Research, Teaching and Industrial Problem Solving Activities in the Field of Production Information Engineering at the University of Miskolc, Hungary

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ABSTRACT

In the last 150 years a rapid progress and several big paradigm-changes have happened in the field of technical sciences. Information Science (IS) has a great impact on today's industrial practice. IS is not only a special branch of sciences considering that the principles, means and methods of information acquisition, processing and transfer are indispensable for every engineer, moreover, for our society as a whole. Today's richness of IS has derived from the enormous area of applications (applied informatics, Information Technology (IT), Information Engineering (IE)). In mechanical engineers' training, Production Information Engineering (IT for Manufacturing) has a key role. These aspects justified the foundation of the Department of Information Engineering at the University of Miskolc. The subjects of IE have already appeared in BSc, MSc and PhD education. Applied informatics has facilitated the introduction and education of engineering systems approach. In the new approach IT has played the most important role because complex, large systems can neither be planned nor be controlled without IT. The demands of industrial enterprises in this field have permitted a consortium-based cooperation of universities, research institutes and enterprises. The paper gives a summary on the results of R&D works connected with an industrial project realized.

Keywords: Application Software, Information Engineering, Production Information Engineering, IT for Manufacturing, Systems Engineering, Digital Factory, Cooperative Production.

INTRODUCTION

In the course of the last 150 years an extremely rapid progress and several big paradigm-changes have happened in the field of technical sciences [1]. In the twenties of the last century the rapid advance of processing industry was established by the activities of *Ford* and *Taylor*, the creators of "mass production" paradigm. The development of automotive industry has been based on this paradigm up to now (*The machine that changed the world* [2]). In the sixties, "automation" paradigm resulted in an unprecedented increase of the productivity of machine tools and manufacturing systems (*Programmable Automation* [3]). The high production performance of technological capacities operating in global economy at present, can be considered as a consequence of this paradigm.

The development of Information Science has the greatest impact on today's industrial practice, on technology in a wider sense and on numerous other areas of society as well. The "digital factory" paradigm, within the framework of several consequent waves, has transformed the entire internal structure of enterprises. It is interesting to recognize that this process has been carried out in a "bottom-up" way. It started with process control digitization (NC, CNC, PLC), then it has continued with digitizing engineering design and planning (CAD/CAM). The top level is the digitization of several enterprise management activities (MRP, ERP, SCM) [4].

In the seventies of the last century, it became clear at technical universities that Information Science required not only separate specialized engineer training (i.e. IT-oriented engineer branch), considering that the principles, means and methods of information acquisition, processing and transfer were indispensable for all kinds of engineers. This recognition resulted in the requirement that it was expedient to establish departments of Information Science, similarly to Mathematics, not only in the faculties of Electrical and Electronic Engineering but at all technical universities.

The two keystones of Information Science are Information Theory and Computer Science, but its richness originates in the wide range of applications built on these bases (see: Fig.1.). These applications represent interdisciplinary fields, where the laws of the systems and processes specific to the given domain (Information Technology, IT) exist together with the laws, methods and tools of applied informatics (Information Engineering, IE). This branch includes computer aided design, planning, organizational, decision making and controlling methods and means using computer tools and applications for defining and solving technical problems.

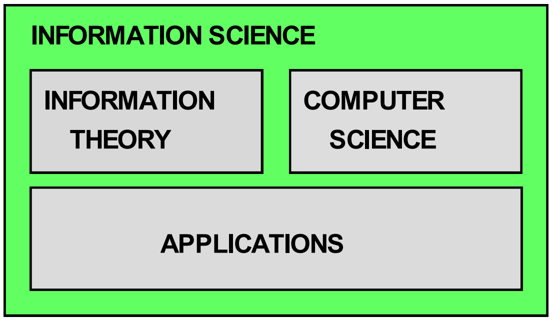

Fig. 1. The main fields of Information Science

The huge quantity of new information can only be used for the members and organizations of the society by means of computer applications. It is known for everybody how and to what extent the role and importance of computer applications, which were implemented in many millions of copies and run every day (e.g.: Explorer, Word, Excell, Power Point or MatLab, AutoCAD, SAP R/3) have been increasing. The development of applications has a special, unique technology, in which platform definition, software engineering and program coding appear only in the second phase of creating the software-product. There is a previous phase, in which

