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# A semantic-web based framework for adaptive selection of learning objects during the authoring process.

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**Abstract:** Semantic Web technology has been proposed as a key to enhance several aspects of e-learning, such as annotation and adaptation to the students' needs. Based on the same technology, we propose an approach to assist teachers in the process of selecting learning objects to build their own courses. We explicitly take into account teacher's knowledge, experience and teaching style to maximize the likelihood of finding the best suited teaching material.

## 1. Introduction

Almost all of the personalized eLearning systems developed thus far are focused on the student. Adaptation to the students' cognitive style and to their knowledge has been debated for years (see e.g. Opperman et al. 1997, DeBra et al. 1999, De Bra 2002, Brusilowsky 2003), and several approaches and prototypes have been proposed.
Although this is certainly a central problem, we believe that there is also a real need to also consider the teacher, who designs and teaches the course. In any educational system, live or on-line, the effectiveness of learning is also dependent on how well the teacher can teach a course. Pedagogical studies, such as Westermann (1991) and Darling-Hammond (2000), support this thesis. A teacher experienced in a particular subject, typically knows better about the ways to deliver the subject material than a novice teacher in the same field. It is not only the students' ability that affects the degree to which they can grasp the subject taught but also the proficiency of the teacher in that subject. Moreover, different teachers have different teaching styles. Some may stimulate exploratory work, others prefer to guide students' discussions. Some prefer presenting experimental evidence, others prefer axiomatic approaches. Different learning materials are needed for these radically different teaching styles. Therefore, teachers should be facilitated in finding the learning material that best suits them.

While in recent years much emphasis has been put on reusability of Learning Objects (LOs), the degree of actual reusability also depends on the teacher's profile: her/his experience, ability in teaching the specific subject or teaching style play an important role. Many e-Learning systems offer authoring tools for building courses starting from scratch or from existing learning object repositories (LOR). To our knowledge, none of them attempts to guide the teacher by taking into account his/her preferred teaching style, domain knowledge, experience in course design and experience in delivery of course material. Hence we decided to focus on adaptive authoring, where adaptation is "with regard to the teacher".
This paper presents a prototype that focuses on adaptation to the teacher's profile in the process of LO selection. Our aim was not to produce a full authoring tool, but rather an instrument that helps the teacher in the process of selecting the "best" LOs among the possibly many found in a LOR. Here "best" means best suited to his/her profile that, as we mentioned, includes the level of knowledge and experience in the particular subject, and other abilities or preferences.

In designing the tool we decided to use semantic web technology (Berners-Lee et. al., 2001). The Semantic Web initiative aims at an extension of the current Web in which machines can understand the meaning of Web resources. Machine-readable descriptions provide meaning, which allows the development of advanced web applications that can process information and reason about it. One of the earliest papers that advocated this approach in an e-learning context was Stojanovic et al. (2001). Several researchers have followed on this theme. In most cases ontologies play a key role in this approach. The paper by Ronchetti and Sant (2007) contains a review of several uses of ontologies in the e-learning scenario.
The reason why we decided to use semantic web technology is that this technology enables us to:

- characterize and model teacher's profile (by means of an ontology);
- describe learning objectives and topics of a course (by means of another ontology);
- infer some missing information by using other information's metadata (in real world situation, not all the metadata are available all the time).

## 2. The system.

As we mentioned, ontologies and inferences are the keys to our approach. For demonstration purposes, we decided to apply our prototype to the case of teaching Computer Science (CS) at the Bachelor level. Our choice was motivated by the fact that a rich domain ontology that was available for CS, and that this could be used for indexing the content of a course. The ontology was generated by Saini et al. (2003) starting from the ACM Computing Curricula 2001 for Computer Science (CC2001). CC2001 is a comprehensive work that defines sound CS curricula for undergraduate studies. Being endorsed by both ACM and IEEE, it has a very broad acceptance in the CS community. The derived ontology provides an exhaustive coverage of the domain of undergraduate studies in CS. It offers a fine level of granularity, having 950 topics that compose the CS body of basic knowledge. Topics are grouped into units and areas. For each of the 132 units the ontology also provides learning objectives.
We tested our system in the areas of Software Architecture and Organization, Programming languages and Software Engineering. Finding LOs with suitable metadata was a really difficult task. The Multimedia Educational Resource for Learning and Online Teaching (MERLOT[1]) seemed to be the LOR best-suited for our study, but even it did not provide metadata suitable for our study. As a result, we had to resort to manually providing the metadata we needed, keeping them in an ad-hoc repository. Our main metadata are reported in Table 1.

