An Electronic Learning Assistant

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Abstract: *In this paper, based on our previous work, we describe the functionality and implementation of a Semantic Web-based e-learning application - an Electronic Learning Assistant (ELA) - with focus on the RDF data model and OWL ontology of the application.*
Key words: *Semantic Web, RDF, OWL, e-learning, ontology, Semantic Web Services.*

INTRODUCTION

The new generation of the Web, the so-called Semantic Web, appears as a promising technology for implementing e-Learning. The Semantic Web constitutes an environment in which human and machine agents may communicate on a semantic basis [2] . One of its primary characteristics, viz. shared understanding, is based on an ontology framework. Ontology enables the organization of learning materials around small pieces of semantically-annotated (enriched) learning objects [10]. Items can be easily organized into customized learning courses (fast and just-in-time) and delivered on demand to the user, according to his profile and business needs.

Our paper outlines how the Semantic Web may be used as a technology for realizing a sophisticated e-learning application - an Electronic Learning Assistant (ELA). This application is a continuation of our previous work [7]. In the following, we first describe the architecture of the Semantic Web. Afterwards, we describe ELA's functionality and its implementation. In the subsequent section, we discuss the advantages of building the application using Semantic Web technology and describe how the functionality can be extended with Semantic Web Services. After a discussion of related work, concluding remarks summarize the importance of the presented topic and outline some future work.

SEMANTIC WEB ARCHITECTURE – XML,RDF and OWL

The term Semantic Web encompasses efforts to build a new WWW architecture that supports content with formal semantics [13]. This means, content suitable for automated systems to consume, as opposed to content intended for human consumption. Such an architecture will enable automated agents to reason about Web content, and produce an intelligent response to unforeseen situations.

Expressing meaning is the main task of the Semantic Web. In order to achieve this, an infrastructure comprising several layers is needed. The following layers are the basic ones:

- the XML layer, which represents data;
- the RDF layer, which represents the meaning of data;
- the Ontology layer, which represents the formal common agreement about meaning of data;
- the Logic layer, which enables intelligent reasoning with meaningful data [3].

It is worthwhile noting that the real power of the Semantic Web will be realized when people create many systems that collect Web content from diverse sources, process the information and exchange the results with other human or machine agents. Thereby, the effectiveness of the Semantic Web will increase drastically as more machine-readable Web content and automated services (including other agents) become available. This level of inter-agent communication will require the exchange of proofs. Three important technologies for developing the Semantic Web are already in place: eXtensible Markup

Language (XML), the Resource Description Framework (RDF) and Ontology Web Language (OWL) [13].

The Semantic Web could be treated as a very suitable platform for implementing an e-Learning system, because it provides all means for (e-Learning) ontology development, ontology-based annotation of learning objects, their composition in learning courses and (pro)active delivery of the learning materials through e-Learning portals [13].

ELECTRONIC LEARNING ASSISTANT

ELA is a Semantic Web-based, e-Learning application. It is meant to be used as a complementary web-based learning tool, to assist the college student in improving his/her performance in the course material by providing additional, relevant learning objects. It is a Semantic Web-based application because it uses technologies such as RDF for storing the metadata, and OWL for storing the e-learning ontology. The latter allows us to link all of the learning objects with commonly agreed metadata vocabularies, thus enabling semantic querying by the student for topics of interest. Moreover, learning material is semantically annotated and, if there is demand for new material, it can easily be appended to the RDF repository and made available to the students. According to the student's background, he can find useful learning material very easily.

ELA is considered as an e-learning application because it satisfies the following generally accepted requirements [6]:

1) Student determines agenda – In our application, there is a core set of concepts than the student needs to satisfy in order to complete the course. However, the list is small and only includes the basics. It is left to the learner to freely query and explore the repository of learning objects.

2) Non-linear – there is no defined progression of knowledge

3) Distributed authority – content comes from the interaction of students as well as instructors – i.e. students have the option of submitting links to the RDF repository as well

4) Personalized – learning content is tailored to fit the student. The user is given a background assessment test the first time he logs in, and the system creates a profile. This enables ELA to serve the student with learning objects matching his/her abilities and previous knowledge of the material. The ontology is the link between user needs and characteristics of the learning material.

5) Adaptivity – Content changes constantly through user input – for example, learning objects which receive a low rating by the students are subsequently not displayed in the main curriculum.