- the conception of application,
- the content and form of input and output,
- the internal model of information processing,
- the method, algorithm, accuracy and validity of problem solution,
- a user-friendly man-machine interface (HMI with graphical display, visualization), and
- the design of application level protocol for machine-machine network communication (Application Program Interface, API)

are the tasks to be elaborated.

It is obvious that the professional users of applications have to know more than the source language of the software and/or the features of the hardware platform. Nowadays there is a special information technology for hiding the latter from the users (“virtualization”, cloud technology [5]).

APPLIED INFORMATICS, PRODUCTION INFORMATION ENGINEERING

Faculties and branches of Information Science, Engineering and Technology have special stories in the life of universities. In Hungary, after a long development process, Information Science became an independent branch of science in the early seventies. It can be originated in two main sources: Electrical and Electronic Engineering and Computational Science as a branch of Mathematics. In the process when Information Science has become independent, Systems Theory also played an important role. The third aspect of the development in Information Science is related to application systems where the specifications of the fields of application come to the front line.

In engineers’ training and in engineering practice an applied informatics branch has become of great significance, which is named as Production Information Engineering (or: IT for Manufacturing). This branch includes computer aided planning, organizational, decision making and controlling methods and means using computer tools and applications for defining and solving technical problems.

The multilevel (multilayer) and concurrent technical systems of today’s modern enterprises (cooperating with the financial, economic and business systems) can not dispense with these tools any more if they want to be competitive in global economy [6].

These considerations motivated the establishment and development of the departments of applied informatics at the Hungarian universities. In conformity with this motivation, Department of Information Engineering was established at the University of Miskolc in 1995. Computer application programs stand in the centre of the activity of the Department. Their development and effective use are of primary importance for industrial practice.

According to the conception suggested by the Department, Production Information Engineering is the field of science of the IT-based methods, procedures and means suitable for planning (analysis and synthesis), organizing and controlling industrial processes.

The scope of the branch is extremely complex and far-reaching [7]. On the one hand, the specific properties of production systems and processes require IT-tools differing from one another to a certain extent (think of the different properties of discrete and continuous technology processes). On the other hand, different IT-applications are required by the rich functional subsystem set of production systems. At last, special application methods have been elaborated for Production Information Engineering using the most general IT-technologies (shared systems, data base handling, artificial intelligence methods, etc) (see: Fig.2.).

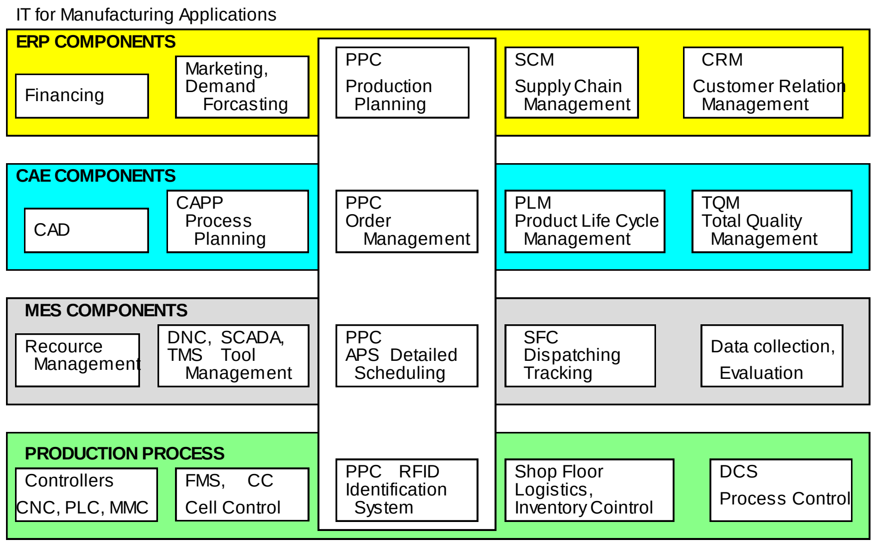

Fig. 2. IT for manufacturing applications

In the focus of research, teaching and industrial (technical problem solving) work are the following:

