derived.

4. MICROSCOPE AND MICROBIOLOGY

Discoveries and ***research*** were made possible due to former technological innovations. Robert Koch (**Fig**. 5 (a)), is one of the fathers of microbiology. He was greatly helped by a previous invention, the microscope.

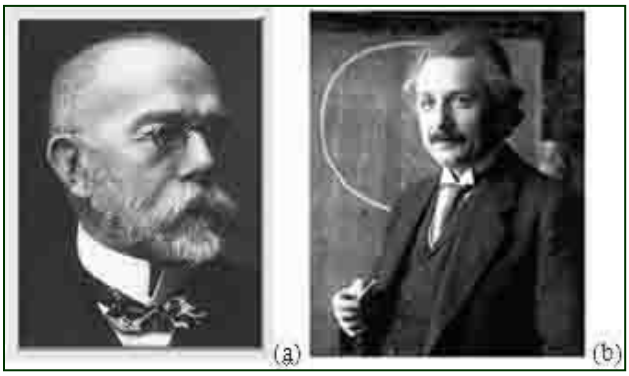


Fig. 5: Scientists: (a) Robert Koch; (b) Albert Einstein.

1. The microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy organisms.
2. The microorganism must be isolated from a diseased organism and grown in pure culture.
3. The cultured microorganism should cause disease when introduced into a healthy organism.
4. The microorganism must be reisolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.

Fig. 6 Koch's postulates which define a disease causing microorganism i.e. a bacterium.

The corresponding relationship (Science and technology) is of the type shown in Fig. 2 (a), where the microscope, the technological invention, helped Koch in his research thus enabling him to arrive at his postulates (**Fig**. 6).

5. EINSTEIN'S THEORY of GENERAL RELATIVITY

Not all discoveries were made solely on previous research. Some came from insights that came from minds of geniuses. Einstein (**Fig**. 5(b)) and his theory of relativity was one such discovery [2]. Later, his discovery was validated using telescopes looking at solar eclipses.

The Eddington experiment was an observational test of general relativity, organized by the British astronomers Frank Watson Dyson and Arthur Stanley Eddington in 1919 (**Fig**. 6). The observations were of the total solar eclipse of May 29th 1919, and were carried out by two expeditions, one to the West African island of Príncipe, and the other to the Brazilian town of Sobral. The aim of the expeditions was to measure the gravitational deflection of starlight passing near the Sun. The value of this deflection had been predicted by Albert Einstein in a 1911 paper, and was one of the tests proposed for his 1915 theory of general relativity. Following the return of the expeditions, the results were presented by Eddington to the Royal Society of London, and, after some deliberation, were accepted. Widespread newspaper coverage of the results led to worldwide fame for Einstein and his theories. Another successful experiment was performed in 1919 (**Fig**. 7).



Fig. 7: The May 29th 1919 solar eclipse, showing the bending light.

Space telescopes were proposed as early as 1923. Hubble was funded in the 1970s (**Fig**. 8), with a proposed launch in 1983, but the project was postponed by technical delays, budget problems, and the *Challenger* disaster. When finally launched in 1990, scientists found that the main mirror had been ground incorrectly, as part of a sphere instead of as part of a parabola. This severely compromised the telescope's capabilities. However, after a servicing mission in 1993, the telescope was restored to its intended quality by adding a corrective lens. Hubble's orbit outside the distortion of Earth's atmosphere allows it to take extremely sharp images with almost no background light.

The advanced telescopes are founded on parabolic mirrors, which are more difficult to produce (due to lack of spherical symmetry enabling a relatively easy method of polishing), but have the property that parallel rays break to a single focus point, based on a mathematical principle (**Fig**. 9), and are more precise than the

classical, spherical ones. The space telescope differs of course from the classical telescopes (**Fig**. 10) by lack of an eyepiece, which was once a great improvement enabling higher quality images.

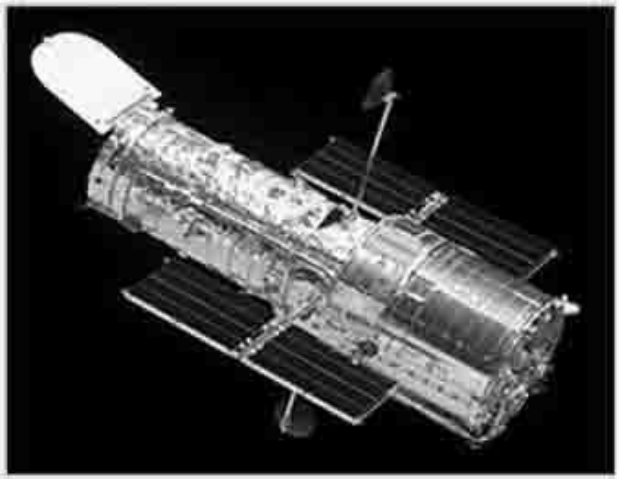


Fig. 8: Hubble telescope**.**

The modern Hubble Space Telescope has the research potential of helping mankind make many dramatic discoveries. This shows that the interplay between research and design can flow both ways.

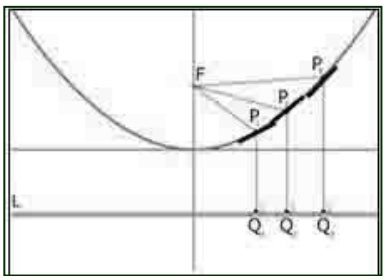


Fig. 9: Parabola demostrating the breaking parallel rays in one pont called Focus, satisfying the following equalities: $FP_i=P_iQ_i$.

