THE ROLE OF LEARNING OBJECT ONTOLOGIES

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Abstract: Educational information systems should provide easy access to learning material. In addition learning material should be linked in a way that the learner can easily access all required material. Unfortunately current metadata standards and learning object content models do not support such features as they do not capture enough semantics of learning objects. In this article we present the ontologies that give the semantics for metadata descriptions, and thus support semantic querying and conceptual navigation of learning objects. Semantic querying differs from traditional keyword based searching in that searching expressions are based on ontologies, which describe the concepts of the domain in which learning takes place. Semantic querying can also be used for content based integration of learning objects. Conceptual navigation in turn means that named links can be used in navigating between learning objects. Named links are analogous with the relationships in conceptual models.

1 INTRODUCTION

During the past few years the term learning object is widely used in the discussion concerning educational information systems. Generally the term is regarded as any entity, digital or non-digital, that may be used for learning.

Educational metadata describes any features of a learning object. Well-designed and sufficient metadata facilitates the learners in retrieving relevant learning objects and aids the educational institutions to provide suitable information about their instruction supply. Learning object metadata is also needed for supporting the management of collections of learning objects, and for supporting the decision process of the learners in looking educational resources.

To standardize learning object metadata specific standards are developed. LOM (Learning object metadata standard) (LOM, 2002) defines the structure of a meta-data instance for a learning object. However, it does not specify the granularity of a learning object. Fundamentally a learning object could be a sentence, a paragraph, a topic, a section, a chapter, a lesson, a course or even a video stream. Using the LOM it is possible to specify for example the grade level of a course, typical learning time of a course, the prerequisites of a course and the relationships of learning objects.

Dublin Core (Dublin, 2002) is a widely known metadata standard. Its metadata elements represent syntactical metadata, i.e., they do not describe the content of the target. Dublin Core also includes metadata attributes that can be used in specifying the relationship between resources. Thorough these attributes it is possible to define for example that a lecture is a part of a course (IsPartOf), a course is a version of another course ((IsVer-sionOf), a laboratory work requires certain software (IsRequiredBy), and a course is based on another course (IsBasedOn).

Both LOM and Dublin Core are metadata standards. By following these standards one can state for example that the course *Introduction to programming* precedes the course *Java-programming* and that the *Java laboratory work* is a part of the course *Java-programming.* The problem however, is that though they allow the specification of the relationships between the instances of learning objects they provide no means for modelling such relationships. As a result, we cannot for example express semantic queries like "Give me all courses that precede the course *Java-programming*" or "Give me all the components of the course *Java-programming*". Such queries require an ontology that gives the semantics for the learning objects metadata expressions.

Learning object content models in turn are developed to increase the reusability of learning objects. They are typically taxonomies, which

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identify the components of learning objects. However, a lack of learning object content models is that they do not provide means for expressing the semantics of the components of learning objects.

For example, using a learning object content model we cannot specify whether a component, say a course, deals with history or mathematics. And therefore they do not allow semantic querying over the components (e.g., querying the courses that deals with discrete mathematics) and conceptual navigation between the components. This is regrettable since semantic querying and conceptual navigation between learning objects would significantly ease the access of learning objects.

In this article we present what kind of ontologies are required for semantic querying and conceptual navigation between learning objects. Essentially semantic querying differs from traditional keyword based searching in that searching expressions are based on content ontologies, i.e., on the concepts of the domain that the learning deals with. Semantic querying is also useful tool in composing learning objects based on their content. Conceptual navigation in turn means that named links can be used in navigating between learning objects. Named links are analogous with the relationships in conceptual scheme of databases.

