The Educational Semantic Web

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Abstract: The big question for many researchers in the area of educational systems now is what is the next step in the evolution of e-learning? Are we finally moving from a scattered intelligence to a coherent space of collaborative intelligence? How close we are to the vision of the Educational Semantic Web and what do we need to do in order to realize it? Two main challenges can be seen in this direction: on the one hand, to achieve interoperability among various educational systems and on the other hand, to have automated, structured and unified authoring support for their creation. In the spirit of the Semantic Web a key to enabling the interoperability is to capitalize on the semantic conceptualization and ontologies, common standardized communication syntax, and large-scale service-based integration of educational content and functionality provision and usage. A central role in achieving unified authoring support plays the process-awareness of authoring tools, which should reflect the semantic evolution of e-learning systems. The purpose of this paper is to outline the state-of-the-art research along those lines and to suggest a realistic way towards the Educational Semantic Web. With regard to the latter we first propose a modular semantic-driven and service-based interoperability framework, in order to open up, share and reuse educational systems’ content and knowledge components. Then we focus on content creation by proposing ontology-driven authoring tools that reflect the modularization in the educational systems, maintain a consistent view on the entire authoring process, and provide wide (semi-) automation of the complex authoring tasks.

Key-Words: - E-learning, interoperability, concept-based WBES, educational Semantic Web

1 Introduction

The Semantic Web vision significantly evolves the Web technology and advertises the opportunity to achieve seamless semantic understanding across cultures, time, geo-graphical borders, and technological platforms. The question is will this also bring us to the next evolutilional step for E-learning?

The Semantic Web offers new technologies to the developers of Web-based applications aiming at providing more intelligent access and management of the Web in-formation and semantically richer modeling of the applications and their users. An important target for the Web application developers nowadays is to provide means to unite, as much as possible, their efforts in creating information and knowledge components that are easily accessible and usable by third parties. Within the context of Semantic Web, there are several hot issues, which allow achieving this reusability, shareability and interoperability among Web applications. Conceptualizations (formal taxonomies), ontologies, and the available Web standards, such as XML, RDF, XTM (XTM: XML Topic Maps http://www.topicmaps.org/xtm/), OWL, OWL-S (OWL-S: OWL-based Web service ontology), and RuleML (RuleML: The Rule Markup Initiative http://www.ruleml.org/), allow specification of components in a standard way. The notion of Web services offers a way to make such components mobile and accessible within the wide sea of Web information and applications.

The research on e-learning and Web-based educational systems (WBES) tradition-ally combines research interests and efforts from various fields. Starting from the traditional Intelligent Tutoring Systems (ITS), moving towards Web-based and hypermedia systems, we witness a growing interest in applying adaptation and personalization of the information offered to the users (e.g. learners, instructors and educational content authors). A characteristic aspect of this move is the attention the application needs to pay to the specific individual user in order to tailor the growing amount of information, coming from various distributed and local sources, to the needs, goals, roles and tasks of the individual users. In an effort to serve better the needs of the education community WBES attempt to employ Semantic Web technologies in order to achieve improved adaptation and flexibility for single and group users (e.g. instructors, courseware authors and learners).
and new methods and types of courseware compliant with the Semantic Web vision. This promising class of Adaptive Web-based Educational Systems (AWBES) forms the basis of the emerging Educational Semantic Web.

The goal of this paper is to present and analyze the main aspects and research trends concerned with the development of a homogeneous e-learning Web space, where various systems collaborate in their effort to satisfy the users’ needs and in the same time use state-of-the-art Web technologies to bring the e-learning to the level of the modern society developments. Our aim is to provide a ground for the design of more process-, context- and user-aware systems that facilitate efficient learning delivery, authoring and consumption. We first present four main aspects for achieving interoperability among WBES, including: concepts and ontologies for adaptive WBES, modularized adaptive WBES architectures, educational standards for the Semantic Web, and Semantic Web educational services. Then we discuss the importance of efficient authoring support covering the three central lines in the authoring of adaptive concept-based WBES.

2 Interoperability of WBES

Considering the constant increasing of resources on the Web (both static documents and functional components and software) it becomes almost impossible for the learners, authors and instructors to get an overview of all the available information relevant to their current needs, tasks, roles and goals. And even if they find some materials, which seem suitable, they are not able to assess completely whether the found content is entirely appropriate for their goals (for instructors) or current knowledge and cognitive state (for learners). Within the class of Web-based educational systems, a major role in various instructional contexts play the Educational Information Systems that are aimed at providing intelligent, task-centered information support for solving problems and performing learning tasks. Consequently, considerable effort is currently focused on defining frameworks and architectures to tackle issues of information support from multiple perspectives.

