Applying Semantic Web Technologies to Achieve Personalization and Reuse of Content in Educational Adaptive Hypermedia Systems

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Abstract. Ontologies and metadata standards for the Web can be used to achieve personalization and reuse of content in Educational Adaptive Hypermedia Systems. Web Ontologies can represent the knowledge of the system concerning the educational content, the domain to be taught, and the learner's profile enabling intelligent behavior in building personalized learning objects. Interoperability to reuse of content can be achieved by having the ontologies terminology based on pre-existing standard vocabularies. This paper describes how Semantic Web technologies were applied to the Adaptive Hypermedia System AdaptWeb.

1 Introduction

Educational Adaptive Hypermedia Systems keep knowledge about the student's profile and the domain to be taught i.e. the *Student Model* and *Knowledge Space* of the system [1]. What our proposal adds to the Knowledge Space is a structure describing the educational content capable of providing composition rules represented in a principled way to construct complex learning objects tailored to the student's profile, setting the stage to implement a powerful adaptation mechanism. This structure is a Web Ontology whose individuals are automatically generated each time new educative content is added to the system [2]. We achieve interoperability across the Web by the definition of an application profile of a standard metadata model envisaged to describe e-learning content. This paper describes the AdaptWeb application profile of the Learning Object Metadata (LOM) [3] standard and the representation of the Student Model and Knowledge Space of the AdaptWeb system as Web ontologies. The AdaptWeb is an in-progress research project supported by the CNPq, Brazilian National Research Council. This work is structured as follows. Section 2 describes the Semantic Web technologies used, section 3 describes the Information Space of the System and the defined Application Profile, section 4 shows the student model, section 5 gives the adaptation scenario and section 6 is a short conclusion.

2. Semantic Web Technologies

We used Web Ontologies and in particular *application ontologies* [4] to both represent the knowledge about the student profile and store explicit metadata modeling knowledge about the educational content in the system, called Student Ontology and Content Knowledge Ontology respectively. We also used a *domain ontology* [4] to represent the taxonomy of the domain being learned, called Domain Ontology. The language DAML+OIL was used to enable interoperability at the syntactic level on the Web, while the ontologies vocabularies derived from standards enable interoperability at the semantic level.

3 AdaptWeb Knowledge Space

The Domain Ontology and *The Content Knowledge Ontology*, some of whose individuals are depicted in Figure 1, forms the AdaptWeb Knowledge Space. The Content Knowledge Ontology is an ontology encoded in DAML+OIL [5] that describes the actual pieces of instructional content giving the rules to correctly assemble them (e.g. prerequisite rules defined as transitive properties). This makes the automatic computation of complex learning objects adequate for each student's profile possible by using ontology services, such as reasoning. Qualified links relate Content Knowledge Ontology elements to Domain Ontology ones indicating how each piece of the educative content approaches subjects on the Domain Ontology, e.g. *apply or define.*