The rest of the paper is organized as follows. First, in Section 2, we give an overview of learning object metadata standards and learning object content models. We also illustrate the possibilities these approaches give for expressing the relationships of learning object instances. Then, in Section 3, we motivate our approach by giving an example of semantic querying and conceptual navigation. After this, in Section 4, we show what kinds of ontologies are required for semantic querying and conceptual navigation. In particular, three ontologies are presented: a content ontology, an education ontology and an instance ontology. The specification of these ontologies by XML-based languages is considered in Section 5. Finally, Section 6 concludes the paper by discussing the advantages and limitations of our proposed approach.

2 METADATA STANDARDS AND LEARNING OBJECT CONTENT MODELS

2.1 Metadata Standards

The notion of metadata (Najjar et al., 2003) has variable interpretations depending upon the circumstances in which it is used. Fundamentally, metadata is data about data. It describes certain important characteristics of its target. Equally metadata can be described by meta-metadata, which is descriptive information of the metadata itself. The typical types of metadata that can be attached to documents include document’s author, publisher, publication date, language and keywords.

There are many organizations which standardize metadata. The idea behind standardization is to achieve interoperability between systems from different origins. An important point in standardization is that it does not impose a particular implementation but rather a common specification which establishes an opportunity for collaboration by diverse groups.

Next we will shortly consider three well known standardization efforts; Dublin Core, IMS and LOM.

Dublin Core (Dublin, 2002) is a widely known metadata standard that has been developed since 1995. The metadata elements of the Dublin Core represent syntactical meta-data, i.e., they do not describe the content of the target. Originally, they are intended to facilitate the discovery of electronic resources from the Web. It includes 15 metadata elements that describe the content, the intellectual property rights and the instantiation of the object. For example, the standard includes the following elements: Creator, Date, Description, Subject, and Language. Even though, the Dublin Core does not include educational metadata elements, it has been used as basis for many educational metadata projects. On the other hand, proposals to extend the standard by educational elements (e.g., Audience, Interactivity type, and Interactivity level) have been done.

Dublin Core also includes metadata attributes that can be used in specifying the relationship between resources. Thorough these attributes it is possible to define for example that a lecture is a part of a course (IsPartOf), a course is a version of another course ((IsVer-sionOf), a laboratory work requires certain software (IsRequiredBy), and a course is based on another course (IsBasedOn).

IMS (Instructional Management System Project) (IMS, 2002) is a consortium of several educational institutions, commercial entities, government agencies, and developers in the area of educational information systems. Its main aim is to develop and promote open specifications for facilitating online distributed learning activities such as tracking learner progress, reporting learner performance, and exchanging student records between administrative systems.

IMS has been a significant contributor to the LOM. For example, it has introduced the use of XML for representing metadata. On the other hand, IMS uses the LOM as its basis for metadata specifications. For example, IMS has contributed to LOM by introducing best practice guides for metadata developers and implementers.

LOM (Learning object metadata standard) (LOM, 2002) defines the structure of a metadata instance for a learning object. A learning object is regarded as any entity, digital or non-digital, that may be used for learning. In addition, the standard facilitates the sharing and exchange of learning objects by enabling the development of catalogues and inventories while taking into account the diversity of cultural contexts in which the learning object will be exploited. The goals of the LOM are to enable the learners to search and use learning objects and enable computer agents to automatically compose learning objects to individual learners.

Using the LOM it is possible to specify for example the teaching or interaction style of a course, the grade level of a course, the difficulty of a course, typical learning time of a course, the prerequisites of a course and the relationships of learning objects' instances.

2.2 Learning Object Content Models

Learning Object Metadata standard does not specify the granularity of a learning object. Fundamentally a learning object could be a sentence, a paragraph, a topic, a section, a chapter, a lesson, a course or even a video stream. A small and self-contained learning object has a good chance of reusability. On the other hand, the complexity of composing learning objects increases as the amount of learning objects increases.

Learning object content models are developed to increase the reusability of learning objects. They are typically taxonomies, which identify the syntactical components of learning objects. Taxonomy is a hierarchical structure (a tree) where the relationship between a parent and its children has some relationship (e.g., is part of).

