MULTI-FACET INDEXING FOR LEARNING OBJECTS REUSE

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Abstract

In this paper we propose a model to represent "learning objects". This model aims at making their reuse easier. The representation of these objects which respects the current standards of e-learning includes the following: metadata, scenarios in which the objects are used and the objects of which they are composed. We enrich these representations by taking into account the semantics of learning object contents. Another contribution of our proposal is that this multi-facet representation relies on ontologies allowing a semantic representation that facilitates communication between machines and users.

Keywords: e-learning, reuse of learning objects, standards for e-learning, ontologies, semantic representation.

Introduction

E-learning relies on the provision of electronic documents called learning objects organized in teaching scenarios.

Many digital pedagogical resources can be found on the web but they are often on-line presentations of existing documents. (Psyché, 2005) notes that more pedagogical approaches and learning designs should be proposed to improve the use of resources in e-learning systems. In addition, learning objects should be reusable in any teaching scenario. E-learning technologies and standardization efforts offer a partial solution to these issues. SCORM (SCORM, 2004) and LOM (LOM, 2002) contribute to the homogenization of learning object representations and facilitate their interworking, while IMS-LD (IMSLD, 2003) considers the pedagogy of training and its progress. However, meta data associated to objects is limited and do not focus on content. It is then difficult for a designer to know if a resource already exists for a given need. As a result reusability is low.

Our contribution is related to the enrichment of e-learning standards with the representation of complementary knowledge in the form of ontologies (Mizoguchi, 2004). This additional knowledge corresponds to the theme studied and pedagogical theories.

In this paper, we present first the main e-learning systems' characteristics and standards. Then we describe the conceptual model we promote to represent learning objects and their usages. Next, we explain the implementation and finally, we give a short example of an instance based on our model.

State of the Art

E-learning Systems: Learning Objects and Standards

E-learning is a teaching-learning activity which aims at knowledge acquisition while reducing the time and space constraints between learners and teachers, thanks to new communication and information technologies (E-TUD) (Boutmedjet, 2004).

An e-learning system must allow:

- access to the relevant learning objects thanks to a good indexing of the resources (Gasevic and Hatala, 2005), (Psyche, 2005), (Lenne et al., 2005), (Abel et al., 2003),
- browsing techniques improving learner / teacher / system interactions according to an adequate pedagogy (Psyché, 2005),
- reutilisability of learning objects and learning design (Knight et al., 2005),
- design and update of the contents of courses by teachers (Lenne et al., 2005), (Abel et al., 2003),
- an individualized monitoring of learners (IMSLD, 2003).

A learning object has been defined by the IEEE-LTSC working group (Learning Technology Committee Standards) as: "Any entity, digital or non-digital, that can be used, reused or referenced during technology supported learning".

Various standards have been defined to help the development of training systems. These systems handle learning objects, their representation, and their relationship. The use of these standards, which are considered as common description languages of digital educational resources (Vidal et al., 2004), guarantees not only the interworking but also the quality of systems. Among e-learning standards, LOM, SCORM and IMS-LD are the most important. LOM focuses on describing resources (objects), SCORM on the structure of objects, and IMS-LD on teaching scenario.

LOM

LOM (LOM, 2002) (Learning Object Metadata) is a standard for learning object annotation with metadata.It specifies the syntax and semantics of the metadata describing educational digital or non-digital resources, and defines the attributes necessary for a complete description of the educational resources. Metadata are classified in nine categories as follow:

1. General: independent characteristics from the context as the identifier, the title, the language of the resource …
2. Lifecycle: groups the features related to the history (Version) and current state (Draft, Final, Revised, Unavailable) of this learning object and those who have affected this learning object during its evolution.
3. Meta-metadata: characteristics of the description as Identifier, Contribution (persons having participated in the elaboration of the metadata), Catalog, language …

4. Technical: technical requirements and technical characteristics as the format (of the necessary software to reach the resource), size of the learning object etc…
5. Educational*:* groups the educational and pedagogic characteristics of the learning object
6. Rights*:* the intellectual property rights and conditions of use for the learning object; Costs, copyrights, description
7. Relation*:* it defines the relationship between a learning object and other related ones.
8. Annotation*:* provides comments on the educational use of the learning object and provides also information on the author and the date in which comments were created.
9. Classification*:* describes the learning object in relation to a particular classification sytem such purpose, reference classification, path etc…

In order to answer the specific and concrete needs of the users, the applications profiles were introduced. An application profile is an instance of a model, as LOM, in a particular context. Thus, it means interpreting, refining, spreading or even simplifying the syntaxes and the semantic of the metadata LOM.

