An Approach To Personalized e-Learning

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ABSTRACT

This paper is devoted to the concept of *personalized e-Learning* for informatics education. Indeed, as stated by many authors, personalization in education context allows to execute more efficient and effective learning processes. On the other side the use of Semantic Web technologies is more and more often considered as a technological basis for personalization in e-Learning (self-regulated learning). In this paper we describe how personalization can be exploited in e-Learning systems, focusing on our proposal: the Intelligent Web Teacher (IWT). Therefore we present an evaluation of our personalization tools tested in real academic courses, where e-Learning activities are carried out to complement the traditional lectures.

1 INTRODUCTION

Recently, e-Learning has become an active field of research and experimentation, with remarkable investments from all parts of the world. It represents the Web-based delivery of personalized, comprehensive, dynamic learning contents, aiding the development of communities of knowledge, linking learners and practitioners with experts.

E-Learning supports the different phases of traditional learning and in some cases it is the only possible method of learning, allowing the knowledge acquisition also in particular conditions (e.g. impaired students, absence of teaching structures). In this context, an important role is played by the definition of educational structure that must be contextualized and tailored on the basis of the requirements of teachers, who have personal teaching approaches, and students, who have personal studying approaches. Traditional teaching methods used in this context, typically followed a "one size fits all" approach: the information offer was standardized and equal for everyone. In recent times, on the contrary, it has become more clear that different people learn in different ways and that a personalized approach can improve the learning process helping people becoming effective life-long learners. Personalization helps learner in developing a feeling of competence and autonomy [**?**], because they are trusted with the management of their own learning process. The topic of Personalization is interconnected with the deep changes involving educational systems: the shift from a teacher-centered perspective to a learner-centered, competency-oriented one. Since it would be difficult to produce several personalized courses for each learner's cognitive state and preferences, Learning Management Systems (LMSs) have a fundamental importance for education through new technologies, because they allow a modular approach to the content creation process and can track the learner's performance. Many researches demonstrated that it is better to let learners consciously construct some parts of their learning profile: the one concerning their learning goals and preferences. Instead, other profile sections can be constructed automatically, by tracking each learner's academic achievements in the e-Learning environment and inferring their current cognitive state. In order to allow an automatic adaptation of learning activities on the basis of learner's needs, it is also necessary to represent, for instance, learning content properties in a machine-understandable way: the system must understand what are the concepts associated to each content and what are content properties (e.g. if it is a text or a video) in order to provide learners with the contents that best suit them. For these reasons, it is important to provide semantic structures, which on one hand allow the definition of the particular educational domain and, on the other side, provide the learning modalities. Ontologies represent the most suitable semantic structure for these purposes.

Gruber, in [5], affirms that an ontology is an *explicit and shared specification of a conceptualization*. He also explains that a common ontology defines a vocabulary by which queries and assertions are exchanged among different agents (both human and software agents). The formal representation of knowledge, and in particular the use of ontologies, has played an important role in many e-Learning projects. These techniques are also useful for Computer Science learning, as can be seen in the development of an educational domain ontology for *C-Programming*, described in [6]. The ontology consists of a central node (*C Programming*) and a set of second level entities, connected to it, representing abstract meta-concepts (*Syntax*, *Programming-Techniques*, *Platforms*), that are further subdivided in more concrete concepts.

In [6], the authors used an ontology design approach, which is based on the following elements: i) development of a glossary, by gathering all the information relevant to the described domain; ii) definition of main levels of abstraction and hierarchies among concepts; iii) execution of a series of refinement processes, in which the bigger concepts are split in a set of smaller ones and similar concepts are grouped in order to create meta-concepts.

The main contributions of this paper can be summarized in three points:

- an ontology-based approach to address the personalization issues in e-Learning;
- the application of the proposed approach in a complete e-Learning system;
- the presentation of the experimental results obtained by testing the overall system in a real scenario of infor-matics-related courses.

The rest of the paper is structured as follows. Section 2 describes the main elements of our e-Learning system: the Intelligent Web Teacher, focusing of the knowledge model and the personalization preferences system. Section 3 describes an interesting case study in which our approach can be exploited. The results of our experiments are reported in Section 4. Finally, Section 5 concludes the paper.