In order to support a richer set of educational functions and increase their effectiveness, such systems need to interoperate, collaborate and exchange content or re-use functionality. A key to enabling the interoperability is to capitalize on the semantic conceptualization and ontologies, common standardized communication syntax, and large-scale service-based integration of educational content and functionality provision and usage. This view is supported also by Anderson & Whitelock’ fundamental affordances for the Semantic Web: “The vision of the educational semantic web is based on three fundamental affordances. The first is the capacity for effective information storage and retrieval. The second is the capacity for nonhuman autonomous agents to augment the learning and information retrieval and processing power of human beings. The third affordance is the capacity of the Internet to support, extend and expand communications capabilities of humans in multiple formats across the bounds of time and space” [1].

Another semantic interoperability vision is given by Stuff & Motta, who envision “a multiplicity of community-based Semantic Learning Webs each with its own, perpetually changing ontologies, knowledge bases, repositories and ways of making sense of the world.”, where ontologies provide means for semantic communication within and across those “Knowledge Neighborhoods” [10]. Stepping on the above three factors for interoperability, we propose a powerful service-oriented framework to support efficient communication between component-based WBES [7].

The following sub-sections summarize the main aspects of adaptive WBES in the context of achieving interoperability in the Semantic Web.

Concepts and Ontologies in Adaptive WBES

We see that currently a considerable amount of the research on knowledge-based and intelligent systems moves towards concepts and ontologies [5] and focuses on knowledge sharing and reusability. In general, an ontology is used to define the basic terms and relations in the domain. It also provides axioms as rules and constraints for manipulating and managing the terms and their relations within this common domain vocabulary. Ontologies allow the definition of an infrastructure for integrating intelligent systems at the knowledge level, independent of particular implementations, thus enabling knowledge sharing [4]. Together with various reasoning modules and common knowledge representation techniques, ontologies can be used as the basis for development of libraries of shareable and reusable knowledge modules (which take the form of software components) [3]. As a consequence the research that focused on ontologies offers tools and technologies for reusing and sharing of knowledge and hence helps intelligent educational
systems to move towards semantics aware environments.

There are a number of concept-based AWBES already developed [2], which typically include: concept-based (ontology-driven) subject domain, repository of learning resources, course (learning task) presentation, adaptation & personalization. The fundamental feature of these systems is the subject domain conceptualization. It supports not only efficient implementation of their required functionality but also standardization: the concept structure can be built to represent a domain ontology that provides a broadly agreed vocabulary for domain knowledge representation. Thus the ontology specifies the concepts to be included and how they are interrelated. The repository contains learning resources (objects) relevant to the defined subject domain concepts. We can think of the resources as being attached to the domain concepts they describe, clarify, or use. If the attached learning resources have also a standards-based representation as opposed to a system-specific internal representation, this will insure that the application’s content is reusable, interchange-able, and interoperable.

Course/learning tasks are typically described/annotated in terms of subject domain concepts and some instructional relationships (such as ‘prerequisite’, ‘uses’, etc) between the involved concepts. The domain concepts are also used as a basis for implementing systems’ adaptive behavior. The latter involves constructing learner models in terms of subject domain concepts, performed tasks, and user profile characteristics.

Educational Standards for the Semantic Web

The learning technology community is quickly adopting many of the Web technologies (XML, RDF(S), streaming video, etc.)[5]. Simultaneously, the educational technology standardization is moving forward at rapid pace, with the IMS and the ADL having become the specification consortia that are tracked by vendors, implementers and academia. Both bring important contributions with respect to the management of educational resources. There is a growing concern though towards the need of extending the existent educational standards, such as the IEEE/IMS LOM standard (http://ltsc.ieee.org/wg12/), in the context of the Semantic Web so as to allow improved semantic annotation of learning resources.

The emerging educational specification for learning content SCORM addresses semantic annotations, content aggregation and sequencing. However, SCORM (SCORM 1.3 specification http://www.adlnet.org/screens/shares/dsp_displayfile.cfm?fileid=836) has chosen its own XML formats and methodologies, thereby limiting the educational community to a restricted universe, and making it much more difficult to integrate E-learning with other business processes. It is thus recognized by some, including leaders of the SCORM development community, that there is a benefit in opening up to the larger (Semantic) Web community. By design, these technologies make it easier to integrate learning material with other material by avoiding cumbersome translations of existing vocabulary and semantic descriptions.