- system and data models, their structures and modeling methods;
- ontological analyses, conceptual and object-oriented approach;
- application of standards in informatics;
- connecting integrating and synchronizing systems;
- practical application of the paradigms of “Digital enterprise” and “Virtual enterprise”.

The most important academic subjects of IT for manufacturing, which are present in the BSc, MSc and PhD trainings at the University of Miskolc are as follows:

- Production systems and processes,
- Operations Research and Mathematical Programming,
- Modeling of production processes,
- Elements of Artificial Intelligence,
- Logistic systems and Supply Chain Management,
- Production Planning and Control,
- Computer Aided Manufacturing,
- Computer Aided Quality Assurance,
- Computer Integrated manufacturing (CIM),
- Virtual Enterprise.

SYSTEMS ENGINEERING APPROACH

Applied informatics has enabled the introduction of a more general and important discipline and approach in engineers’ training. This branch is called Systems Engineering (SE) in the literature. This includes all the specific knowledge that characterize the whole complex technical (engineering) system during its planning, implementation and operation. Nowadays, being an expert of technical systems means not only to be a “system engineer” or “system administrator”, because this latter refers mainly to a specialist of introducing (installing) and servicing systems. In this new approach, the professional knowledge of a “system engineer” is the result of the technical scientific progress occurred in the last 25 years with the establishment of large complex technical systems. In this process IT has played the most important role, because these systems can neither be planned nor be controlled without IT. In today’s industrial practice the expert support of controlling large systems generally means IT management service.

The two basic fields of SE are:

- structure and dynamics of technical or socio-technical systems,
- structure and operation of information systems.

The first branch deals with the theory, build-up, processes, temporal behaviour and energy management of the most fundamental general and specific technical systems. The second branch is concerned with the theory, means and methods of integrating systems, with special regard to IT infrastructure.

Manufacturing Technology based on discrete parts and assembly is one of the leading technologies in industrial practice and its position seems to be immutable. In mechanical engineering practice production systems, logistic systems, energetic systems, transport systems are good examples of systems approach for engineering applications. At the University of Miskolc the Information Engineering program had formed from a Mechanical Engineering background in the nineties. It was clear from the beginning that the students of Information Engineering program should attain a special IT knowledge in such a way that special application fields suitable for testing their current expertise should be available already in the course of their undergraduate period (see: Fig.3.).