ELA FUNCTIONALITY

There are three main notions on which the functionality is based – student, concept and learning object. The idea of student is clear enough. It is implemented as an RDF file that holds his/her preferences and accomplishments. Concept is an abstract term describing some sub-topic found in the learning domain. Examples of concepts in the field of Operating Systems may be Synchronization, Virtual Memory, Scheduling, etc. Learning objects, on the other hand, are any digital resource that can be reused to support learning. In ELA, they are links to learning resources that might be online or offline (books). Every link in the application is annotated with RDF statements that will provide a description about the linked learning object. So far we have included the following descriptors: "name", "author", "URL", "difficulty", "comment" and "rating". One of the most important characteristics is "comment" because all students can comment upon the learning object, so a user will benefit from this sharing of information. Learning objects are directly linked to one or more concepts, and one concept usually contains many learning objects.

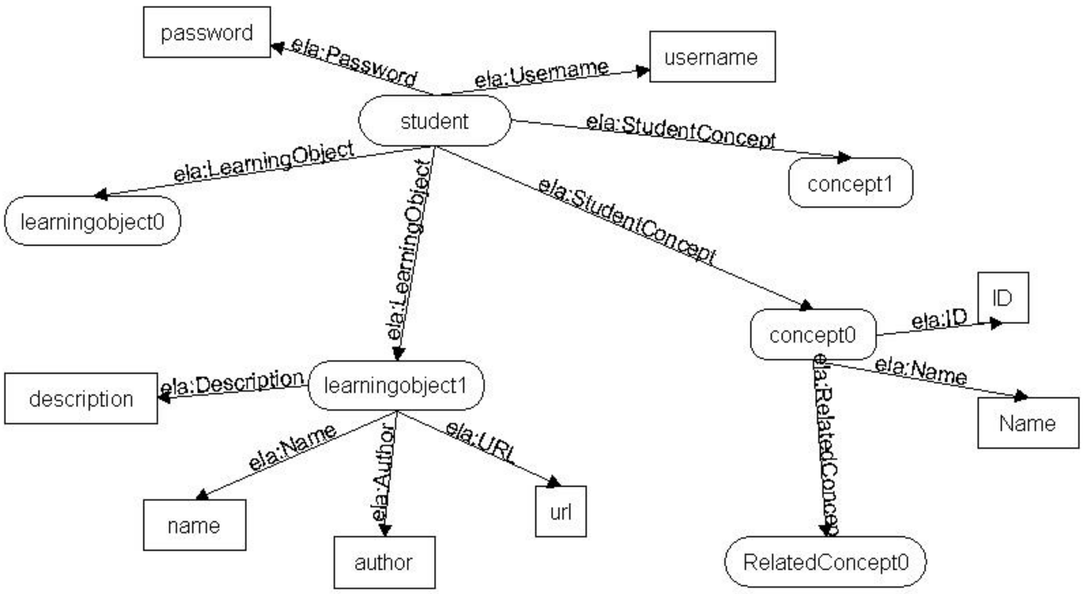

Figure 1. Relationships between the main classes in ELA.

After logging in for the first time, a student user is required to complete a background assessment questionnaire. Since our learning application is course-specific, we have chosen the area of Operating Systems as the basis for the test. The student chooses the concepts he feels that he has some knowledge of and the software generates the questions from a database. A sufficient number of questions with a broad range of difficulty is stored for every concept to provide a realistic assessment of the student's familiarity with the topic. After assessing the student's performance on the test, ELA stores the background profile in an RDF repository for future reference.

Once the student has gone through the test, it is time to present to him the core curriculum needed to successfully complete the online course. Because there may be many concepts in the application, the instructor may choose which ones are appropriate to be labeled as "core", or required concepts, ones that the student needs to learn before he can successfully complete the course.

The core curriculum page consists of a list of the required concepts. Some concepts might have prerequisites that need to be fulfilled before these concepts are learned. Moreover, every concept has a list of related concepts, so the student can freely explore the topic of his interests.

IMPLEMENTATION

ELA was conceived as a multi-tier web application. The multi-tier architecture allows us to implement dynamic content and separate presentation from business logic. Therefore we needed a reliable and scalable platform to implement ELA, a platform that would also allow us to integrate seamlessly to Jena, the Semantic Web Toolkit [9].

We selected J2EE as the platform for the ELA because it provides a component-based middle-ware infrastructure and content-delivery functionality required to build integrated learning content management systems [10]. The J2EE platform also provides a multi-tiered distributed application model, an ability to reuse components, a security model and flexible transaction control that ease application development by abstracting low-level details from the business logic [12].

Our multi-tiered application was implemented using J2EE and Jena. It consists of four layers, as presented below.