The SCORM (SCORM, 2005) Content Aggregation Model is a taxonomy which is comprised of the following levels (Figure 1): Assets, Sharable Content Objects (SCO) and Content Aggregations. For example, text, images, audio and other data that can be presented in the web client are Assets. A Sharable Content Object is a collection of one or more assets. In order to increase the reusability of Sharable Content Objects should be independent of its learning context. So it can be reused in different learning experiences to fulfil different learning objectives. A Content Aggregation is a structure that can be used to aggregate learning resources in an integrated unit such as course or chapter.

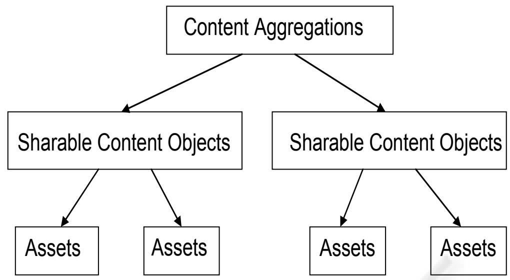

Figure 1: The Structure of the SCORM Content Aggregation Model.

3 SEMANTIC QUERYING AND CONCEPTUAL NAVIGATION

Semantic querying and conceptual navigation allow easy searching facilities of learning objects. Further semantic querying can be used for automatic composition of learning objects.

In order to illustrate semantic querying and conceptual navigation let us consider the following example. Assume that a learner wants to renew his or her programming skills. Now, in order to find appropriate course the learner performs the following action.

First the learner asks the educational system to display a content taxonomy *Programming*. Then the system displays the taxonomy presented in Figure 2. Then the learner chooses from the taxonomy the concepts that should be included to the course, say *Object oriented programming, Java-programming* and *C++ programming* and returns them to the system. The system then returns a course, say *Object oriented programming languages* and provides links for *preliminary courses, lectures*, *exercises* and *exercise solutions.*

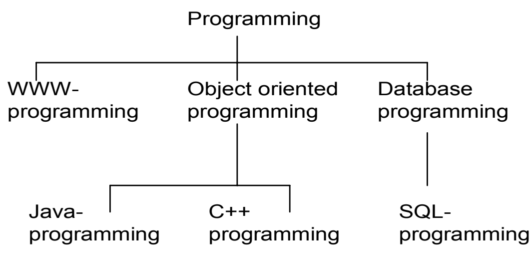

Figure 2: Taxonomy Programming.

4 LEARNING OBJECT ONTOLOGIES

4.1 The Goal of Ontologies

An ontology is a general vocabulary of a certain domain (Davies et al., 2002), and it can be defined as “an explicit specification of a conceptualization” (Gruber, 1993). Essentially the used ontology must be shared and consensual terminology as it is used for in-formation sharing and exchange.

Ontology tries to capture the meaning of a particular subject domain that corresponds to what a human being knows about that domain (Daconta et al., 2002). It also tries to characterize that meaning in terms of concepts and their relationships. Ontology is typically represented as classes, properties attributes and values. So they also provide a systematic way to standardize the used metadata items.

Ontology languages provide representational entities without stating what should be rep-resented, i.e., they do not commit to any particular domain (Antoniou and Harmelen, 2004). For example the ER-model (Ullman &Widow, 1998), RDFS (RDFS, 2005), ODL (Ullman &Widow, 1998), UML, DAML+OIL (DAML, 2005) and OWL (OWL, 2005), which define concepts such as entities or objects, attributes and relations, are ontology languages.

A salient feature of ontologies is that depending on the generality level of conceptualization, different types of ontologies are needed. Each type of ontology has a specific role in information sharing and exchange.

4.2 Content Ontologies

The purpose of the content ontology is to describe the concepts of the domain in which learning take place. So, the content ontology may for example describe the concepts related to mathematics, history or to computer science. To illustrate content ontologies a simple content ontology Programming is presented in Figure 3.