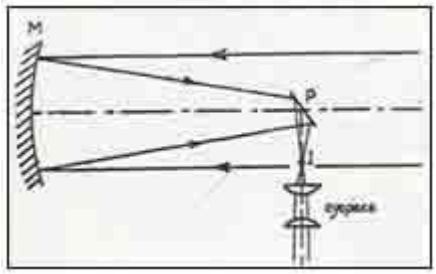


Fig. 10: Reflecting telescope.

6. BIOINFORMATICS

Bioinformatics represents collaboration between biology and computer sciences thus creating a new scientific field. This is an aggregation type (Fig. 2 (e)) of the technology-science relationship example. The common research tools are sequence matching [6]: looking for a track (sub-sequence) in a DNA or RNA strand (**Fig**. 11) and three dimension optimizations using conformational matching.

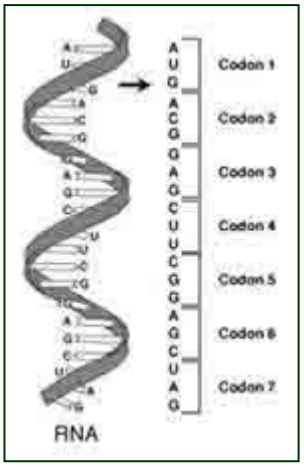


Fig. 11: Ribonucleic Acid strand and its schematic description

7. COMPUTERS AND ROBOTS

Many areas of research mutually upgrade and improve themselves in a positive feedback loop (**Fig**. 2 (d)). Computers fit into this type of category. Computer systems and their applications upgrade the next generation of chip designs using different simulation /optimization/layout programs. These improved chips are then used in programming faster and more complicated applications for designing next generation chips and so on.

The production cycle includes the following components (**Fig**. 12): the CAD (Computer Aided Design) and CIM (Computer Integrated Manufacturing) programs, the production of an upgraded wafer (later integrated in the next generation computers), an online production quality inspection and a computer analysis.

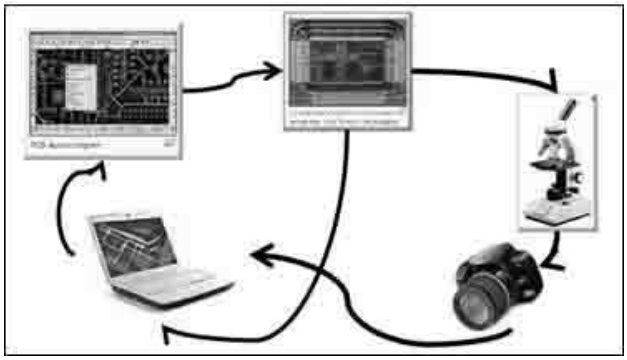


Fig. 12: The chip's production cycle including: CAD, CIM, wafer, measurements and inspection's tools.

Robotics, in a similar fashion to computers has also benefited from this positive feedback loop (**Fig**. 13).

8. THEOREM'S PROOF- AN HYBRID OBJECT

Another kind of ***symbiotic*** research-design relationship lies in mathematical proofs. This relationship's type, so called aggregation**,** integrates a group of sub-relationships into a new component (**Fig**. 2 (e)).

In the past few years, computer programs were harnessed to prove mathematical theorems. An example of this is the use of a computer program to solve the long standing four-color problem [3] (**Fig**. 14). Controversy does exist as to the reliability of such computer aided mathematical proofs [4].



Fig. 13: Robot's production's elements: the design and the product.

Lemma: Every triangulated planar graph, which has less than 40 vertices, is ***4_colorable.***

The classical proof characteristics are based on the following properties:

1) **Convincing-** the computer program is based on hardware and software reliability and therefore it cannot be assured that it is 100% correct.
2) **Surveyable-** computer programs may be traced in the so called debugging mode, statement after statement. But if the program performs millions of operations and maybe even more, it's humanly impossible to follow those statements.
3) **Formalizable –** Formalization means to put the ideas into forms (proof). It's difficult to relate to programming language and to the programs as to formal language. The programming resembles in some aspect, art since it is programmer depending.

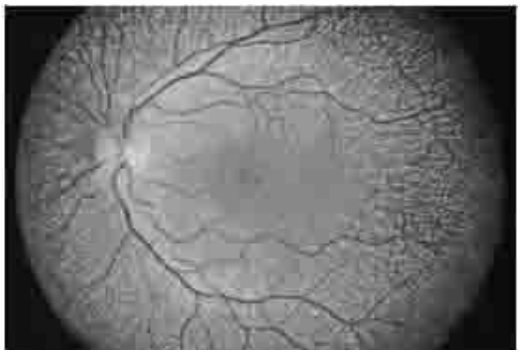
The mathematical proofs based on computer's assistance do not conform to the classical property proofs. Computerized proofs are not surveyable and not formalizable. Universal programming verification and validation are not yet assured.