2 THE INTELLIGENT WEB TEACHER APPROACH

The Intelligent Web Teacher (IWT) is primarily an e-Learning platform that enables the definition and the execution of personalized learning experiences, packaged in a Unit of Learning (UoL) (i.e. a course, a module or a lesson structured as a sequence of Learning Activities represented by Learning Objects and Learning Services). The foundation element of the UoL building process is the Learning Model described in [1]. The Learning Model allows to automatically generate a UoL and to dynamically adapt it during the learning process according to the learners' preferences and cognitive state (personalization process). The Learning Model can be seen as divided in two layers: i) **Knowledge Layer** in which there are all the machine-understandable representations of the educational domains, learning objects and other relevant entities that we use in our approach; ii) **Computational Layer** containing a set of algorithms that leverage the information of the first layer to execute the personalized e-Learning experiences building process. Both teachers and students interact with the Knowledge Layer, providing respectively new artifacts and personal information. In order to achieve the expected adaptation capability, the Learning Model uses two specific sub-models: the Knowledge Model and the Learner Model, which are exploited by a specific process used to define personalized e-Learning experiences (at Computational Layer).

2.1 THE KNOWLEDGE MODEL

The *Knowledge Model* [3] is used to represent the subset of the educational domain that is relevant for the e-Learning experience. Educational domains are modeled using ontologies. In IWT an e-Learning ontology can be represented with a graph in which nodes are relevant concepts (arguments, topics, etc.) within the educational domain of interest and edges are binary relations between two concepts. The most important relations are: HasPart (HP) that is a part-of relation and IsRequiredBy (IRB) that is an order relation. Let us now consider how to build an e-Learning ontology.

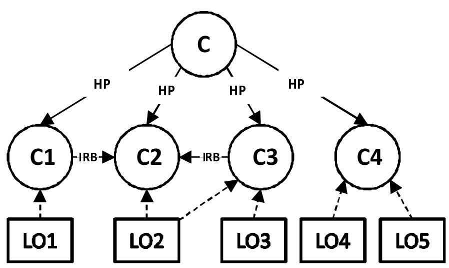

Figure 1. Semantic Modeling of an educational domain (D).

Supposing we have to model the educational domain D (Depicted in Figure 1), we try to conceptualize the knowledge underlying D and find a set of terms representing its relevant concepts. The result of the previous step is the list of terms $T = C, C_1, C_2, C_3$ where T is one of the plausible conceptualizations of D. The existence of the relations $HasPart(C, C_1)$, $HasPart(C, C2)$ and $HasPart(C, C3)$ means that in order to learn a subject C learners have to learn subjects C_1, C_2 and C_3 without considering a specific order. If we add the relations $IsRequiredBy(C_1, C_2)$ and $IsRequiredBy(C_3, C_2)$ to the previous set of relations we can state that C_1 has to be necessarily learned before C_2 and C_3 has to be necessarily learned before C_2.

2.2 THE LEARNER MODEL

The *Learner Model* describes the main actor of the e-Learning process. Each learner is represented by a cognitive state and a set of learning preferences. The cognitive state is composed by a list of subjects (concepts within e-Learning ontologies) each with an associated grade that shows how much the student knows about that subject. The grade can range from 0 to 1, where 0 testifies the complete absence of acquired knowledge with respect to a given subject, whilst 1 represents a complete mastery of the subject. A subject will be considered as "learnt" by the learner if the above defined grade is greater than a fixed threshold, determined through experimentation. The learning preferences declare the properties that learning resources (learning objects or learning services) should have in order to fit with the learner's characteristics. They are expressed using a couple (*propertyName*, *propertyValue*). Examples of properties are *Learning Resource Type*, *Interactivity Type*, *Interactivity Level*, *Typical Learning Time*, *Difficulty*, *Language*, *Context*.

2.3 THE UNIT OF LEARNING CONSTRUCTION PROCESS

In this section we provide details about the Unit of Learning construction process. In particular, we present the steps for the creation of an e-Learning experience tailored to a single user's preferences. For the sake of simplicity we will consider that an e-Learning experience is represented by a sequence of learning objects, but the approach is also suitable when e-Learning experiences are made up of complex sets of learning activities.