This standard is useful to assure access to pedagogical resources. However, it does not specify the semantic content of resources. For this reason, we complete a LOM indexation with a content representation based on theme ontology.

SCORM

SCORM (Sharable Content Object Reference Model) (SCORM, 2004) of Advanced Distributed Learning (ADL) is a suite of technical standards that enable web-based learning systems to find, import, share, reuse and export learning content in a standardized way.

SORM treats the following elements:

- Packaging: It has for objective the transmission of contents between platforms. It is also interested in the structuring of the educational objects.
- Metadata: they came from LOM and have for objective to share the standard information which describe the nature and the objective of the contents. This information can be used either for the research and the discovery of documents or for the management of the rights and the technical needs.
- Communication or environment of execution: determine the communication with a Web environment. The notion of environment is also present in IMS-LD.
- Séquencement and navigation: defines a method of representation of the navigation between learning objects. Specifically, it describes connections and stream of learning activities in terms of tree of activity.
- Content Aggregation: it distinguishes three levels of resources:
    - The elementary digital resource *(Assets)* establishes the basic elements of learning resource; it can involve a simple document (JPEG image or GIF, WAV sound or MP3, web page) but also of any set of information which can be released towards a Web client (Flash document, Javascript code, etc.).
    - A Shareable Content Object *(SCO)* is a coherent set of Assets. Respecting the SCORM protocol of execution, it represents the lowest level of resource granularity which can be followed-up in a platform of on-line learning (Learning Management System).

- A *Content Aggregation* is a set of educational resources structured in a coherent way within an entity of higher level, such as a lesson, a chapter, a module, etc.

The structuring of the contents of the modules of education according to the SCORM model allows them to be reused in others modules for various training formations or systems. Furthermore, it improves the dialogue between the educational objects and the system on one hand, and between the actors and the system on the other hand.

In addition, the learner's progress is supervised and reported back. In our model, SCORM is used to represent learning resource structure and to insure interoperability.

IMS-LD

IMS-LD (Instructional Management System Learning Design) standard (IMS-LD, 2003) aims at helping to design any teaching-learning process in a formal way. It structures learning units through "**play**", "**act**", and "**role-part**" elements. The "**play**" element (that is often unique) contains several "act" elements. These acts are run in sequence; each one being triggered by the end of the preceding one. The play is complete when the last act is finished. The transitions between acts thus form a set of synchronization points for all the participating "roles" (teacher, learner…). In the proposed model, IMS-LD is used to define interaction between learners and computers during pedagogical objects.

These standards solve several problems such as interoperability and use in pedagogical scenarios. Nevertheless, reuse and access (how to find the most relevant resources) are not solved. Another problem is how to assign the same meaning to given metadata. Finally, the links and relations such as the content, sequencing, and dependence of prerequisites between every learning object must be mentioned to allow the system to effect treatment or automatic tasks on these objects.

Before describing the model, we present related works that try to enrich learning object representation using ontologies.

Ontology-based e-learning system

Using metadata as recommended by e-learning standards is not sufficient to solve the problems of object reusability and accessibility (Zarraonandía, 2004). Indeed, these problems will be solved only if a common meaning for metadata values is used by the system and the actors. On the other hand, bonds and relations such as content, sequencing, and dependence of pre-knowledge between learning objects must be included to make it possible, not only to carry out automatic treatment or tasks on these objects but also to produce new knowledge from what already exists. The use of ontologies in the model of an e-learning system is an interesting solution. An ontology gathers the concepts which represent the knowledge of a field in an explicit and formal specification (Studer et al., 1998). MEMORAE "MEMoire ORganisationnelle Appliquée à l'e-learning" (Organisational Memory Applied to e-learning) (Lenne et al., 2005) (Abel et al., 2003) is an e-learning tool which allows resource indexation. This tool provides learners with educational resources, either within a local resource repository, or on the web. Compared to MEMORAE which presents courses structured according to the relations of inclusion, usage, reference and prerequisite between the concepts to be learnt, (Gasevic and Hatala, 2005) allow the users to formulate queries. Moreover, they respect the LOM standard. These two studies represent the system knowledge through ontologies. An ontology describing the concepts such as the people (students, tutors, secretaries…), the documents (books, presentation slides, web pages…) is called ontology of the training field for (Lenne et al., 2005) and target ontology for (Gasevic and Hatala, 2005). (Mitrovic and Devedzic, 2002) also uses an ontology to represent the domain of each tutor. Another ontology is used to represent the concepts to be learnt (ontology of application for (Lenne et al., 2005) and source ontology for (Gasevic and Hatala, 2005). In order to ensure reusability, (Hernandez, 2005) advises separating task (learning context, documents…) and theme (concepts to learn) while maintaining bound the concepts of both ontologies.