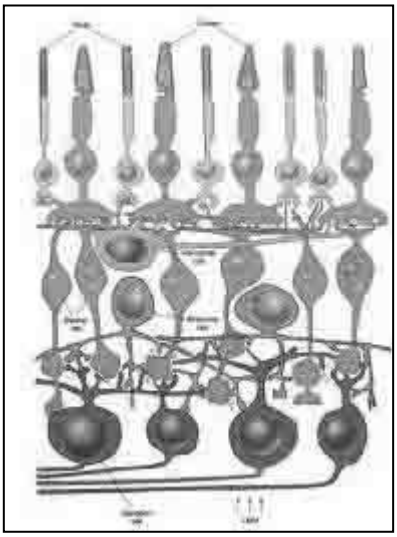
Fig. 14: An example of a four-colored map illustrating - the ***four color map theorem*** that states: given any separation of a plane into contiguous regions, producing a figure called a *map*, no more than four colors are required to color the regions of the map so that no two adjacent regions have the same color.

9. ARTIFICIAL TRANSPLANTATION

The following relationship belongs to the aggregation class (Figs. 2 (e) and (f)). This is a system composed mainly of domains from physics, electronics, biology and neurosergery. An example of an ultimate symbiotic relationship for research and design would be the futuristic possibility of melding the human brain and its technological counterpart, the computer chip. This would be due to advancements made in computer technology and transplantation techniques, such as transplantations performed on the human retina [5]. The main components of such transplantations are displayed in **Fig**. 15.



(a)



(b)



(c)

Fig. 15: Retina in various aspects: (a) frontal view; (b) retina's layers; (c) artificiel retina-chip [5].

This type of novel techno-scientific research came to existence in the last two decades spurred on by advances in nano-technology enabling discoveries in physics (new particles) and biology (bio-cellular research).

11. DUALITY

In general the roles are allocated as follows: Science investigates nature leading to discovery**.** The technology creates an imitation i.e. invention (aviation, genetic algorithms, artificial intelligence). In this context, the classification of the mathematical theorems is still philosophically problematic: are mathematical theorems human discoveries or human inventions?

This type of a techno-scientific problematic definition might be classified as a dual type (Fig. 2 (g)). This duality resembles the duality of light which behaves also as a wave and also as a particle i.e. a hybrid definition.

12. CONCLUSIONS

To summarize, research and design are both derived from the same origin of human intellect and their relationship is symbiotic in the majority of cases.

The technology supported by science or vice versa, enables humans to improve, extend their senses and capabilities. This allows us to see smaller and farther objects, to think faster, more precisely and more sophistically and remember more forever.

In our modern times, when there is competition between research and design, it is the more practical design that wins against the more theoretical research. The simple reason for this is that there is more money available for practical applications than for the more esoteric basic research. Governments can encourage more basic research by increasing funding. In this way, the best and the brightest will be found in both of these important human endeavors.

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The Minister's Black Veil. Transcending the Cloak in Peer Reviewing

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Abstract

Ensuring quality and reliability of research, as well as, ensuring that funds invested in it are appropriately assigned is in the interest of the scientific community as a whole. Peer Reviewing (PR) has been so far the most widely used process to guarantee these objectives. PR is in most chases the only criteria to accept or reject an article for publication in journals, conferences, and workshops. In this paper, we identify salient issues and areas of improvement, illustrate the drawbacks in the current practice of PR at the hand of the Australian evaluation system ERA, and propose a new PR model.

Keywords: Quality of Peer Review, Participative Reviewing

1 Introduction

Peer Review (PR) is considered one of the main safeguards of excellence and quality in scientific research. It is rarely questioned as the main procedure to select articles for publication, assess the quality of research proposals or decide on career promotion. Moreover, these overly relevant scientific milestones are with no doubt intimately related, whereby journal publication plays a prominent role in decisions related to funding and career.

The influence of this procedure reaches far beyond publishing research work, since it involves complex social exchanges and is intimately related to broader career goals such as selection of proposals for funding and career promotion. Despite its cardinal importance, the PR process has remained largely unchanged and unquestioned.

The complexities associated to this process are most evident in the lack of clear and definable procedures to adhere to. PR as a community process involves complex social exchanges and is subject to a considerable level of subjectivity. Evidently, this claims for a serious and responsible evaluation in order to factor a beneficial and fair PR process.

The next section introduces a historical overview of PR. Sect. 3 identifies salient issues in the PR process and discusses these at the hand of the Excellence Research Australia case. Sect. 4 presents our proposal for a community-oriented PR process, the paper is concluded in Sect. 5.

2 A Historical Snapshot

The first international congress on Peer Review in Biomedical Publications encouraged a systematic examination of journals [7]. The congress highlighted issues across a wide spectrum of experiences, disciplines and journal and that whilst there was general agreement of peer review not be abolished, there are still questions regarding validity and usefulness [12]. Over time the empirical approach to peer review has led critics to discribe the whole system as generally allowing conventional work to succed whilst discouraging innovative thinking [7]. There are many differing aspects to the social life of the peer review process. To expanding on the concept of the social life of peer review, [7] discusses the study of peer review as ... "a social process, not a technical one; that it differs from time to time and place to place; and that so far no precise empirical means exists to choose 'the best' method of peer review".

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The lack of faith regarding the peer review process has not prevented the adoption of the process becoming a metric which academic scientists need to adhere to in order to maintain and build careers, as well as, ensuring grant funding. The groups of scientists that are working to produce papers and are also involved with the peer review process are in some ways working on a couple of different levels (at least).