| | |
|---|---|
| Title: | Title of the object |
| URL: | Location of the learning object |
| Language: | Language which the content is in |
| Filetype: | pdf, doc, html, jpeg etc. |
| Category: | Category of learning object: text, picture, audio, video, simulation, flowchart and user driven simulation |
| Level: | Lickert scale 1 (easy) to 5 (difficult) |
| Description: | Short description about the object |
| Primary Audience: | Type of the target students for the objects |
| Time: | Approximate time needed by the LO |
| Type: | Type of LO: Theory, Example or Quiz |

Table 1 – Metadata structure for LOs

Our first version of the teacher ontology is a simple one. Its main concept is the one of "Domain competency", which in turn is based on "Qualification" and "Experience". The teacher has to provide a small amount of information. This information may include such things as educational background, experience teaching the topic, the teacher's familiarity with the domain itself, and the average student type expected for the course. The teacher's profile is defined as an OWL file, and the teacher's data is saved as an RDF file. Similarly, the course description is defined as an OWL file while the course instantiation in expressed as an RDF file.

[1] www.merlot.org

Given the above information, together with the LOs' metadata, the system applies some rules and provides an evaluation of the overall suitability of a LO to a particular condition given by the triple (course, teacher, students). The application of the rules is performed by a semantic search engine. We chose to use CORESE[2].
CORESE (Corby et al. 2002, Corby et al. 2004) is a Semantic Search Engine ) developed at the Institut National de Recherche en Informatique et en Automatique (INRIA). We found the java-based CORESE engine to be robust, easy to use and easy to understand. Its name stands for COnceptual REsource Search Engine. It is an RDF engine based on Conceptual Graphs, and enables the processing of RDF Schema and RDF statements within the CG formalism. CORESE integrates an RDF Rule Language based on the CG Rule model. It also implements some statements from OWL Lite and the query pattern part of SPARQL. The query language integrates additional features such as approximate search, group, count, graph path. The inference rule engine works in forward chaining. It has been used to develop several other semantic applications and it is available for downloading.

By using semantic capabilities, we can infer missing or new data from the available information. For example, in our framework, Domain Competency is not stated explicitly. The domain competency of a teacher is rather inferred by his/her experience and qualification. These inferences are the result of the rules applied in the semantic search engine. The approximate search capabilities provided by the engine make its use quite different and more powerful than querying a traditional, relational database.
Having discussed the main components of the system, we present a simple use case. We will assume that a teacher has already been registered into the system and has defined his profile, which can be modified or updated at any time. The profile may include some specific information about any course that the user teaches, since teaching experience and learning style can have different values for different courses.

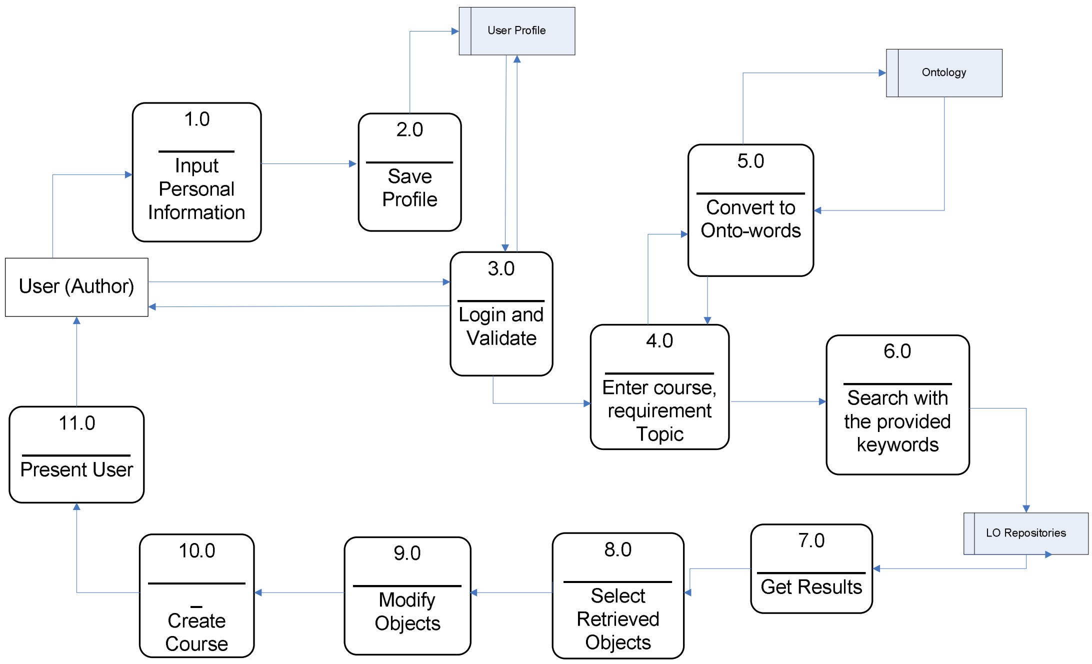


Figure 1 – Action flow in the use case for retrieving LOs.