It is important to consider effective specification of sequencing and annotation of material on a semantic level. One step towards achieving this is proposed in (Aroyo et al., 2003) by mapping the sequencing in the current SCORM standards onto OWL and DAML-S (http://www.daml.org/services/owl-s/). Such a DAML-S translation can then be used to integrate SCORM based learning environments with other business processes or Web services that have a DAML-S description.

Semantic Web Educational Services

In the current efforts targeting integration of various educational systems and content providers, Devedzic [6] proposes educational servers, which are based on using standards, ontologies, and pedagogical agents to support interaction between clients (authors and students) and servers (hosting educational content and services). He suggests that the interaction in the future educational systems will be between learners and services through educational service directories. While agreed with this vision, we believe that WBES interactions in the near to medium future will be between educational systems and/or their components, i.e. before achieving the large scale service-based integration, possible effective communications between systems and their components must be explored and exploited.

Another service-oriented perspective on the integration is given by the Elena project [9], which defines a smart learning space of educational service providers based on the Edutella [8] peer-to-peer framework for interoperability and resource exchange between heterogeneous educational applications and different types of learning resource repositories. In the same context, we also see specific efforts trying to fill the gap between adaptive educational systems and dynamic learning
repository networks, by proposing service-based architectures for personalized e-Learning.

Modularized Adaptive WBES Architectures

The analysis of many current adaptive concept-based WBES shows that they share common architecture features. This enables the specification of a common reference architecture for adaptive concept-based WBES, which will allow for a more structured and common approach in their comparison, evaluation and building.

If we consider the problem of efficient construction of adaptive concept-based WBES that complement (serve as advisors to) each other by sharing resources and components, the obvious answer is a modularized approach in building such systems. This implies a component-based architecture that allows sharing knowledge (e.g. domain ontologies, learning resources, course models, and user models) and components (e.g. user modeling, course sequencing, ontology visualization, keyword search).

We have proposed such a general reference architecture [7] addressing the following research questions:
1. Level of granularity of information exchange: what should be the information contained in one communication transaction? For example, in the second scenario, should the author be allowed to ask about importing the entire domain model of another system in one transaction?
2. Request semantics: What kinds of questions the requesting system should be able to ask?
3. Request syntax: In what a form the questions should be expressed?
4. Domain or user model awareness: Should the requesting system send any indication about what it “knows” or its user already “knows”, so that the responding system doesn’t send information already known? If so, what kind of information and in what a form?

With regard to the grain size of exchanged information, we consider two issues as important for the communication quality and efficiency between the systems, conciseness of the request and the reply, and completeness of the request and reply.

Concerning the “understanding” between each other, the systems must “know” the basic terms for structuring and using ontology-based learning resource repositories, such as ‘concept’, ‘relation/association’, ‘role in a relation’, ‘resource’, etc., which make the common ground for the semantic understanding. In other words, the different systems must know how to map their internal knowledge to the basic concepts of this common ground. This lightweight mapping process, as opposed to very expensive reasoning processes, is a key aspect of the proposed approach. In this context we also propose using XML-based protocols, so that any application can “understand” them. In relation to the domain and user awareness we propose that the systems share a common user model, possibly through using a user modeling service. In that case the responding system will not need to ask the requesting system what the user already knows. A common (shared) user model is only feasible if all WBES systems within the framework have concept-based representation of their subject domain.

![Figure 1. General architecture for component-based EIS interoperability](image)

Thus, the proposed general architecture for supporting sharing and exchanging information between adaptive concept-based WBES include (Figure 1):
- Stand-alone, component-based independent WBES using their private subject domain ontologies.
- Information brokerage bureau where all applications are registered.
- Services to support systems communication, including ontology-related services, e.g. for ontology mapping.
- Communication bridges between the systems supporting standardized transport mechanisms and a common interaction protocol.

The communication between the systems requires not only standardized transport mechanisms and communication languages, but also common content languages and semantics. As to the communication semantics, in order for the applications to understand each other we propose using a communication ontology that defines the vocabulary of terms used in the messages at both message and content layers. To
interpret the requests and answers standardized domain ontologies, UM ontologies, as well as upper-level ontologies such as WordNet (http://www.cogsci.princeton.edu/~wn/), SUMO (SUMO: Suggested Upper Merged Ontology http://ontology.teknowledge.com/), etc. can be used.