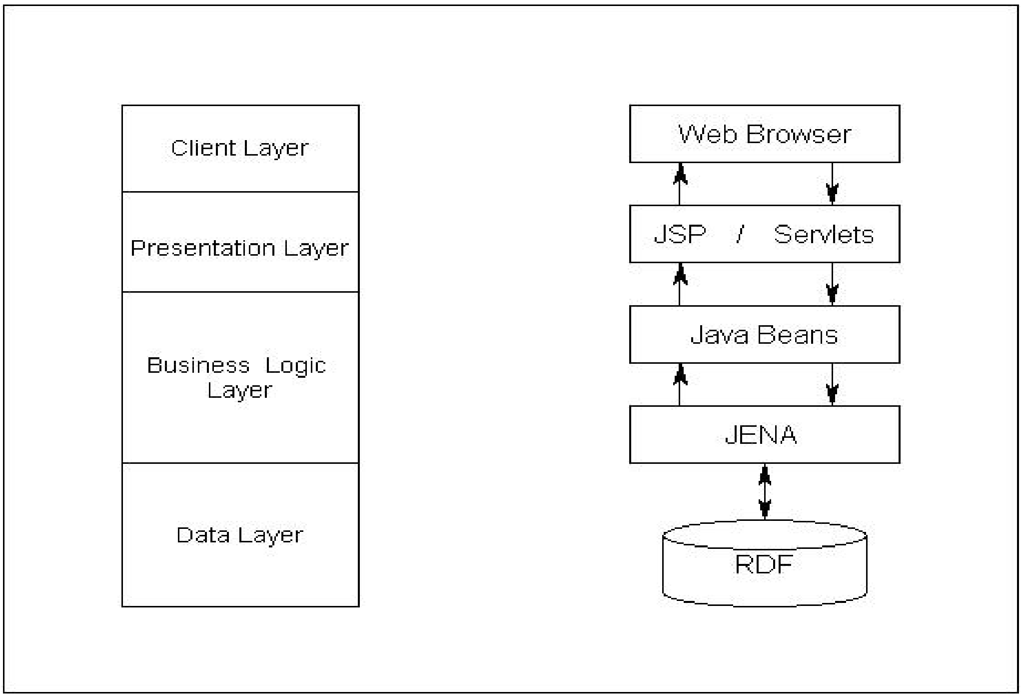

Figure 2. Architecture of ELA

SEMANTIC WEB LAYER

The most distinguishing feature of our application is that we are using an RDF-based data model to store the information. We decided to use Jena, a Semantic Web Toolkit, as our RDF parser [9]. Jena is a Java API capable of manipulating and parsing RDF statements, and storing them as graphs (or *models*), thereby allowing straightforward manipulation of the RDF. Jena is much more than an RDF parser, it also provides support for converting OWL-specified ontologies to an RDF form, and also implements a *Resource Description Query Language* (*RDQL*), an SQL-like query language for RDF statements.

In ELA, we mostly used Jena for two distinct purposes:

1) Parsing RDF and storing the data in a graph-based model. Since RDF/XML syntax is quite cumbersome to work with, the parser (called ARP) comes in quite handy because it converts all of the RDF triples into a graph. All of the RDF files' update is done in the data access layer, and using the ARP Parser expedited the development process.

2) Developing ontologies**.** The Jena ontology API is intended to support programmers who are working with ontology data based on RDF. Specifically, this means support for OWL, DAML+OIL and RDFS. We developed three OWL-based ontologies for the purposes of ELA: student, concept, and learning object ontologies. In these ontologies, the actual resources and properties specified in the RDF models are defined. For example, there is the student class with its properties ela:username and ela:password. By defining the properties in the ontology, we prevent any data inconsistency in the RDF model. Our ontologies are based on OWL – which is the most expressive ontology language available and designed by W3C [14].

SEMANTIC WEB SERVICES

There is one web service currently provided by our application. It returns the learning objects for a given concept. It is developed and deployed using Apache Axis, which is an open source implementation of the Simple Object Access Protocol (SOAP). Our web service enables other applications, potentially even intelligent agents to tap into the resources of our system. It allows agents to query the metadata repository for a given concept and retrieve a list of learning objects.

Currently, we are working on extending the functionality of the web service by adding a layer of semantic description. The biggest difference between a SOAP-based Web Service and an OWL-based Semantic Web Service is that the latter also incorporates a computer-interpretable description of the service, and the means by which it is accessed. There is a need for a framework within which these descriptions are made and shared. Such framework is currently being developed as part of the DARPA Agent Markup Language program [5]. It is called OWL-S and consists of three main parts: the service *profile* for advertising and discovering services; the *process model*, which gives a detailed description of a service's operation; and the *grounding*, which provides details on how to interoperate with a service, via messages [11].