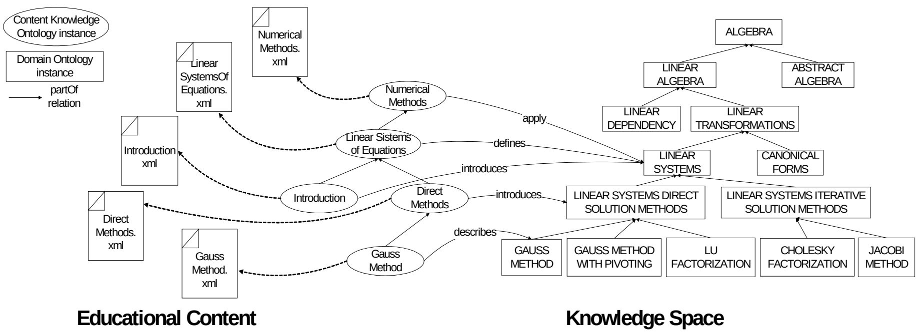

Fig.1. Instances of the AdaptWeb Information Space

3.1 Domain and Content Knowledge Ontologies

The Domain and Content Knowledge Ontologies schemas are represented in Figure 2. The abbreviation *awo* stands for Content Knowledge Ontology that defines the namespace located at http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.daml and *dom* stands for Domain Knowledge Ontology that defines the namespace located at http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.daml. Instances of class *awo:Topic* represent the explanation of some idea supported by examples, exercises and complementary material represented in classes *awo:Example*, *awo:Exercise*, *awo:Complementary* and *awo:e-Support*. A topic may have sub-topics giving more specific explanations related by the *awo:isPartOf* relation. The order in which the topics are presented according to learning purposes is given by the a*wo:learningPath* relation. The class awo:Course contains customizations of disciplines for students with common background knowledge and learning goals. Class *awo:Contributor* contains creators of educative content and recommenders of Web resources created and maintained out of the system context but described in class *awo:e-Support*.

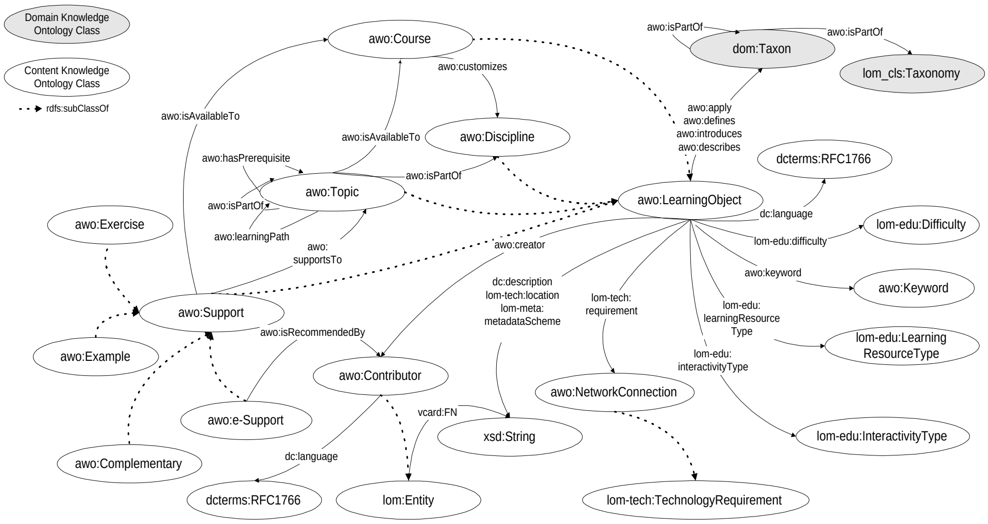

Fig.2. Classes and Relations of Domain and Content Knowledge Ontology

3.3 Application profile Definition

The Learning Objects Metadata Standard - LOM [3] is a metadata standard to be used in descriptions concerning objects for learning purposes. An application profile [6] takes elements from standard schemas and eventually refines them to create a set of metadata descriptors tailored to a particular application while retaining interoperability with the original base schemas. Several application profiles of LOM such as ARIADNE [7], Heal [8] and CanCore [9] were developed, and some crosswalks providing mappings between them exist. There are a number of implementations of LOM in XML motivated by the current maturity of that language. Nevertheless, the use of RDF [10,11,12,13] to represent LOM metadata provides a standard way to reutilize Web standard vocabularies. We created a new application profile of the standard LOM based in the RDF binding presented in [14], whose elements are defined on the Content Knowledge and Domain ontologies. The elements used with no refinement were 1.3 Language, 1.4 Description, 1.5 Keyword, 2.3 Contribute, 3.3 Metadata Schema, 4.3 Location, 4.4 Requirement and 5.1 Interactivity Type. Table 2 shows the refinement of other LOM elements, for example, the relation *dcterms:requires* was refined to *awo: hasPrerequisite* standing for a learning object that is needed to correctly understand the learning object intended to be taken. This relation was also declared as transitive, and has an inverse relation *awo:*isPrerequisiteOf, both of which are useful to inference tasks. Any web agent that can not understand our ontology specifications about the *awo:hasPrerequisite* relation can still understand the more general property dcterms:requires, and interpret the *awo:hasPrerequisite* relation with the semantics of this known property, which is the basis to achieve interoperability at the semantic level. The abbreviation dc stands for http://purl.org/dc/elements/1.1/ and dcterms for http://purl.org/dc/ terms/.