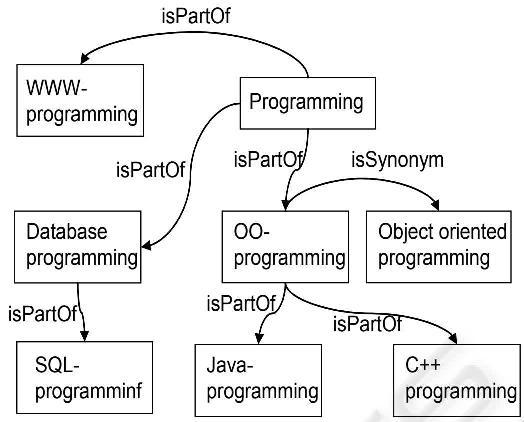

Figure 3: Content Ontology Programming.

4.3 Education Ontology

Education ontology captures the entities that are related to learning. In addition it captures the relationships of the entities. It has a similar function as database scheme defined by data definition languages (e.g., ODL (Ullman & Widom, 1998)). A difference, however, is that education ontology is presented by ontology languages and thus it provides syntactically and semantically richer means than database definition languages.

In Figure 4, an Education ontology is presented. It captures entities that are related to learning in universities. It is presented in a graphical form but it can also be presented in OWL. In the figure, a relationship (property in OWL terminology) related to the object (Class in OWL terminology) “course” is “precedes”. In OWL one can specify that this property is transitive. So, for example if *Course A* precedes *Course B* and *B* precedes *Course C,* then the system can infer that also *Course A* precedes *Course C*. This is one feature that can be defined in ontology languages but not in the data definition languages developed for databases.

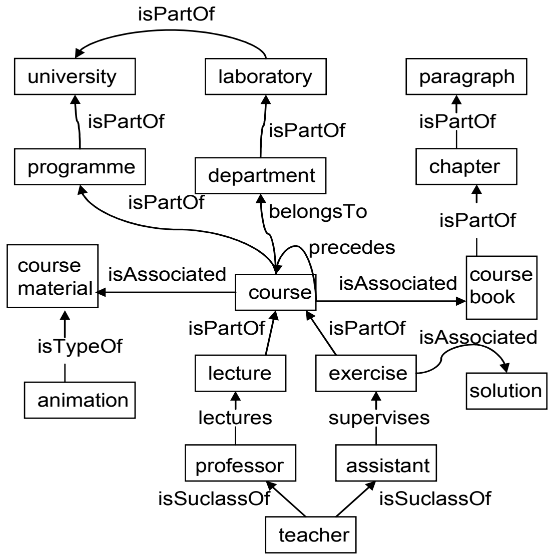

Figure 4: An Education Ontology.

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4.4 Learning Instance Ontologies

Learning instance ontology describes the instances of learning objects. In our graphical representation (Figure 5) the types of each instance are also described in the ontology. In addition the subject of each instance can also be defined. Type is defined by connecting an instance to the learning object ontology (typeOf edges) while subject is defined by connecting the instance to the content ontology (subjectOf edges).

Learning instance ontology deviates from content ontology and learning entity ontologies in that it is described by the content creator (e.g. a teacher). In other words a content creator annotates a learning instance according to the concepts presented in content and education ontology.

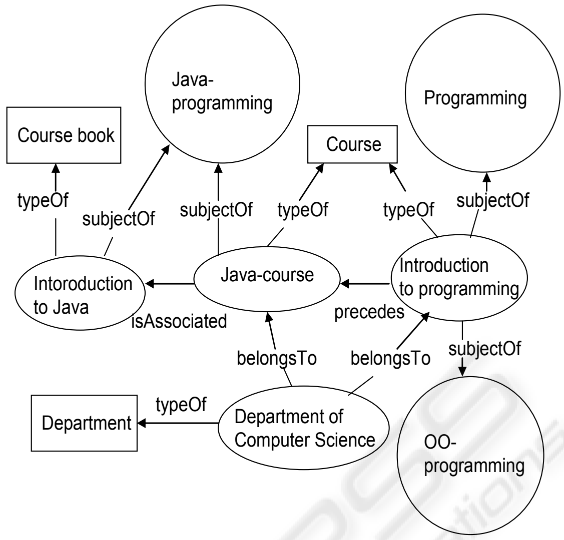

Figure 5: An example of an instance ontology.