3 Debating Peer Reviewing

3.1 Peer Review Processes Viewed as Social Knowledge Networks

In more recent times "peer review has become a powerful social system" [7] which has multiple layers of knowledge networks linking and supporting its members within these communities of practice. There are the established groups which maintain long standing networks, and in relatively recent times, are emerging as much more formal and systematic, which points to a more impersonal process over all [7]. Peer review is not by any means a linar process, and like any community which is active and dynamic involves complex social exchanges.

There are many differing types of contraints, both positive and negative which have impacted the emerging development of the current peer review process. The social complex adaptive activities of the peer review can not be dismissed, as journal editors themselves discribe the path of the peer review as "as ineffable and subjective, human process... which should be a civil discourse between colleagues", but this can be at odds with the reviewers themselves [1, 5–7]. This highlights the difficulties involved with assuming that the approach to peer review has clear and definable "definitions" to adhere to.

The difficulties involved with definable "definitions" in the form a matrix was recently the subject of a Federal Government program in which over a number of years, journals themselves were given rankings. The whole process however, was abandoned in May 2011, with authorities citing that these rankings were subsequently being used applied in ways that were never intended.

Whilst the now defunct journal ranking process no longer applies, it was a useful and harmful demonstration of the unintentional havoc metrics reign on early and early-mid career academics. Those responsible for the management of research program were quick to apply the new ratings measurements as a means to evaluate funding applications. The following subsection presents an explanation of what (in hind sight) the real intention of such rankings of journals really was of the ERA (excellence research Australia).

3.2 ERA 2012 Refinements

Based on feedback received and experience gained from the ERA 2010 evaluations, the following improvements to the ERA methodology were proposed.

- The withdrawal of the Ranked Outlets indicator and the introduction of a refined journal indicator that does not use prescriptive ranks.
- Improved capability to accommodate interdisciplinary research - in an extension of the arrangement successfully trialled in 2010 for the mathematical sciences, institutions will be permitted to code a journal article with significant content (66% or greater) not represented by the journal's FoR(s) to the FoR code that best describes the content.
- For peer review disciplines, an increase in the low volume threshold to 50 apportioned weighted outputs, bringing it in line with the threshold for citation disciplines (50 apportioned indexed articles).
- A change in the rules for the attribution of patents, plant breeders' rights and registered designs to allow them to be submitted when they are granted to eligible researchers (as well as when they are granted to institutions).
- The modification of fractional staff eligibility requirements so that staff employed at 0.4 FTE or greater are automatically eligible, while staff below this threshold are eligible where affiliation is shown (through use of a by-line, for instance). In addition, the ARC is exploring ways to strengthen the peer review process.

3.3 Publish or Perish and Reviewers Fatigue

As the Australian Research council identifies, the peer review process as central element in the evaluation process requires transformation. We identify a perceptible

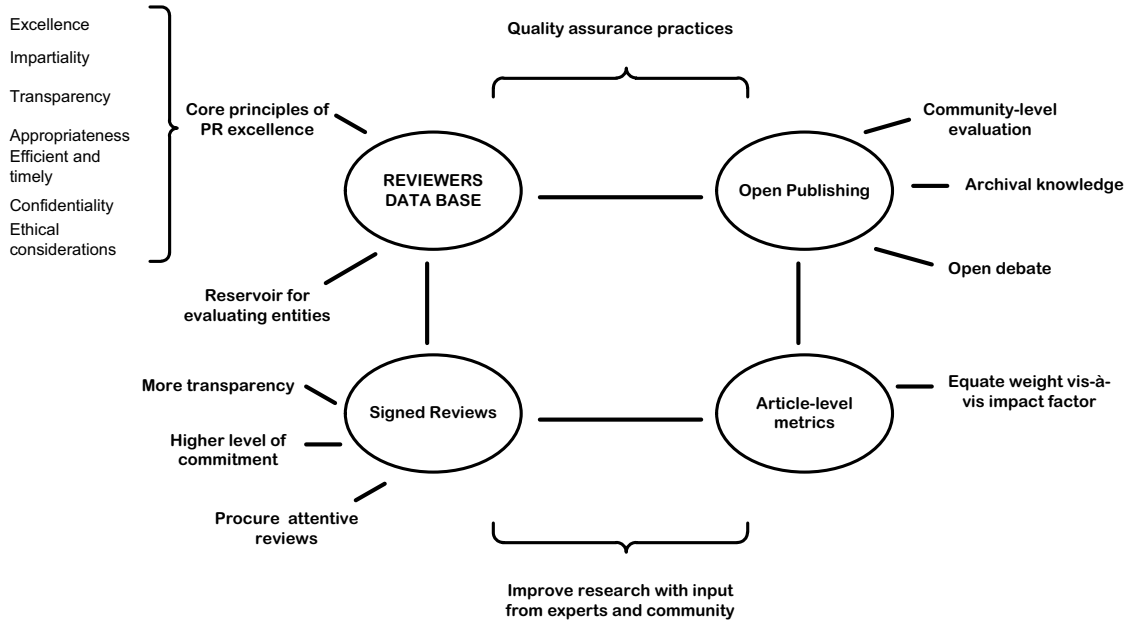


Figure 1: A Community-oriented Peer Reviewing Process

symptom in the emphasis placed on journal and high-ranking conference publications. This can be considered the cause of a phenomenon commonly known as "Publish or perish" [9].