Table 2. LOM properties refinement in the AdaptWeb application profile

Ontology Property	**Specialized Property**	**Ontology Property Description**	**Domain**	**Range**
awo: hasPrerequisite	dcterms: requires	A topic necessary to take the given topic. *It is transitive*.	awo:Topic	awo:Topic
awo:isPartOf	dcterms: isPartOf	The whole of which the topic is part of. *It is transitive*.	awo:Topic	
awo: isAvailableTo	dcterms: isPartOf	To which courses the material is available.	awo:Learning Object	awo:Course
awo:customizes	dcterms:is VersionOf	A Discipline customization. *It is functional.*	awo:Course	awo: Discipline
awo:supportsTo	dc:source	Educative content supporting a Topic learning.	awo:Support	awo:Topic.
awo: isRecommended By	lom-life: educational Validator	The person responsible for recommendations to use an external learning object.	awo:Learning Object	awo: Contributor.
awo:learningPath	dc:relation	Order to present topics for learning purposes.	awo:Topic	awo:Topic
awo:creator	dc:creator	The creator of the learning object.	awo:Learning Object	awo: Contributor
awo:defines	dc:subject	The L. Object defines the subject.	awo:Learning Object	dom:Taxon
awo:apply	dc:subject	The L. Object apply to the subject.	awo:Learning Object	dom:Taxon
awo:describes	dc:subject	The L. Object describes the subject.	awo:Learning Object	dom:Taxon
awo:introduces	dc:subject	The L. Object introduces the subject.	awo:Learning Object	dom:Taxon

4 Student Model

The student ontology, encoded in DAML+OIL [5], available at http://www.inf.ufrgs.br/~tapejara/Ontology/Student.daml and depicted in Figure 3 models the main properties that characterize the student´s profile. The functional property *st:hasLearningStyle* indicates the student's cognitive style of learning [15]. The property *st:hasLearning Goal* points to the course the student is taking. The property *st:wantsTutorial* indicates if the student currently prefers to work in a tutored mode.

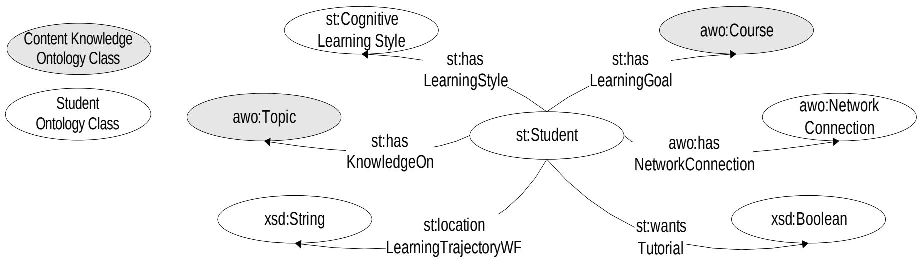

Fig.3. Student Model

The student's knowledge in each topic is indicated by instances of relation *st:has KnowledgeOn* pointing to the topics in which the student has knowledge. The functional property *awo:hasNetworkConnection* indicates the current student's network connection. The property *st:locationLearningTrajectoryWF* indicates the URL where the current learning trajectory for the student is. The remaining elements in the model are defined in the Content Knowledge Ontology and the XML Schema namespace.

