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Curriculum Management and Review: an ontology-based solution

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Abstract: Ontologies provide a means to classify some aspects of the world and then to reason on that classification. Recently, various authors have recommended the use of ontologies that classify subject domains, courses, learning objects and educational processes in E-Learning systems and processes. One promising application of ontologies is in the general management of entire curricula and in program reviews. In this paper we present a strategy for managing, inspecting and monitoring a full course of study (a program), that will aid in the quality assurance of didactic offerings and thereby help improve the overall quality of these offerings.

1. Introduction

There is little doubt that the Semantic Web technology (Berners-Lee et al. 2000), and in particular ontologies, has an important role in the future of e-learning. Many authors have suggested various benefits that ontologies could bring to the field. A seminal work in this area is Mizoguchi and Bourdeau (2000). They have argued that the use of ontology-based solutions can solve many severe problems suffered by Intelligent Instructional Systems (IIS). Among them are the deep conceptual gap between authoring systems and authors, the lack of intelligence and user friendliness of authoring tools, the difficulties in effectively reusing or sharing learning objects, specifications and functionalities and the existence of a gap between instructional planning for domain knowledge organization and tutoring strategy for dynamic adaptation of the IIS behavior. Many other authors have suggested various ways in which ontologies can be applied to e-learning. In this paper, we propose another possible application of ontologies. We claim that predefined subject (i.e. domain) ontologies can be used in the monitoring and management of the academic offerings of an educational institution. We present a prototype that implements our concept and demonstrate its utility through a test case. In the following sections, we first review the various uses of ontologies to accomplish some e-learning related tasks, and then present our idea, the related tool and the case study.

2. Overview of the uses of Ontologies in E-learning.

There is already a considerable body of research dealing with the interplay between ontologies and e-learning. Our intention here is not to review the whole field, but only to outline the main ideas about the roles they can play. A recent overview of the field, together with references to several workshosps and special issues of journals can be found in (Dicheva et al., 2005). Moreover, a long list of interesting papers on these topics can also be found on the *Ontologies for Education* web portal[1].

Pasin and Motta categorize the main purposes of ontologies in e-learning. Based on their work, we propose a slightly modified classification. The use of ontologies can be being finalized to:

[1] http://iiscs.wssu.edu/o4e/ResearchPapers.do?tm=O4E.xtm

a. construct advanced strategies to present annotated resources to the user, or allow the user to create and share his own annotation of learning resources;
b. enhance the learning objects reusability by linking them to an ontological description of the domain;
c. associate educational processes with appropriate elements of an ontology;
d. help authoring systems to retrieve and/or organize learning objects into a course.

The use of ontologies as a component for implementing user-adaptation could be classified in the above category "a". Often the main focus is on automatic generation of hypertext structures from distributed metadata based on a user model. Examples of this approach are the works in Adaptive Educational Hypermedia by Cristea (2004) and in adaptive navigation support by Karampiperis and Samson (2004). Henze et al. (2004) put the emphasis on the ability to provide individually optimized access to information by taking the individual needs and requirements of the users into account, therefore creating personal learning paths. Dzbor et al. (2005) investigated the integration of ontologies into navigation, intended as a methodology for supporting the interpretation of web resources through "ontological lenses", as a tool kit for supporting and realising Semantic Web browsing, and as a framework for building semantic web applications.

Annotation, which is a general theme in the Semantic Web domain, also falls in category "a". In the context of e-learning various specializations are annotation of authoring activities, of instructional activities and of learning objects. An example is the case of ontology-based management of personalized annotation and real-time discussion (Yang et al., 2004). In (Fernández-Breis et al. 2005), annotation is done with reference to the knowledge contained in the examinations, especially those that include open questions. This facilitates evaluating the students' understanding of ideas, their ability to organize material and develop reasoning, and the originality of their arguments.
The proposal of using ontologies in exploratory learning also falls into category "a". Dichev and Dicheva (2005) argue that well organized and structured knowledge (i.e. ontologies) can be used as a source of knowledge exploration if provided with meaningful annotation to guide students to think and explore. Exploratory learning is highly effective, because learners can focus on self-directed learning on the vast information space. Ronchetti and Saini (2003) expressed a similar concept, called *implicit ontology navigation*. Their *explicit ontology navigation* instead was mostly meant to be used by teachers for enhancing reusability of learning objects, and fits category "b". A seminal paper by Stiiojanovich et al. (2001) also deals with reusability, besides setting the ground for a full semantic-web-based architecture for e-learning.