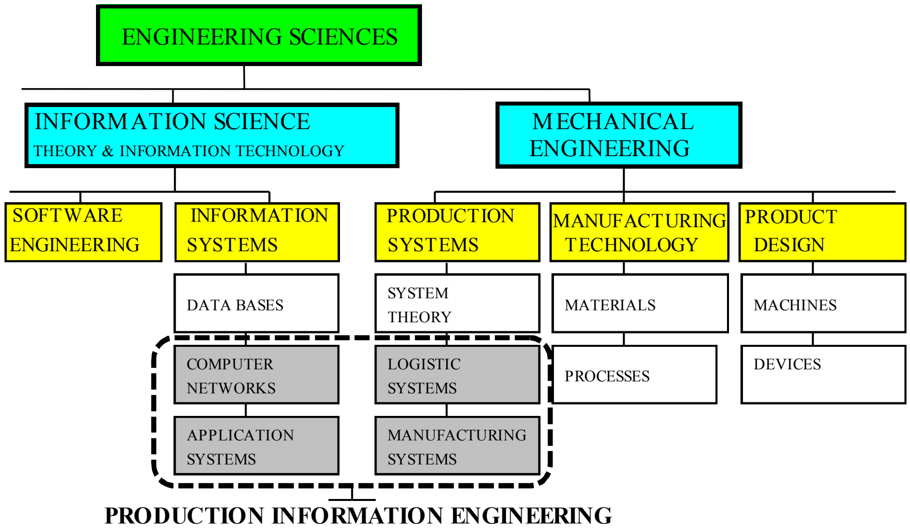

Fig. 3. System engineering approach for Production Information Engineering

At the Faculty of Mechanical Engineering there were many departments which used and taught applications connected with Information Sciences. This was the basis of the complex planning work of Information Engineering students. Joining to this process at the Department of Information Engineering of the University of Miskolc we have taught and studied Production Information Engineering for several years, which field fits into the line of Systems Engineering to a great extent [8], [9].

R&D TASKS, THE PERFORMANCE OF PRODUCTION SYSTEMS

In the last few years several industrial development tasks have been presented for the Department of Information Engineering which permitted the application of the theoretical results and the improvement of the education of students.

Production Information Engineering has obtained a key role in an interesting and important application area, in the field of performance evaluation of production systems. In Hungary, the demand of the industrial companies has made the consortium-based cooperation of universities, research institutes and companies possible in this area [10].

Production performance can fundamentally be measured on the basis of the quantity and quality indices of the products manufactured, but this should be complemented by keeping the customers' terms of delivery, by minimizing the stock levels, and by maximizing the capacity of machine- and labor force. In addition to the demand for measuring performance, there is a continuous need for improving production scheduling which makes the analysis and synthesis of dynamic production models necessary. However, the models proposed in the literature are not in all cases able to satisfy the ever-growing requirements to the extent desired [11].

Last year, a large-scale industrial development project series connected to an actual industrial demand and led by the Production and Business Intelligence Research Laboratory of the Computer and Automation Research Institute of the Hungarian Academy of Sciences was closed successfully. These projects are connected to factories of Hungarian and multinational companies which are operating according to the principles of Customized Mass Production (CMP). Their production is characterized by a wide variety of products, but the demand for the products is highly fluctuating and is therefore hard to predict. In order to keep their market positions the customers' (great shopping centers') terms of delivery (e.g. product parameters, ways of packaging, deadlines for delivery) should strictly be fulfilled. Accordingly, customer-centered production policy has become vitally important at these companies, which makes the measurement of production performance and the integration of multilevel production planning and control indispensable.

For handling the tasks appeared, new model classes have been defined by the researchers which are appropriate for the solution of extended flexible flow shop (EFFS) problems, and their computer representations have been developed as well [12]. The new model representations enable the consideration of the parameters and requirements of customized mass production even in the case of higher technological and management demands.

The integrated method of this new approach supports the decisions on combining and/or dividing the orders, on the dynamic determination of production lot sizes, on handling technological alternatives, on positioning machine resources, on specifying production tasks and on scheduling their accomplishment. The solving algorithm of the method, beside using initial heuristics and search techniques, applies problem-space transformation based on discrete event type simulation. A new mathematical model and solution technique have been developed by the researchers for the joint manipulation of objective functions and for quantifying the quality of the solutions allowed. The method can also be utilized in other multi-objective combinatorial optimization tasks with different structure, where the objective functions have dynamically changing importance, differing dimensions and co-domains.

Depending on the effects of unexpected events on the production performance indices, various re-scheduling procedures can also be used. There exist conservative, time-shifted, partial, parametric and full re-scheduling. Conservative re-scheduling aims at minimizing the number of set-ups. In the case of time-shifted re-scheduling only the time of completing certain tasks or jobs are modified without changing the resources and lot sizes assigned to them. In partial re-scheduling only the jobs directly concerned are modified. In this case the intervention has a smaller impact on the resources. By parametric re-scheduling the rates and paths may be changed. Full re-scheduling serves for creating a totally new, realizable schedule.