In other words, a scientist's career and projects are at stake whenever she/he submits an article to a journal or *tier 1* conference. The number of publications in tier 1 journals and conferences is a decisive criterion when it comes to evaluating proposals. This is particularly critical in the case of researchers at an early stage in their careers, which need to fulfil multiple goals without the security enjoyed by seasoned researchers. Achieving a number of publications has a prominent place among these goals. As a result of a system that grades researchers based on high-ranking publications, authors are under extreme pressure to publish their results and submit to high-ranking journals and conferences. This results in a vicious circle with negative consequences for authors, editors, and reviewers.

Citing Alison McCook [8] "Editors at high-impact journals are reporting that the number of submissions are increasing every year" . Consequently, reviewers are more prone to make mistakes.

This pattern is reinforced by the fact that Scholarly societies depend on revenue to carry out a range of activities, including publishing. In most cases, securing funding depends on evaluation processes in which journal publications play a salient role.

This problem has been acknowledged by the European Science Foundation in [3], identifying that 73% of their participant organisations have detected some decline in the reviewer's willingness to participate in PR processes.

PR is considered a sacred pillar of excellence in scientific research, despite open or covert disagreement about its current methods. However, this dissent is hardly ever voiced.

The need for a fair and unbiased review process is evident.

4 Time to Change

In order to realise a PR process oriented to fostering the advancement of science we propose a four element system. These are a regional database of reviewers, shift-

ing from blind to signed reviews, supporting the evaluation process through open publishing, and balancing the weight between article level metrics and impact factor. A schema for the proposed model is introduced in Fig. 1. In the following we explain this proposal.

The first piece we propose for a community-oriented PR process is a database of reviewers. This database may serve a number of purposes. In the first place, equip evaluating bodies (be it journal editorial teams or project evaluators) with the means to track and record reviewers' performance. This performance may then be measured in view of the Core Principles of PR Excellence [2]: Impartiality, Benefit (for the work), Transparency, Efficiency and Timeliness, Confidentiality and Ethical Considerations.

A second principle in the proposal relates to promoting signed instead of blind reviews. It has been long discussed that anonymity does not guarantee objectivity, while it sometimes allows for inappropriate and harsh comments, signed reviews should be the norm, as is the practice in journals such as the British Medical Journal, Journal of Interactive Media in Education, PLoS Medicine, BMC Series, and Biology Direct.

A third tool we propose to improve PR is Open Publishing [11], allowing multiple experts to scrutinize the results, keeping a record of the discussion. The foreseeable result of this exercise is to allow peers to openly debate articles and authors to improve their work with expert opinion. Therefore restoring that element of science that makes it science. Finally, a fourth element we suggest is to achieve a balance between article-level metrics and impact factor. The particular implementation of such a system should be defined according to the nature of the research field.

Finally, as we explain in Sect. 3.3, the emphasis set on the impact factor of high-ranking journals saturates these venues and causes reviewers' fatigue, with a negative impact on the evaluation process itself. Therefore, the fourth element of the model intends to substitute impact factor for article-level metrics. Further work on defining standards for this indicator will have to be the subject of community-level discussion. As explained in [10], "article-level metrics will attempt to capture the actions and opinions of entire communities of readers to give a rich and sophisticated picture of research impact that will be helpful to authors and readers alike. Readers may then frame that picture in the context of their particular field and their own work."

5 Conclusions

PR is a fundamental constituent in the development of science and the life of researchers. A review process is needed to secure quality in research. Therefore, approaching PR as a social construct to achieve a fair and advantageous process acquires great relevance for the scientific community. This paper proposes a model for PR relying on four key elements: a regional (or supra regional) database of reviewers, signed reviews, open publishing to involve expert opinion in a debate that contribute to the improvement of research work, and shifting the weight from journal ranks to article-level metrics.

As Green [4] says, it is time to act. It is time to bring the science back into one of the most relevant exercises in the scientific world, by profiting from todays ICT tools for real and ongoing debate, as well as, more transparency in tune with the character of todays advanced societies.

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Developing Academic and Professional Virtual Peer Communication

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ABSTRACT

This unique virtual peer learning forum for student teachers took place in an academic college of education. The focus was the teaching of basic mathematical concepts courses by means of discussions conducted through an on-line forum and carrying out action research among the peers, who were novice computer users. Both of these activities were aimed at enhancing the level and the quality of the research activity and developing virtual communication. This study followed studies that indicated that student teachers do not know how to communicate and do not communicate enough between themselves, especially with regards to the didactics.

Most studies were carried out by the student teachers who participated in the virtual forum focused on integrating disciplines with pedagogic-didactic applications. The method of the course was based on virtual peer teaching, sharing their knowledge, information and experience.

The findings indicated that the process advanced very fast. The student teachers could integrate theory and practice while carrying out their action research. This certainly affected the student teachers' professional quality up to a level where they were capable of communicating virtually about their research. The procedure used in this research fostered the student teachers' quality of planning, designing and evaluating the research. The process was successful, apparently thanks to collaborative activity. Consequently, the student teachers gradually learned to evaluate and manage their own research. The method enabled activating this knowledge in the real world. Cooperation through the use of the computer resulted in virtual peer learning, exchanging instructional and academic experiences, discussing issues, etc.