An example of category "c" is the cognitive-based selection of Learning Objects discussed by Karampiperis et al (2006).

The need of adaptation to the teacher falls into category "d". Azouaou et al. (2005) suggested a model for adaptation to a teacher's current experience with respect to both pedagogy and subject area. Another case of adaptation to the teacher aims at helping her/him in the choice of the learning objects that best suit her/his teaching style and experience level (Joshi et al. 2007).
In category "d" we also find some work aimed at building courses directly referring to a supporting ontology. These include Šimi, et. al (2004) and Sant et al, (2007). In the same category, Wang (2006) consider adaptation with a different meaning, being interested in the modification of existing learning resources for constructing customized material for different requirements.

A few papers do not properly fit into any of the above categories. For instance, some people see ontologies as a key for solving interoperability problems: interoperability to open up, share and reuse educational systems' content and knowledge components (Aroyo et al. 2004), or interoperability of video resources in an Educational Digital Video Library (Milrad et al. 2005).
Guo and Kobayashi (2006) use ontologies for an administrative purpose: they propose a credit transfer system using IEEE/ACM Computing Curricula as intermediate curricula in the area of computer science in order to reduce the number of mutual comparisons to n. This paper, itself, also does not fall into any of the categories above. We propose to use ontologies as a management tool for coverage of a full study course...one that would be useful in curriculum improvement and program reviews.

3. Using ontologies as a course management tool

Ontologies provide a means to classify some aspects of the world and then to reason on that classification. There is a very good fit between ontologies and e-learning as evidenced by the amount of research that combines the two. This suggests that in the near future there may be e-learning systems that use classification of subject domains, courses, learning objects and educational processes. In this scenario, it will be possible to use all this information for the many uses discussed in the previous section, but also for other purposes. The one we suggest in the present paper is to use ontologies as a tool for managing, inspecting and monitoring a full study course. In fact, once you have a domain ontology of a full study course (i.e. program) and you are somehow able to infer the topics that are discussed in all the single courses, it is easy to provide a manager (e.g. the dean) with a tool for verifying overlaps between courses, areas that are not covered, and possible synergies with courses offered in other schools of the same institution. We present a case study based on this idea and a prototype tool that a proposed user interface. Our study concerns the domain of Computer Science, for which we had access to an ontology.

The ontology was extracted by Saini et al. (2003) starting from the ACM Computing Curricula 2001 for CS (CC2001). CC2001 is a comprehensive work that defines sound Computer Science (CS) curricula for undergraduate studies. This reference curriculum is produced every 10 years by the Association for Computing Machinery. Its development is a community process involving several focus groups composed of specialists in various CS sub-fields as well as experts in pedagogy. The derived ontology covers the domain of undergraduate studies in CS exhaustively. Since it is the product of a large group of specialists and practitioners it has a very broad acceptance in the CS community.

CC2001 defines a suite of courses, subdivided into three categories: introductory, intermediate and advanced. For each of the 47 introductory and intermediate courses, prerequisites and syllabus are specified. In order to define courses, some finer-grain elements have been identified: topics, units and areas. Topics are the smallest-grain elements. Some examples are "Systolic architecture", "Paging and segmentation". Topics are collected in Units, such as "Multiprocessing and alter-native architectures", "Memory Management". Units are further gathered into Areas: Discrete structures, Programming fundamentals, Algorithms and Complexity, Architecture and Organization, Operating Systems, Net-centric computing, Programming languages, Human-computer interaction, Graphical and visual computing, Intelligent systems, Information management, Social and professional issues, Software engineering, Computational Science and numerical methods. The 14 areas, 132 units and 950 topics constitute the Body of Knowledge.