3 Authoring of Adaptive Concept-based WBES

Building adaptive concept-based WBES requires a lot of work and often is done from scratch. It becomes even more demanding with the constant increase of the information available on the Web and with the involvement of complex adaptation strategies for the instructional content presentation and navigation. A central problem in maintaining WBES popularity and benefiting from their wide use in practice is the fact that the current approaches for their building are rather inflexible and not efficient. The current way of designing such systems offers little space for reusing or sharing of content, knowledge and functional components. In addition, e-learning systems often lack a good authoring interface and require low-level programming skills from the content experts. The high and dynamic user demands in many aspects of software production are influencing research in the field of intelligent educational software as well. The ultimate problems are related to keeping up with the constant requirements for flexibility and adaptability of content and for reusability and sharing of learning objects and structures. Another problem in the current WBES research is that assessment of the existing systems is difficult as there is no common reference architecture, nor standardized approaches. Thus, there is an increasing need for efficient support environments for the designers and builders (authors) of adaptive WBES. We envisage that such support should include automatic or semi-automatic performance of some authoring activities, intelligent assistance to the authors in the form of hints, recommendations, templates based on recognizing different information patterns within subject domain content/ontologies or presentation (sequence) patterns, etc.

Considering the specification of modularized common reference architectures for WBES, the authoring of adaptive concept-based WBES should also be based on a strict separation and independency of the roles of the domain expert and the course author, which implies separate definitions of the domain knowledge (including also educational resources) and the instructional/course knowledge (including also the adaptation and personalization strategies) [3]. We identify three groups of authoring activities: authoring of the content, authoring of the instruction process and authoring of the adaptation and personalization. These authoring activities ensure structuring and editing of domain concepts and resources, modeling of the process of course task sequencing and choosing and applying an appropriate adaptation strategy.

Authoring of Instructional Process

Authoring of the instructional process in concept-based WBES typically involves course construction activities, which include generating a course model to represent a course structure and to serve as a basis for the further sequencing of course tasks. In order to produce an instructional task sequence the author usually selects concepts from the domain model and assigns them to course topics; selects specific sequences of course topics realizing the learning goals; and assigns course tasks for each topic (each task will cover more than one learning activity).

Authoring of the Adaptation and Personalization

The authoring of adaptation considers user-related authoring activities that deal with the definition of user model attributes and their application in the adaptation and the course task sequencing. At this stage the authors typically define and apply various adaptation strategies in order to achieve the most efficient tailoring of the learning content to the individual learners.

In educational adaptive hypermedia systems, for instance, the adaptation primarily concentrates on the navigation structure and the construction of links and content in such a way that the presentation is adapted to the user. Even in the more general class of adaptive Web information systems the focus on navigation engineering is relatively high. In the adaptive task-based WBES the adaptation is styled quite differently, as the personalization is mainly constructed via the identification of tasks and the subsequent instructional sequencing.

4 Conclusion

To conclude, in the field of (A)WBES, it is clearly a transition stage, where the information is
reaching critical amounts, the user demands for more personalized and adaptive system interaction are constantly rising, and the Web technologies are racing the clock to conquer new horizons. In this context, semantics plays a central role. It has become more explicit and this steadily changes the way in which we deal with information. Dealing with ontologies and concepts increases our conceptual awareness and influences the style of information perception, which reflects in the demands for using and authoring (A)WBES. The strive towards machine-readable semantics, on the one hand allows systems to more easily reach a conceptual agreement and exchange in-formation and functional components. On the other hand, it provokes a ‘greediness’ to have more and more intelligence in the user-system interaction. With the new frameworks and architectures that are evolving in order to meet the semantic challenge the goal has become to provide the users (both students and authors) with a seamless personalized interaction with the WBES. It is unfeasible to predict, in the longer term, where e-Learning is going to go and what will be the new challenges then, but for now it is unambiguous that the current vision of the Educational Semantic Web propagates interoperability, reusability and shareability, all grounded over an extensive expression of semantics with a standardized communication among modular and service-oriented systems. An essential element for success is the availability of support for user-friendly, structured and automated authoring of educational systems, where it is important to find the balance between, on the one hand, exploiting explicit semantic information for agreement and exchange of educational information, and on the other hand, collecting and maintaining that information semantics.

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