The teacher now wants to prepare some learning material for a given course, reusing what is available in (one or more) LORs. After logging into the system and specifying the context (i.e. which course is s/he dealing with) s/he will start searching for LOs by providing some keyword and/or identifying some concept on the Ontology: for the particular case that is used in the prototype (i.e. the CS ontology) this means picking a topic. The system will

[2] http://www-sop.inria.fr/acacia/soft/corese/manual/

perform a search based on the course and teacher characteristics and find the best matching LOs. These items are returned to the teacher, who can incorporate them into his/her new lecture (possibly after some customization if needed). Figure 1 shows the logical flow of this scenario.
The system lends itself to easy modification. In fact, its behavior is coded in logical rules, and both teacher and domain model are specified through ontologies. The CORESE rule language is based on the triple model of RDF. Writing rules is very simple, which means that our system is easily extendable simply by adding more rules, increasing the sophistication of existing rules, and/or by enriching the teacher ontology. The application domain is obviously not restricted to Computer Science: it is enough to plug a different ontology into the system to change the application domain.
The system's detailed architecture and implementation are described in more detail elsewhere (Joshi, 2007).

## 3. Discussion and conclusions.

Other authors have explicitly put the focus on the teacher. For instance, Azouaou et al. (2005) propose a model of semantic annotation dedicated to the teacher. Here, the focus is on adaptation to the teacher's activity specificity, as s/he needs to master both a pedagogical and domain expertise. They identify the concepts of an annotation language used by the community of teachers, and then they propose a conceptual model of this language based on ontologies.
Another case is the paper on adaptive authoring of adaptive educational hypermedia by Cristea and Aroyo (2002). They argue that an authoring tool also has to be adaptive to the teacher. Their main argument is that creating adaptive courses (where adaptation is *on the student*) is a difficult task, and it is necessary to help teachers to skillfully apply adaptation to their new on-line courses. They suggest that this can be achieved by having authoring tools that are able to adapt themselves to their user (i.e. *to the teacher*). However, the skill they consider is however the ability of creating adaptive hypermedia, and not didactic or pedagogical competence.
Our focus is different, in that we aim at helping the teacher in the selection of the learning material. Ronchetti and Saini (2004) suggested ontology navigation as a tool for helping the teacher in the task of finding relevant resources in a LOR, but their focus was only on the content of the LOs. Here the scope is broadened by including a teacher's profile with respect to teaching style, preferences and experience in any search for Learning Objects.
A possible objection to the present work is that, in given the current state of LOR's the issue of finding the best suited LO's is moot - often one is just content to find any material at all! While we acknowledge that this is indeed and important problem at present time, we are confident that the situation will change over time. As electronic support for teaching and learning becomes more popular, the number of available LOs will grow.
Another problem is that typically very little metadata can be found in LORs, both because the LOR might not contain certain metadata (like a classification of LOs on their suitability to certain learning styles), and because often authors do not provide the requested metadata. In view of this issue the whole approach might seem to be doomed to failure. However, there is active research trying to semi-automatically extract metadata from the LOs themselves, as shown by Saini et al. (2006) and Dehors et al. (2005). While these metadata are still mostly content-oriented, other metadata relative to the suitability to learning style and experience might emerge, e.g. from analysis of annotations. Social networks might also prove to be a mine of metadata, when the behaviors of the participants are monitored and studied. Explicit rating mechanisms like the ones provided by on-line communities, like e-bay, Amazon or U-tube, could be another source of the needed information.

In summary, we presented a tool meant to personalize LOR searches made by teachers while preparing a lecture or a course. The system is not meant to be a full authoring tool: it can rather be conceived as a filter between an authoring tool and a LOR. This filter optimizes the choice of LOs on the basis of the teacher's profile. The system is based on semantic web technology and uses an engine for performing approximate search.
Our prototype contains a simple classification of teachers' characteristics and is applied to the Computer Science domain, but both these aspects can be easily modified: the first by adding more sophisticated rules to the semantic search engine, the second by using a different domain ontology.

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