Keywords: Communication, Online Forum, Virtual Peer Learning, Teacher Education.

1. INTRODUCTION

This research may affect virtual peer learning while preparing student teachers in colleges of education, theoretically and practically, as it will be detailed below.

The scientific contribution of virtual peer learning focuses mainly on five issues:

1. Presenting new ideas and innovations that have not been disseminated in any other way.]
2. Enhancing professional communication among the student teachers.
3. Discussing highly important issues.
4. Enabling student teachers to contribute and receive new ideas and materials from their peers' experience.
5. Carrying out action research based on integration of theory and pedagogy.

2. THEORETICAL REVIEW

Student teacher programs are being called on to provide models of authentic teaching, and offer meaningful opportunities for teachers to develop skills in using technology (International Society for Technology in Education (1)). It is essential that all K-12 teachers be able to demonstrate an ability to use technological tools in their standards-based curriculum to promote student learning, improve student achievement, and provide students with the skills they need in their future education and/or workplace careers. The National Research Council (NRC) in its publication How People Learn: Brain, Mind, Experiences and School (2) argued that "technology resources for education, whether a software science simulation or interactive readings exercise, function in a social environment, mediated by learning conversations with peers and teachers" (p. 218). Using synchronous and asynchronous communication, hypertext-based programs to promote debate, “real life” problems, and computer programs such as databases and artificial intelligence, enables distance education learners to work together to solve problems and provide the social interaction necessary to translate educational material into meaningful experiences (3).

The World Wide Web supports information sharing with the dual aspects of publishing and finding information. As the Web has expanded to embrace a diverse population of users and a broad range of uses, more activities have become important; for example, regular activities like person-to-person communication and educational activities such as online course materials, interactive tutorials and distributed science experiments (4).

Harnad (5) indicated that ideas and findings are discussed informally with peers. This is an interactive process that will substantially restructure the pursuit of knowledge.

The research literature attributes to guides/advisors the management of a multifunctional computerized forum. Mason (6) stresses the importance of a guide/advisor managing the forum in building a virtual learning community and in creating a fruitful discussion in the forum. It is imperative that he react to the participants' questions and enter the forum very frequently. This is necessary to stimulate the participants' enthusiasm and increase their motivation to participate in the forum. Consequently, the functions of the online instructor include the functions of a teacher, conference head, mediator and organizer of a learning community. The community is the apparatus that must be "activated" in order to enable an environment supporting sharing of knowledge and creating new knowledge (7).

Among the aims of one such project, "yahadnet," carried out by Goldstein, Kosminsky and Simca (8), we note the exposure of teachers instructing in teacher-training colleges to new techniques enabling them to access, through the Internet, a great variety of information providing support for learning and professional development, devising a model for teleprocessed dialogue among teachers in teacher-training colleges, and

creating their own community in the virtual environment, as well as examining the contribution that the teleprocessed environment made to their professional development. Their training process included workshops for acquiring the tools required for working in a teleprocessed environment, face to face meetings and a teleprocessed forum. The various frameworks of the project contributed to the professional development of the pedagogical counselors that participated in it. The researchers concluded that the learning experience in the project enabled the pedagogical counselors to integrate the teleprocessed environment in their work with students and colleagues.

Goldstein's, Kozaminsky's and Simca's research (9) was intended to examine the components that helped a group of education college teachers create a learning community ("siachnet") and to study the characteristics of the online discourse of the group and their contribution to learning. The "siachnet" framework created a common learning culture stressing mutual relationships in constructing relevant knowledge for teacher training.

Analyzing the findings on "siachnet," we are able to clearly discern the quality of the online professional discourse of this community of teacher trainers that enabled access to other staff members of the college as well. The discourse of the "siachnet" community began in a face to face meeting of the participants and in a joint study of the potential use of the online forum, creating empathy and friendly support among them. The participants held a discussion focusing on the significance of making decisions and competing ideas (10). "Siachnet" also included the participants' reflective and critical reactions, which were mostly positive. One of the researchers' conclusions was the need to provide individual support for all the participants, both active and passive, in order to train them in guiding learner groups in subjects of their specialization.

The virtual meetings can provide a participant with a massive amount of information since the amount of knowledge in the world continues to double itself with increasing speed (11). Gray (12) claims that creating virtual learning communities increases the participants' social involvement, cooperation with the others in the group, motivation and expectations of themselves.

The contribution of the Internet learning site called "The Virtual Campus" to teacher educators and to teachers in general (13) consists of the following: development of learning strategies including peer teaching; focusing on teaching; access to new knowledge products of the in-service trainees; references to relevant information and professional information; access to new knowledge created as a result of discussions in the forums; mindfulness in using knowledge including making knowledge available to all participants; user-friendly access and availability of information; a change in the perception of the functions of learner and teacher; and presentation of all learning proceedings that took place during the in-service training at any given place and point in time.

According to Vigotsky (14), learners actively construct concepts through the process of mediated actions. According to the notion of mediated actions, human beings use cultural tools (such as language as well as tangible features of the environment) which fundamentally change the structure of the cognitive functioning and activity (15) (16).

The notion of Fullan (17) regarding "relationship building" and "shared knowledge" serves as a means for creating shared language and shared responsibility toward technology, a crucial step toward the development of a shared vision about technology in education and a coherent strategy in the school of education for meeting state and national technology standards. It has been argued that in order to achieve meaningful and lasting educational reform, teachers must collaborate around a strong and commonly held and understood shared sense of purpose (18) (19).