6 Adaptation Scenario

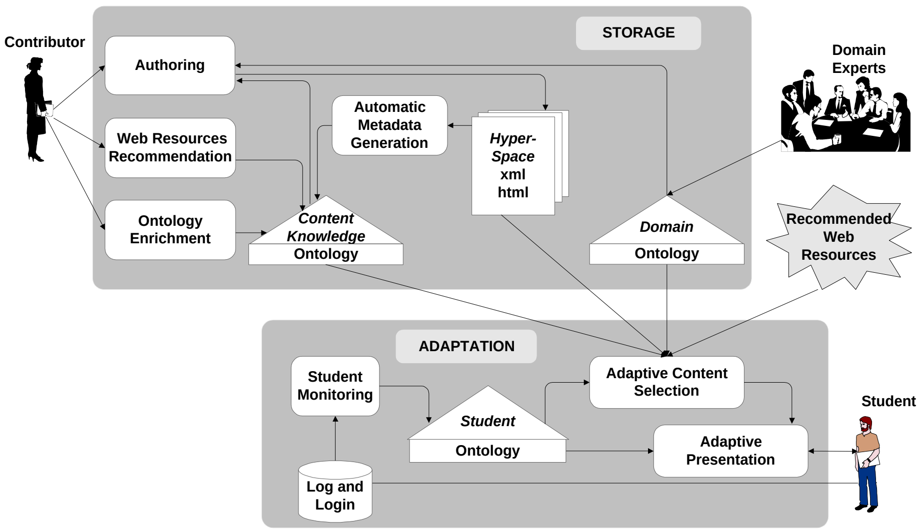

Fig.4. System Architecture

The AdaptWeb architecture showing the adaptation scenario is depicted in figure 4. During the authoring process, the author can consult the Domain Ontology and the Content Knowledge Ontology to be aware of existing learning objects concerning a given subject to eventually reuse them. Each time new content is authored, the Automatic Metadata Generation wrapper generates its fundamental metadata as RDF descriptions that are instances of the Content Knowledge Ontology. The *Student Monitoring* agent continuously updates the Student Model according to the student's activities. The *Adaptive Content Selection* agent selects the contents to be presented creating a learning trajectory tailored to the student's profile based on the knowledge available about the student and the educative content. The *Adaptive Presentation* module determines the presentation style according to the student's preferences.

7 Conclusions

This paper describes how Semantic Web technologies were applied to manage metadata describing learning objects in the AdaptWeb project, delving into the definition of an application profile of the Learning Object Metadata (LOM) standard and the representation of the Student, Content and Domain models as Web ontologies. Reasoning support is possible in order to implement a powerful adaptation mechanism.

References

[1] Brusilovsky, P. Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. in T. Murray, S. Blessing and S. Ainsworth (Eds.), 2002.

[2] Silva Muñoz, L. Ontology Based Metadata for e-learning Content. Master´s Thesis. Federal University of Rio Grande do Sul, Porto Alegre, Brasil, 2004.

[3] Learning Technology Standards Committee of the IEEE. Draft Standard for Learning Object Metadata (LOM) IEEE 1484.12.1-2002.

[4] Guarino, N. Formal Ontology and Information Systems. In N. Guarino (Ed.) Formal Ontology and Information Systems. pp-15, 1998, Amsterdam, Nederlands.

[5] Connolly, D. van Harmelen, F. Horrocks, I. McGuinness, D. Patel-Schneider, P. Stein, L. DAML+OIL (March 2001) Reference Description. W3C Note 18 December 2001.

[6] Duval, E. Hodgins, W. Sutton, S. Weibel, S. Metadata Principles and Practicalities. D-Lib Magazine 8(4), 2002.

[7] Ariadne. http://www.ariadne-eu.org.

[8] Heal – Heath Education Assets Library. http://www.healcentral.org.

[9] Cancore – Canadian Core Learning Resource Metadata. http://www.cancore.org.

[10] Lassila, O. Swick, R. Resource Description Framework (RDF) model and syntax specification. W3C Recommendation, 1999.

[11] Brickley, D. Guha, R. RDF Vocabulary Description Language 1.0: RDF Schema. W3C Working Draft 10 October 2003.

[12] Nilsson, M. The semantic web: How RDF will change learning technology standards. CETIS, September 27, 2001 http://www.cetis.ac.uk/.

[13] Nilsson, M. Palmer, M. Brase, J. The LOM RDF binding – principles and implementation. The 3rd Annual Ariadne Conference, 20-21 November 2003, Belgium.

[14] Nilsson, M. IEEE Learning Object Metadata RDF binding. May 2001. http://kmr.nada.kth.se/el/ims/metadata.html.

[15] Souto, M. Verdin, R. Wainer, R. Madeira, M. Wapechowsky, M. Beschoren, K. Zanella, R. Correa, J. Vicari, R. Palazzo, J. Towards an Adaptive Web Training Environment Based on Cognitive Style of Learning: an Empirical Approach. AH'2002 Conference..