(Psyché et al., 2005) and (Knight et al., 2005) integrate the notion of teaching scenarios thanks to an ontology based on the standard IMS-LD. (Psyché et al., 2005) only take into account the educational theories. As in (Lenne et al., 2005) and (Hernandez, 2005), (Renaud et al., 2006), (Bouzeghoub et al., 2005) use an "ontology of theme" which represents all the concepts describing the domain knowledge to semantically index resources. However (Bouzeghoub et al., 2005) is characterized by the use of two types of metadata: one for describing the pedagogical aspects and the other for the semantic aspects of the resources.

In the studies (Gasevic and Hatala, 2005), (Psyché et al., 2005), (Lenne et al., 2005), the context of learning object use is not taken into account. In order to increase the reusability of scenarios and learning objects, (Knight et al., 2005) introduce an "ontology of context".

To obtain all the qualities required for an e-learning tool like reusability, accessibility, interoperability and durability (SCORM, 2004) (Fage, 2005), we take into account learning theories as well as the contexts of training and uses of learning objects. Our approach is based on ontologies as well as on the e-learning standards. This paper focuses on the aspects corresponding to the representation of learning objects and their uses.

Semantic Representation Model and Use of Learning Objects

Multi-facet Representation and Usage of Learning Objects

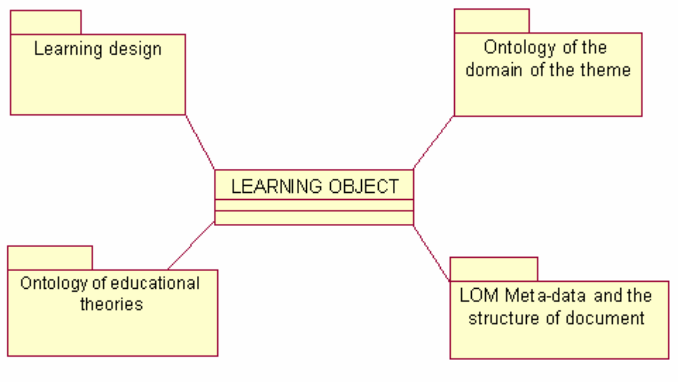

Figure 1: Useful knowledge to represent a learning object and its use.

The model we promote takes into account the various aspects of learning objects. Our model includes technical description, pedagogical description but also related uses of the learning objects. This model allows building a system that relies on an appropriated pedagogical approach. It also enables the reuse of learning objects and learning design.

To represent a learning object we consider various items of knowledge (see Figure 1).

- Knowledge about the structure (standard SCORM), and about the resource itself (standard LOM),
- Knowledge about the theme : notions to learn,
- Knowledge about educational theories,
- Knowledge about learning design (IMS-LD standard).

The various aspects of a learning object are described in the following sections.

SCORM and LOM description

A learning object is a semantic unit of an educational resource. It can be an exercise, an examination question, a definition, examples, or a lesson, etc… Each learning object can gather elementary components (as an image) named Component (called "Assets" in SCORM standard) which can be in different digital (.DOC, .PDF, .JPG etc) or physical formats.

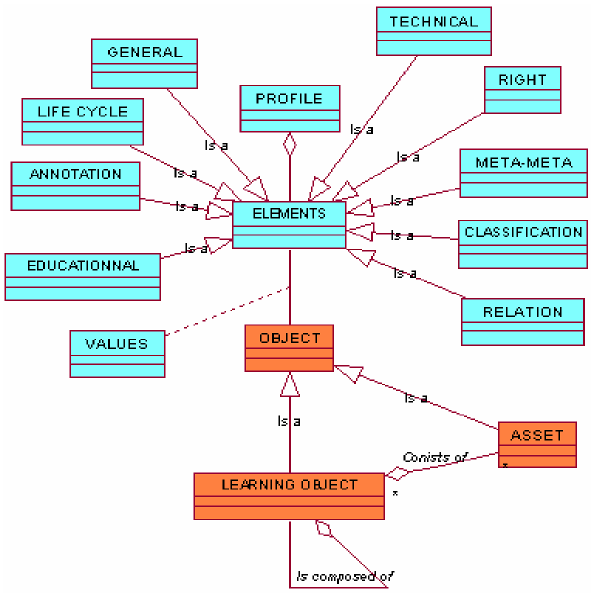

Figure 2: Model of SCORM and LOM descriptions

The description of the metadata associated with a pedagogical document corresponds to LOM description. As in (Duval et al., 2002), we propose the use of a *Profile of application* in order to indicates what is mandatory and optional as metadata for an object. In our proposal, a LOM description is attached to each learning object (elementary or composed object).