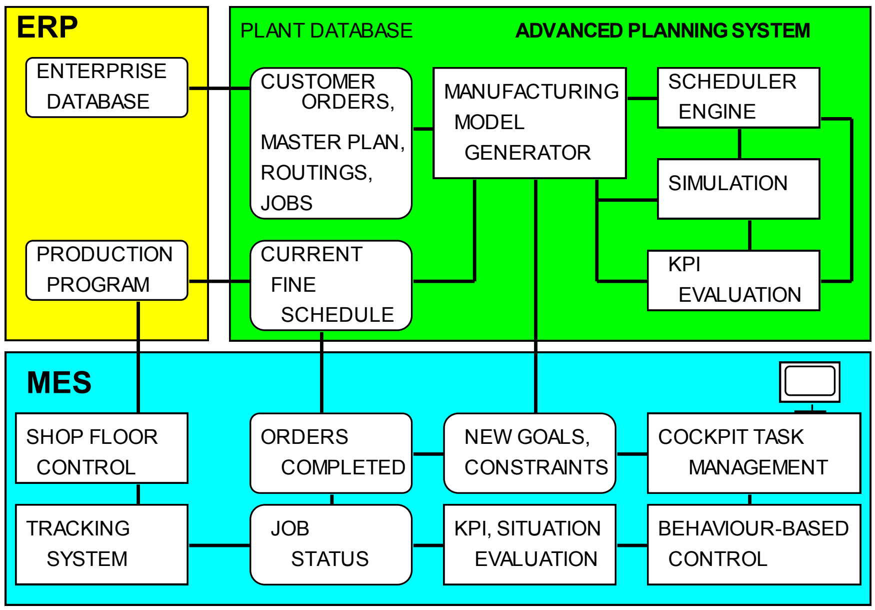

Fig 4. Integrated scheduling and res-cheduling system

During the course of the research the optimization of the component-based stock management policy of the suppliers has also been investigated. The task has been interpreted as a nonlinear optimization problem and the analytic solution of a multi-period model has been developed. By introducing the concept of specific stocking cost, a new heuristic solution has been proposed for determining the number of periods of parallel production on a production time horizon with arbitrary length. The bases for handling models with multiple products and resource limitations have also been developed. The results of the simulations show that the computational time complexity of the method is low enough to be applicable for decision support and for testing different strategies and decision alternatives [13].

CONCLUSIONS

Nowadays Information Science has the greatest impact on engineering, on industrial practice and on technology in a wider sense, and also on several other fields of our society. In the seventies of the last century, it became clear at technical universities that Information Science required not only separate specialized engineer training, considering that the principles, tools and methods of information acquisition, processing, visualizing and sharing by network were indispensable for all kinds of engineers.

The two fundamental fields of Information Science are Information Theory and Computer Science, but its richness originates in the wide range of applications built on these bases. These applications represent interdisciplinary fields, where the laws of the systems and processes specific to the given domain (Information Technology, IT) exist together with the laws, methods and tools of applied informatics (Information Engineering, IE).

Application programs stand in the centre of the activity of the Information Engineering Department at the University of Miskolc, Hungary. Effective use of application is of primary importance for Hungarian industrial practice, too. In the focus of research, teaching and industrial (technical problem solving) works are the following:

- system and data models, their structures and modelling methods;
- ontological analyses, conceptual and object-oriented approach;
- application of standards in application design;
- connecting, integrating and synchronizing applications to information systems;
- practical application of management paradigms: “Digital enterprise” “Cooperative production” and “Virtual enterprise”.

The projects demonstrate the efforts that agile enterprises in Hungary have to make in the competitive global market in order to achieve the strategic goals in planning and control of the production systems and processes. These tasks, in the majority of the cases, can only be solved by means of a new approach, new models and new software applications of information engineering and technology.

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