In our approach, a learning object is a learning content (or a packaged aggregation of learning contents) that can be delivered through a Web Browser, and annotated with an instance of a metadata schema (interoperable with IEEE Learning Object Metadata), and stored and indexed into a Learning Object Repository.

In the Learning Model, an e-Learning experience is composed by (i) a set of *Target Concepts* (TCs) (known also as Learning Objectives), (ii) a *Learning Path* (LP) and (iii) a *Presentation* (PR). TCs are high level concepts that are the final goal of an e-Learning process. They can be set by a teacher or by the students themselves and can be obtained by manually selecting concepts on ontologies or by selecting pre-defined groups of concepts. Excluding the selection of TC and other customization parameters, the building process is fully automatic and realized through the execution of several algorithms. The most important are *Learning Path Generation Algorithm* and *Presentation Generation Algorithm* [2] constituting the Computational Layer mentioned above in section 2.

In the *Learning Path Generation Algorithm* the TC are used to generate the *LP*, the ordered sequence of atomic concepts needed to reach a satisfactory level of knowledge about the selected TC. The right order of concepts is identified by taking into account the Learner's cognitive state and all the dependencies between concepts described into the ontologies. Following the example in Section 2.1, in order to understand the concept C a student has to learn concepts in this order: C_1, C_2, C_3.

The *Presentation Generation Algorithm* creates the *PR*, an ordered list of Learning Objects that the learner has to use in order to acquire knowledge about subjects included in the *LP*. *PR* is created starting from *LP* and querying one or more LO Repositories to find the Learning Objects that have a *HasResource* relation with the concepts in the *LP*. The algorithm acts trying to minimize the number of learning objects within the Presentation that are necessary in order to cover the whole Learning Path. This problem can be formulated as a *Plant Location Problem* on a bipartite graph.

In the IWT implementation, the Plant Location Problem is solved with a Greedy Algorithm that constructs the required set of learning objects step by step starting from an empty set. At each step, the algorithm selects among the not yet used learning objects the one that implies the maximum decrement for the sum of all distances of learning objects currently included in the set. The Greedy Algorithm is really quick, but its solutions are not very good because it cannot go backward and modify decisions taken in previous iterations. Let's see a comprehensive example to understand the complete process.

Consider the situation of Figure 1 when IWT has to define a personalized e-Learning experience for a learner named Jane, whose TC is equal to C.

The *Learning Path Generation Algorithm* analyzes the structure of the domain ontology (see Figure 1) and Jane's cognitive state and learning preferences state (see Figure 2) and extracts the following personalized Learning Path:

$$LP(TC) = [C_3, C_2, C_4]$$

Cognitive State
C1 (0.8)
C4 (0.3)

Learning Preferences State
Language (it)
Learning Resource Type (Narrative Text)
Context (Higher Education)
....

Figure 2. Jane's cognitive state

Note that the subject C_1 has already been "learnt" by Jane, so it has been deleted from the path. At this point the *Presentation Generation Algorithm* performs a binding between available learning objects and subjects in *LP*.

LO1 (en, Narrative Text, Higher Education, Explain(C1)
LO2 (en, Narrative Text, Higher Education, Explain(C2), Explain(C3)
LO3 (en, Narrative Text, Higher Education, Explain(C3)
LO4 (en, Narrative Text, Higher Education, Explain(C4)
LO5 (en, Simulation, Higher Education, Explain(C5)

Figure 3. Metadata content of the LOs in the LO Repository.

In particular, the binding must minimize the number of learning objects and select the learning objects whose metadata (illustrated in Figure 3) satisfy better Jane's learning preferences . In our example, $PR = [LO_2, LO_4]$. In particular, LO_4 is preferred to LO_5 because the second one doesn't match with Jane's learning preferences.

3 CASE STUDY: FOUNDATION OF INFORMATICS

As a description of the case study we firstly introduce the reference e-Learning ontology for the Foundation of Informatics university course, then we discuss about the Learner Profiles and associated Learning Objects.