Each instance in the instance ontology in Figure 5 is presented by an oval, and corresponding objects (classes in OWL) are presented by a rectangle, and they are connected by the typeOf-edge. The content of an instance is represented by edge subjectOf edge to an item of the content ontology which is presented inside of circle.

The instance ontology of Figure 5 describes that *Java programming* and *Introduction to programming* are instances of the object (class in OWL) Course and both courses belong to the Department of Computer Science, which is an instance of the object Department. The "precedes" edge (property in OWL) between the courses *Java-programming* and *Introduction to programming* indicates that before the execution of the course *Java-programming* the course *Introduction to programming* must be executed. The ontology also indicates that the course book *Introduction to Java* is associated to the course *Java-programming.*

5 XML-BASED LANGUAGES AND LEARNING ONTOLOGIES

We now give a short introduction to the XML-based languages that we are using in specifying learning object ontologies.

RDF provides a means for attaching semantics (e.g., metadata values) to objects (e.g., to Java-course). So it nicely adapts for specifying the edges in ontologies. For example, the description (see Figure 5) "The subject of Java-course is Java-programming" can be expressed in a RDF-statement. The relationship of XML and RDF is that XML provides a way to express RDF-statements. In other words, RDF is an application ox XML.

Fundamentally, RDF defines a language for describing relationships among resources in terms of named properties and values. It however, provides no mechanisms for describing these properties, nor does it provide any mechanisms for describing the relationship between these properties and other resources. That is the role of RDF vocabulary description language RDF schema (RDFS, 2005). It defines classes and properties that may be used to describe classes, properties and other resources. Hence, there is a straight correspondence between RDF schema and object oriented design.

OWL Web Ontology Language (OWL, 2005) has more facilities for expressing meaning and semantics than XML, RDF and RDF Schema, and thus OWL goes beyond these languages in its ability to represent machine interpretable content of the ontology. In particular, it adds more semantics for describing properties and classes, for example relations between classes, cardinality of relationships, and equality of classes and instances. For example, the graphical representation "*Object oriented programming* is a synonym for *OO-programming*" in Figure 3 can be expressed in OWL.

6 CONCLUSIONS

Educational information systems should be designed in a way that they provide easy access to learning objects. Well-designed and sufficient metadata facilitates the learners in retrieving relevant learning objects and aids the educational institutions to provide suitable information about their instruction supply

To standardize learning object metadata specific standards, such as the LOM, are developed. The lack of the LOM, as with all metadata models, is that it does not provide semantics for the metadata items As a result, many useful learning object retrieval methods such as semantic querying and conceptual navigation cannot be implemented in educational information systems that are based on metadata standards.

By introducing sharable learning object ontologies we can specify the semantics of the metadata items. In order to give a semantics for metadata items, we have represented a simple ontology, called educational ontology. Further in order that we can specify the content (subject) of an educational material (e.g., a course) we have given an example of a content ontology. We have also introduced instance ontologies. Through an instance ontology we can tie learning instances to the objects of the education ontology and to a content ontology.

The main gain of our proposed ontologies is that they provide a conceptual model on which semantic querying and conceptual navigation can take place. Semantic querying can also be used for content based integration of learning objects. So they can also be used for extending the function of learning object content models which compose learning object components solely based on their structure without considering their content.

A drawback of our approach is that it burdens the content creator (e.g., a teacher) in that he or she has to annotate learning material according to the ontologies. However, it is turned out that computer support can alleviate this function in many ways.

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