Along with the main objective of the present paper, developing communication through virtual peer learning and discussions regarding methods of teaching, this research was aimed at advancing this issue (20).

3. RESEARCH PRESENTATION

The group consisted of 116 student teachers, majoring in K-12 education at the same college.

The research focused on the assumption that carrying out action research and discussing it in a virtual peer learning forum would develop peer communication among student teachers. Consequently, their research activity and quality would increase and advance.

The training was designed to last one year. The communication of the main researcher with the participants was conducted once a week and more frequently, as needed.

At the end of the year each student teacher among the participants in the course was asked to submit an academic presentation file**.**

The research report was based on qualitative research composed of using the online forum and the academic presentations.

The Research Method

The student teachers planned their research and reported on each stage they completed. They then described their positions and educational experiences through the virtual forum of the national e-learning site. The student teachers' action research focused on theoretical and practical questions and difficulties in carrying out the study. Thanks to the use of this method based on instruction via the peer forum, and the personal involvement of the participants in the research process, the student teachers became highly motivated and diligent in their work. Moreover, collaborative discussions of the participants in the virtual peer forum regarding the studies served as integral components of the research activity of this course.

The Procedure and its Significance

The virtual peer learning dealt with actual and authentic issues relevant to the course. The uniqueness of the virtual peer forum became clear to the student teachers as they communicated through this forum, where they discussed and consulted regarding their own and their peers' opinions, positions and experiences. The student teachers also suggested their own topics for discussion like "Learning as an experience." As the research activity proceeded, they reported the procedure they used according to the guidelines they had received for writing an academic presentation.

1. Communicating knowledge by transferring the information through e-learning software.
2. Applying theoretical and practical knowledge by the student teachers in their practical work.

The techniques used for fostering the virtual interaction between the student teachers:

1. The student teachers engaged the contents with real life experiences and implemented it in their practical work with the pupils.
2. The peers communicated virtually.

Through this study, the knowledge of the student teachers was developed by carrying out research regarding his/her practical work. The peer learning communication between the student teachers as a group was then developed as well. The relationships also lead to inter-personal communication between the student teachers.

Before Intervention
Case (1)
The student teacher taught a learning-disabled 14-year-old girl studying in the eighth grade at a regular school. Due to the pupil's low achievement in mathematics, and difficulty understanding and solving fractions, etc., she had been already referred to a special education school (Milshtein, (21)).

Evaluation:

1. Comparing the products created by the student teachers.
2. Comparing the quality of the student teachers' responses in each sub-forum reviewing each procedure.
3. Examining the level of the student teachers' practical work.

4. FINDINGS

As the course ended, the student teachers could communicate through the virtual learning forum and carry out educational action research. The student teachers' research reports became clearer and more detailed as well. The student teachers could connect between the pedagogic-didactic achievements and theoretical scientific approaches they used as the basis of their research works. In addition, the student teachers' motivation and self-confidence were also enhanced. The change ocurred in the virtual interaction created between them became rapid, especially when considering the absence of experience in using computers before the study (See Tables 1, 2 and 3).

Table 1: Topics of Sub Forums and No. of Responses

Topics of Sub-forums	Sample Responses of the Student Teachers	No. of Responses
Guidelines for carrying out action research	"How can I motivate the pupil to learn mathematics after finishing the pre-test?" "How can I concretize the fractions that the pupils are having difficulty with?"	97
Why do children hate math?	"In my opinion, children hate math because teachers do not concretize enough during the lessons. Therefore the pupils have difficulty understanding the basic concepts". "Sometimes the instructions given in learning materials are not clear to the pupils".	95
Mathematics and language	"Mathematics is an exact language; we do not use, then, enough verbalization".	55
Integrating spatial orientation and mathematics	"When we teach geometry, we use shapes, sizes and location, When we teach fractions we use spatial concepts, When we teach algebra we also use spatial concepts".	54
Mathematical activities	"I suggested to the teacher to use floor games for teaching mathematics".	50
Learning as an experience – suggested by the student teachers	"Experiences stay with us. We always remember experiences. We can thus use a basketball for counting the number of basketballs thrown into the basket", etc	48
Why do we need to teach mathematics?	"We need to begin learning mathematics at a young age, through everyday life activities such as buying food, games, getting change in the store, calculating percentages, scores, etc. The pupils will need these skills in their daily lives".	31
Which method should we use for teaching mathematics and in which case?	"It is much easier for us using chocolate pieces, candies and so on for learning and exercising counting".	28
Teaching the addition and subtraction concepts	"May we teach them together? Does the act of addition precede the act of subtraction? " etc.	25
Spatial and conservation concepts	"We can use here the number line chart".	25
Using computers as a means of teaching mathematics	"Learning by computers challenges attracts and motivates the pupils to learn mathematics, by giving immediate feedback by way of sounds and especially animations".	17

It seems that the most active sub-forums were the guidelines for carrying out action research and reference to the question: 'Why do children hate math?'