3.1 E-LEARNING REFERENCE ONTOLOGY

Creating a reference ontology is often an error-prone and onerous activity. One suitably way to minimize the cost of e-Learning ontologies is to reuse those already created. Our system supports reuse not only of learning resources but also of domain knowledge. An existing learning concepts can be a starting point for new perspectives or used for interchange. Indeed our IWT platform supports ontology reuse through matching and merging techniques. Together with the advocation of a common understanding of concepts through ontology matching algorithms, it allows the addition of new meaning to preexisting e-Learning concepts by means of ontology merging tools.

In the definition of the Foundation of Informatics ontology we have considered in five steps. Namely they are:

- **Vocabulary filling**: gathering of the information relevant to the particular learning domain with the identification of the specific terms. This step is usually performed by a domain expert (i.e. the teacher of the course) through the use of the vocabulary tool of our systems. This tool helps to create new terms and to locate existing terms that may be reused in the new context (avoiding renaming of the terms by means of semi-automatic matching techniques [4]). In our case we may introduce, for example, the concept `Programming` and reuse the existing terms `Algorithm` that has been used in other courses. The vocabulary is stored using the SKOS[1] schema.

- **Hierarchization**: finding the relationship among the concepts and representing them in a hierarchical way. For example the concept `Computer_Architecture` may have a `HasPart` relation with the concept `Von_Neumann_model` in the Foundation of Informatics ontology.

- **Decomposition**: detailing coarse-grained concepts into a set of more fine-grained ones via top-down strategy. For example the concept `Passing_parameters` can be decomposed in the two concepts `Passing_by_reference` and `Passing_by_value`.

- **Categorization**: grouping similar concepts together, in order to create "high-level" concepts to generalize the groups.

- **Refinement**: analyzing the created ontology in order to eliminate contradictions, synonymy and useless relations among the different concepts

All the steps can be supported by our tool, the IWT Ontology Editor which is a visual CASE tool that can be used for the definition of the e-Learning reference ontology of a course.

[1] http://www.w3.org/2004/02/skos/

3.2 LEARNER PROFILES AND LEARNING OBJECTS

An important element we must consider during the predisposition of a course is the the final users of the e-Learning materials, i.e. the learners. To maximize the learning experience the course must be adaptable to the user's preferences (e.g. way of studying, preferred materials, etc.). As described in Section 2.2, also in the preparation of Foundation of Informatics course, we can describe the general profile of learners, that will be used for the first interaction with the e-Learning objects. The learning preferences defined in these steps are part of all the students' profile and are now general. Indeed, the course is customized by means of the preferences and preferences change as a result of the behavior of the particular student during the course (e.g. making a test related to concepts explained by specific learning objects). In this way the system becomes adaptive not only on knowledge (the concepts learned and to learn) but also on the type of learning resources to be presented. Attached to each course we can insert a number of Learning Objects of different types (plain text, HTML pages, slides, etc.). The preparation of the learning objects which we insert in the wider concept of UoL (Unit of Learning) is described in Section 2.3.

Finally, each concept of the Foundation of Informatics course which, practically, represents a concept to be learned, may have a set of correlated metadata which explain the didactic context, the difficulty, the interactivity level, etc.

4 EXPERIMENTAL RESULTS

We experiment the overall approach during the first term of the current academic year in six different courses of the Electronic Engineering faculty. The fruition of the courses is conventional in the sense they include both classroom lectures and laboratory exercises.

Course	Students	Passed	%
Foundation of Informatics	186	96	51,6%
Informatics II	69	12	17,4%
Principles of Databases	125	57	45,6%
C Programming	68	17	25,0%
Computer Nets I	95	62	65,3%
Mathematics I	171	46	26,9%

Figure 4. Exams results before the introduction of IWT.

IWT was used together with the traditional learning activities and as a complimentary virtual classroom environment for study and additional classes before the exams. In each course we support the teacher with a skilled IWT tutor as an help to manage the technical stuffs and to avoid student's confusion. We analyze the situation in the year before the introduction of our system, considering the results of the exams at the end of the term for each course. The collected data are summarized in Figure 4. Then we experiment our platform during the last term, and we noticed more participation by students especially during the laboratory sessions in which the use of the platform were more massive. The collected data after the introduction of IWT is summarized in Figure 5. It can be observed that we make our test on both the two exam sessions for each course, in order to have better statistics.