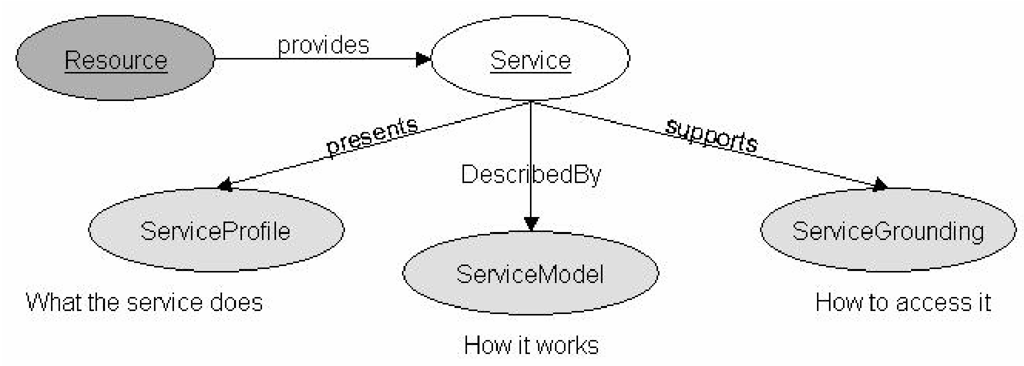

Figure 3. OWL-S models

RELATED WORK

Stojanovic et al. [13] describe an e-learning scenario based on the Semantic Web, in particular concentrating on ontologies for e-learning objects.

Sabin-Corneliu Buraga [4] proposes an agent-oriented, extensible framework based on XML for building a hypermedia e-learning system. His work focuses on implementing a web-based e-learning system by depoliying mobile agents that can exchange information in a flexible way via XML-based documents (such as RDF, or SOAP-based web services).

Baraniuk et al., [1] have developed a repository of free, open-licensed educational materials in fields such as music, electrical engineering and psychology. The application includes Content modules encoded in XML, Authoring Tools to facilitate collaboration, Course Composer to build courses and Annotations to personalize Modules.

CONCLUSIONS AND FUTURE WORK

In this paper we have described ELA – a Semantic Web-based, e-learning application. Our aim was to outline the architecture and functionality of ELA, and the advantages of using the Semantic Web as a development platform. We are working on adding semantic descriptors to our application in order to make it intelligent agent-friendly.

REFERENCES

[1] Baraniuk, R et al. Connexions Project. Available at http://cnx.rice.edu/

[2] Berners-Lee T. (2000). What the semantic web can represent, http://www.w3.org/DesignIssues/RDFnot.html.

[3] Berners-Lee, T. Semantic Web - XML2000. http://www.w3.org/2000/Talks/1206-xml2k-tbl/slide10-0.html

[4] Buraga, S. Developing Agent-Oriented E-Learning Systems. Proceedings of The 14th International Conference on Control Systems And Computer Science – vol.II, I.Dumitrache and C.Buiu (eds.), Politehnica Press, Bucharest, 2003.

[5] DAML Semantic Web Services. www.daml.org/**services**/

[6] Drucker, P. Need to Know – Integrating e-Learning with High Velocity Value Chains. Delphi Group White Paper, 2000. www.delphigroup.com

[7] Galletly, J., and Kolovski, V. Towards E-Learning via the Semantic Web. Proceeding of the International Conference on Computer Systems and Technologies, Sofia, 2004.

[8] Infrastructure Content Management. http://www.vignette.com/Downloads/DS_IBM_WAS.pdf

[9] Jena. Available from http://jena.sourceforge.net/

[10] Nejdl W. Learning Repositories – technologies and Context, To appear in Proceedings of ED-MEDIA 2001 World Conference on Educational Multimedia, Hypermedia & Telecomuunications, June 25-30, Tampere, Finland.

[11] Ontology Web Language for Services (OWL-S) Version 1.0. http://xml.coverpages.org/ni2004-01-08-a.html

[12] Oracle Technology Network. Overview of Java and J2EE. http://otn.oracle.com/sample_code/tech/java/j2ee/javacookbook/overview.html

[13] Stojanovic L, S Staab, R Studer. Elearning based on the Semantic Web. WebNet2001 - World Conference on the WWW and Internet, Orlando, Florida, USA, 2001.

[14] World Wide Web Consortium. OWL Web Ontology Language Overview. http://www.w3.org/TR/2004/REC-owl-features-20040210/

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