Topics are divided into "core" and "elective". One of the goals in CC2001 was to keep the required component of the body of knowledge as small as possible. Units where there was a broad consensus that the respective material was essential to anyone obtaining a CS undergraduate degree were marked as "core". Out of the 950 topics, 402 are marked as "core". Any units that were considered candidates for inclusion in an undergraduate program but which fell outside the core were considered to be "elective".
The extracted ontology contains both the curriculum items and the relations between them expressed both as XML and as RDF.

Our experiment is based on this ontology, and is based on an analysis of the syllabi of the courses offered for the Computer Science Bachelor at the University of Trento, Italy. The data were collected by one of the authors some time ago, before we started the project described here, and we reuse them in this context. The Bachelor in CS is fairly recent, since its offering started in year 2000. After a few years it went through a internal program review, which was meant to evaluate the consistency of our didactic offering. As part of this procedure, all syllabi were matched against the ontology extracted from CC2001. Each teacher was asked to identify the units that they were teaching in their courses. Data were examined manually at the time of their collection, and such exercise later motivated the start of the present project. The operation in itself was very helpful and successful, since it gave a general, objective overview of the state of the course, and allowed identifying some useful adjustments. It was found out that our bachelor covered 65% of the core topics. This seemed an alarmingly low number which warranted further investigation. By analyzing the coverage of individual areas it was discovered that the whole area "Social and Professional Issues" appeared not to be covered. While it is probably true that in no course in the curriculum that specifically targeted topics such as "Social implications of networked communication", many of the topics the Social area were actually touched in a non-systematic way in various courses. However the teachers who compiled their reports tended to focus on their main area, overlooking the topics contained in other areas (after all

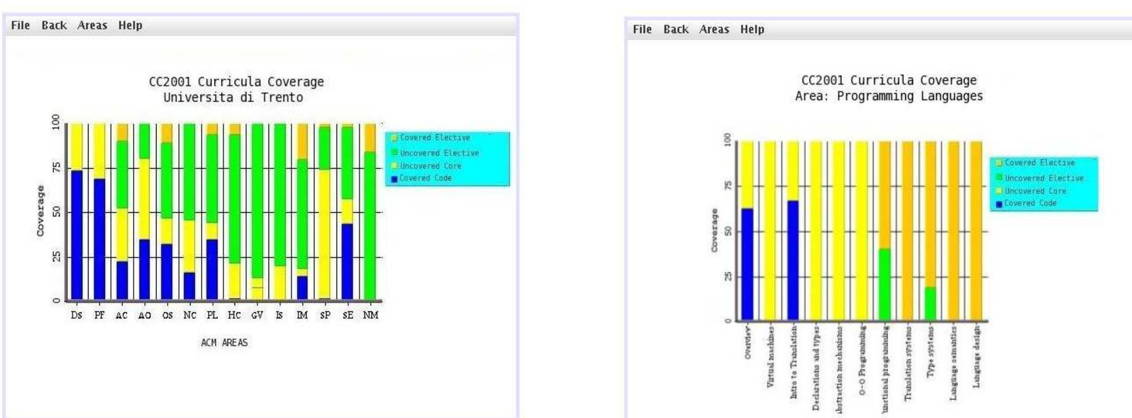
there were 950 of them!) □ending in an underestimation of the overall coverage. At first sight this might seem to defeat the whole approach, but we think this is not the case. In fact, it was possible to separately examine every single area and to discover how well that was covered, finding out critical issues such as missing coverage of relatively important items, or double coverage of some other (not necessarily an evil thing: *repetita juvant!)*. As a result, it was therefore possible to identify and fix the problems, therefore increasing the quality of our Bachelor Degree Program.
This work can be generalized, and the related analysis can be made faster and simpler by using visual tools. In the next section we present an example of what such a tool could look like.

4. Sample User Interface

Once the topics in the model curriculum have been associated with the reference ontology, a tool will be needed to enable managers to interpret the mappings between their own curriculum and the ontology. Ideally this tool will enable managers to develop a quick overview of the state of their curriculum, and allow a more detailed looked for possible problem areas. This is a challenge given that there are about 950 topics and 131 units. An approach commonly used for interpretation of hierarchical data such as this is to use drill-down charts. . Drill-down charts display high-level data in a chart such as a pie chart, bar chart, or stacked column chart, but allow users to □drill-down□into the hierarchy by clicking on an element of the higher-level chart (e.g. a slice of the pie chart, or a column in a column chart). This will result in the display of a new chart only relating to the specific bar or slice that was clicked.