Course	Students	Passed	%
Foundation of Informatics	152	97	63,8%
Informatics II	81	32	39,5%
Principles of Databases	110	60	54,5%
C Programming	81	30	37,0%
Computer Nets I	98	65	66,3%
Mathematics I	149	55	36,9%

Figure 5. Exams results after the introduction of IWT.

In Figures 6 and 7 a comparison between the courses with and without the introduction of our personalized e-Learning system is reported. The average results for all courses are summarized in Figure 8.

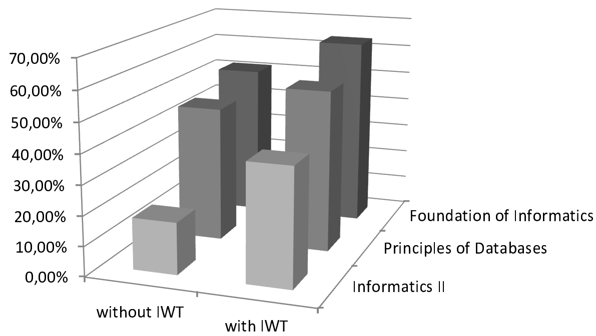

Figure 6. Comparison about IWT using (part 1.

As we can see from the figures the number of the students who passed the exams has grown after the introduction of IWT. We observed that the average level of the students, in general, has dropped in quality over the years, maintaining a level of complexity of the exams nearly constant. Therefore the conclusion is that the introduction of personalized led to a relevant increase in the

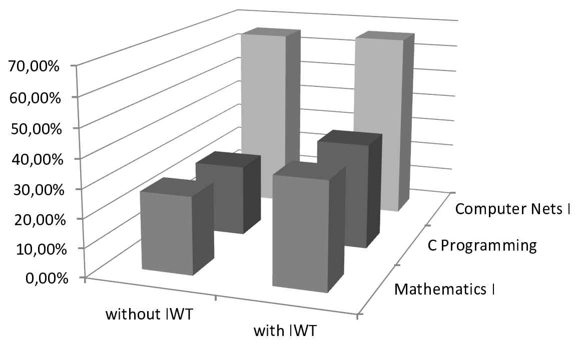

Figure 7. Comparison about IWT using (part 2.

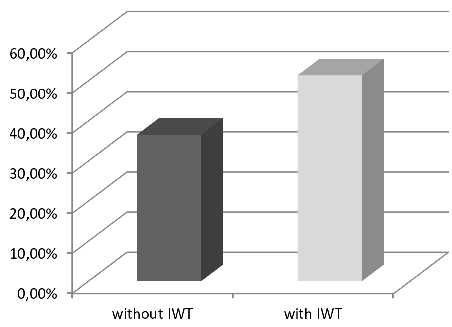

Figure 8. How many students pass the exams?

percentage of students who successfully completed a test, particularly during the first exam session. As a side-effect we also noticed that the students' course satisfaction has been augmented after the introduction of personalized e-Learning activities.

5 CONCLUSIONS

In this paper we have proposed our approach for the realization of personalized e-Learning experiences improving the feature of our IWT system. The personalization allows to execute more efficient and effective e-Learning processes. The knowledge domain of a course can be easily represented by our e-Learning ontologies that can also be used to exploit the cognitive state of the learners. The use of ontologies also permits the reuse of "human attention", in the sense a teacher can always takes benefits from the knowledge (e.g. ontology concepts) already defined for other courses. Our personalization proposal has been fully implemented in a complete system, that can be used in different domain other then Informatics. We evaluated the proposed approach, with good results, within specific e-Learning settings, where it highlighted an increasing level of satisfaction by both teacher and learners. Moreover, and even more important our experiments have shown that the number of the students who passed the exams is globally increased. Future works will concern the augmentation of the personalization approach through the analysis of other Semantic Web features (e.g. linked data for ontologies). Moreover we are investigating some algorithms and techniques to extract concepts from knowledge bases of heterogeneous documents (e.g. plain text, PowerPoint slides, XML, etc.). This can lead to an improvement in the ontology creation that may also be very helpful for the preparation of personalized e-Learning courses.

Finally, we are experimenting the overall systems in wider scenarios, including more courses and faculties, to better understand both strong and weak points of the approach.

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