Table 2: Types of Responses and Samples of Appropriate Responses of the Student Teachers

Types of Responses	Samples of Appropriate Responses
Suggesting methods of instruction.	Besides the coordinator, the student teachers added their suggestions, including mathematical activities integrated into everyday situations.
Attaching authentic presentations regarding the course themes.	Attaching a presentation regarding the beauty of mathematics.
Reporting on the effectiveness of the course.	"This course was very successful since I received many practical tools for teaching, and due to the fact that I did not major in teaching before".
Asking for advice for methods of teaching certain mathematical concepts and challenging pupils on certain occasions.	The student teachers added their own suggestions relating to their own experiences.
Changing attitudes towards advancing pupils with special needs as a result of carrying out action research.	"At the beginning of the course I did not believe that the 5-year-old learning-disabled pupil would understand and use basic mathematical concepts, but at the end of the course I became very surprised by the pupil's achievements".
Suggesting effective educational websites for teaching mathematical concepts following personal experience.	Examples of activities on the computer which have been done by the student teachers in the past and Internet sites they have found.
Requests for getting website addresses of teaching and using certain mathematical concepts effectively.	Requests for getting website addresses dealing with teaching and using multiplication.
Asking for attaching articles that are included in the references of the syllabus.	The student teachers cited the articles and referred to the contents.

Each entry to the student teachers' virtual peer forum shows the continuing process of responding to the coordinator and peer responses and/or requests for advice regarding the professional and practical experience.

Table 3: Example of Differences between the Student-Teachers' Level of Action Research Performance at the Beginning and Ending of the Course

Starting the Course	Ending the Course
Having difficulties summarizing articles.	Summarizing articles briefly focusing on main issues and applying theory to practical work.
Designing the action research, in general, without using authentic examples.	Designing the action research according to the criteria, following the guidelines given by the coordinator.
Writing long, complex sentences with spelling, grammar, syntax and semantic errors.	Formulating brief and correct sentences.
Focusing on using e-mail exclusively.	Communicating through virtual peer learning forum frequently and fluently.
Focusing on certain objectives. Having difficulty differentiating between main and secondary objectives. Formulating assumptions as objectives.	Focusing on the main objective and assumptions. Formulating the assumptions correctly.
Mixing the details regarding the practical process.	Analyzing the practical process and briefly reporting this process, focusing on the main teaching stages, describing the main activities of the student teachers and their pupils; accordingly, emphasizing the interaction between them and indicating the results of each stage.
Mixing results and discussion.	Differentiating between results and discussion, Summarizing each table of the results briefly, Analyzing the results according to the theory.

The student teachers improved the academic and linguistic quality of their responses to the topics and peer responses in the virtual forum.

Example of Results Achieved after Intervention

The student teachers' virtual peer communication and action research reports concerning their pupils' improvement strengthen the case exemplified in this paper.

We may highlight the progress noted among the student teachers by demonstrating the project which he/she performed.

Case (1):

Thanks to the pupil's fast advancement in the regular mathematics tests in the classroom, from 40% to 100%, successively, the school committee decided the pupil would stay at the regular school instead of moving her to a special education school. The gradual achievements in fractions led to easier understanding of decimal fractions. Consequently, the student teacher and pupil's motivation and self-confidence were also enhanced.

5. DISCUSSION

The scientific importance of the research lies in the student teachers' increased ability to carry out research and write high-level academic reports while telecommunicating and sharing knowledge (22) (23) (24) (25). The sharing of knowledge among the student teachers (24) created social interaction between them, which is necessary for accommodation with and solution of "real life" problems that appear in the real world of daily scientific work (26). Consequently, basing the interaction on real life activities apparently affected the educational environments of the pupils. This resulted in improving knowledge communication during the courses, while the student teachers themselves would apply the methods suggested in the virtual forum. Education is being partially transformed by new technologies. Currently, the enormous amount of available information, coupled with the fact that the amount of knowledge in the world continues to grow at an increasingly quick rate, requires a transformative approach to education. It is imperative that the student of nowadays learn how to be an information manager (27).

In a technology-rich environment, one must remember that the educational focus is on learning and instructional goals instead of the technology itself because technologies are merely tools or vehicles for delivering instruction (28).

The results indicated that both unique activities, the participation in the virtual peer learning forum and carrying out action research, were highly successful. The combination of theory and practice was successful too, as cited by Milshtein (21) "Unexpectedly, my best experience was in this on-line course".

It seems that the integration of both, the virtual peer learning forum and the action research created a feedback cycle, each of them promoting and increasing the other one.

6. SUMMARY AND CONCLUSIONS

The present study showed that the use of the virtual peer learning forum academically among the student teachers, and carrying out action research, fostered professional virtual communication and improved the quality of research designing, implementing and reporting, besides the enormous knowledge achieved during the process. The results also indicated that the student teachers increased their theoretical knowledge (29) (30). Barr (29) goes on to say, "If we wish to prepare students for life-long learning, we must begin to introduce them to the tools which they will use in the careers they pursue after their formal education is completed" (p. 84).

The approach of activating knowledge that has been investigated in business (31) was implemented in our case with regards to education. The implementations were manifested by using the knowledge practically and activating it according to the learning contents and experience of the course participants. The direct and virtual conversations between them dealt with the research contents rather than socializing'. The conversations became meaningful, as they used real life situations in their research work. Cooperation in the computer world is maintained by the lecturer and student teachers' meetings in virtual knowledge areas where they can actively deposit, jointly view, exchange and arrange documents. In addition, they can annotate each other's documents and link them to one another and to external resources (32).

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