The key item of interest for a manager in this scenario is how well an area or unit from the reference ontology is covered by his/her curriculum. This, however, is complicated by the fact that the CC2001 specifies both Core and Elective topics. A manager, given real constraints on □program hours□in a curriculum might opt to only consider Core elements of the reference ontology. Based on this, there are four possible states for the coverage of an individual reference ontology topic: covered core, uncovered core, covered elective, and uncovered elective.

A user interface that achieves this purpose is a drill-down stacked column chart that shows the relative percentage coverage for each state for each top-level area (e.g. Networking, Programming Fundamentals, etc) and allows a drill down to any Area to view the percentage coverage of individual units within that Area (e.g. view only units within Networking). Drill-down display of charts is a common feature of many charting libraries and data analysis tools. The screenshots in Figure 1 illustrate the top-level display of all 11 areas, with each bar showing percentages for covered core, uncovered core, covered elective and uncovered elective.



a.) Top-Level for All Areas

b.) Drill-Down to Individual Area

Figure 1 □ Sample User Interface with Drill-Down to Unit

Once a manager has viewed the various charts and identified areas that merit further inspection, he/she might ask the content area specialists or individual faculty to look further into the details. The data for this analysis must be stored in a manner which allows a hierarchical analysis. For instance, content area specialists and faculty might need information on the status of individual topics and perhaps group totals for the number of topics in each of the four states for each Unit. The required group total and detail reporting capability is a necessary feature of every reporting tool. The CC2001 had a three-level hierarchy (Area-> Unit->Topic|Learning_Objective). Other ontologies may be set up using deeper hierarchies. This will not significantly influence the complexity of the display or processing since it only requires 1 more drill-down for every extra level in the hierarchy and a slightly different configuration for the reports.

5. Discussion and conclusions.

One possible objection to these reference ontologies take considerable effort and time to develop, and since CS evolves very rapidly, the ontology might not support new topics that emerge. This is certainly true, but this objection applies to other uses of ontologies in e-learning (such as indexing learning objects etc.). Of course ontologies need to be maintained. For instance, after CC2001 several similar documents appeared that either update it (e.g. Shackelford et al. 2006) or go deeper in subfields (CSE2004, Gorgone et al.2002). Also, in some domains, especially when education at a Master level is concerned, it might be useful to extend the ontology to cover more specialized areas, as reported by (Ronchetti 2006) for the Semantic Web field).

Another objection might be that all this, i.e. creating an ontology and indexing all the courses’ content against it, is too much work for the goal we intended to reach.

Our response to both these objections is that ontologies will be available in e-learning scenario anyway, and they will need to be updated and integrated in any case. Working with multiple, partially overlapping ontologies is a hot research topic today that most likely will produce solutions that will help evolving and maintaining ontologies over time. Learning objects will be indexed on the ontology, and simple inferences such as “if course X uses learning object Y and learning object Y is about topic Z, then course X deals with topic Z” will allow producing “for free” the mapping we need. We therefore believe that the approach we presented can be of great value in the crucial task of guaranteeing the quality of the didactic offering. Once enough learning objects have been indexed against the ontology using this approach it will be possible to infer a “draft” topical coverage of a course from its learning objects thereby dramatically reducing the actual amount of work involved in associating topics with course. The “draft” could be used by teachers as a starting point, only requiring validation and if necessary the addition of extra topics. This would be very useful since the original task of mapping domain ontology topics to the individual courses required considerable effort.

In summary, we have presented a strategy for managing, inspecting and monitoring a full course of study (a program), that will aid in the quality assurance of didactic offerings and thereby help improve the overall quality of these offerings. This strategy involves mapping the elements of a standardized domain ontology to an actual course of study. This has been applied in the ongoing refinement of a Computer Science Curriculum at the Univesita di Trento. We also presented a possible user interface to enable managers to quickly interpret these mappings and to act on those interpretations. This strategy is synergistic with existing approaches to ontology-aided e-learning, potentially enhancing such things as the quality of metadata in LORs.

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