The useful metadata for a given application is filtered via the application profile. A modeling of this description is shown in figure 2. When an object is used in a given course, certain values of metadata associated with the course itself are automatically filled in for the associated learning objects.

Modeling this information does not require the use of an ontology. Hence, this description is not based on an ontology but rather on simple metadata associated to objects.

However, as indicated above, the semantic representation of object contents proposed in current e-learning standards is not sufficient to allow their complete or partial reuse in other applications or other systems. We therefore supplement it by a thematic representation of contents.

Thematic description

Learning objects are also represented according to the themes or concepts they deal with. Learning objects are indexed with concepts of a theme ontology describing the notions associated to the considered domain. For example, in the domain of data processing and more precisely of data bases, the concept of *"relational data base" is conceptualized* by an *"Entity-Relationship model"*. These concepts, theme and knowledge to be learnt are gathered in an ontology. To represent the semantics of learning object contents, concepts from the theme ontology are associated with them. In other

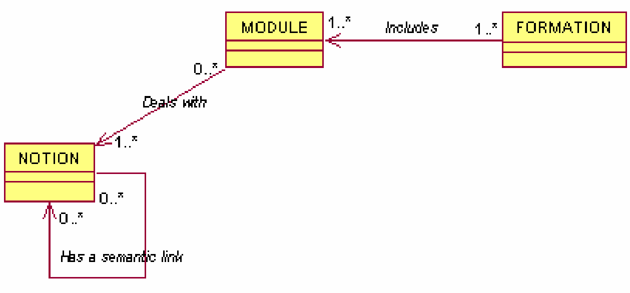

Figure 3: Model for a theme ontology.

words, for a given module, the concepts to be learnt are specified in a theme ontology and learning objects related to this domain are indexed using these concepts.

This approach has various advantages for teachers as well as for learners. Indeed, when a teacher wishes to create a lesson, he can have access to the set of learning objects which were indexed by a specific concept. A teacher can then reuse these retrieved objects or decide to design new ones if they are not appropriate.

Educational theories description

According to educational theories, each pedagogy belongs to a specific approach (Empiricist, Rationalist, Interactionnist) (Lebrun, 2002) and consists of several distinct *stages* to follow. A given pedagogy will give place to several teaching scenarios (*Methods)*.

A **Stage** indicates the theoretical structure of a given teaching approach, as illustrated in figure 4. It can be a phase of information, motivation, interaction, production, analysis, etc… ***Pedagogy*** describes the set of educational theories which can be used for carrying out trainings successfully.

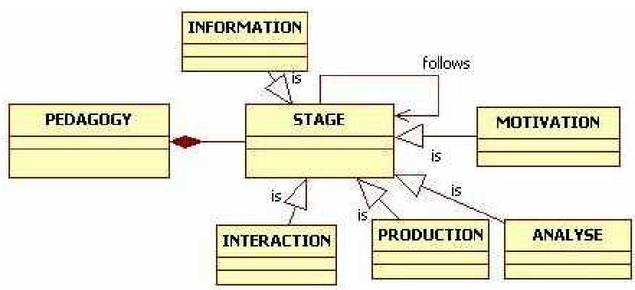

Figure 4: Ontology of the educational theory.

Knowledge associated with teaching theories is represented through an ontology. This representation is justified by the fact that we wish to be able to associate reasoning. More specifically, it would then be possible to guide the construction of a scenario starting from a learning object, and using knowledge from educational theory. This representation is inspired from EML-OUNL (Koper, 2001).

Learning design description

IMS-LD proposes to model the sequencing of activities allotted to each role to attain the goal of the course, while following a well defined pedagogy. Knowledge that must be taken into account is of various type as follows:

- Knowledge about actors involved in the course (learner, teacher …). It is represented by the *Role.* Each role has some activities.
- Knowledge about scenarios in which learning objects are used. It is called *Method,* it can be composed of *plays*. A play is composed of *acts* which are composed of *role-parts.* A role-part associates a role with an activity.
- Knowledge about the activities in which a learning object is used. In our model, *Activity* describes the tasks a learner performs (exercise, lecture…).
- Knowledge about the context in which a learning design is used. A learning object may be used differently in different activities. The context makes it possible to describe the use of a given learning object in an activity.

All this knowledge is represented thanks to an ontology, as shown in figure 5. Concept interlinks are introduced. For example, the concept **Pedagogy** of the educational theories ontology is linked to the concept **Method** of the learning design ontology. So, according to the chosen educational theory, a teacher can be helped while constructing a resource. The concept **Notion** of the theme ontology is linked to the concept of **Activity** because learning a notion can be carried out in different activities. The same object can be used for several **Notions** and in several **Activities**.

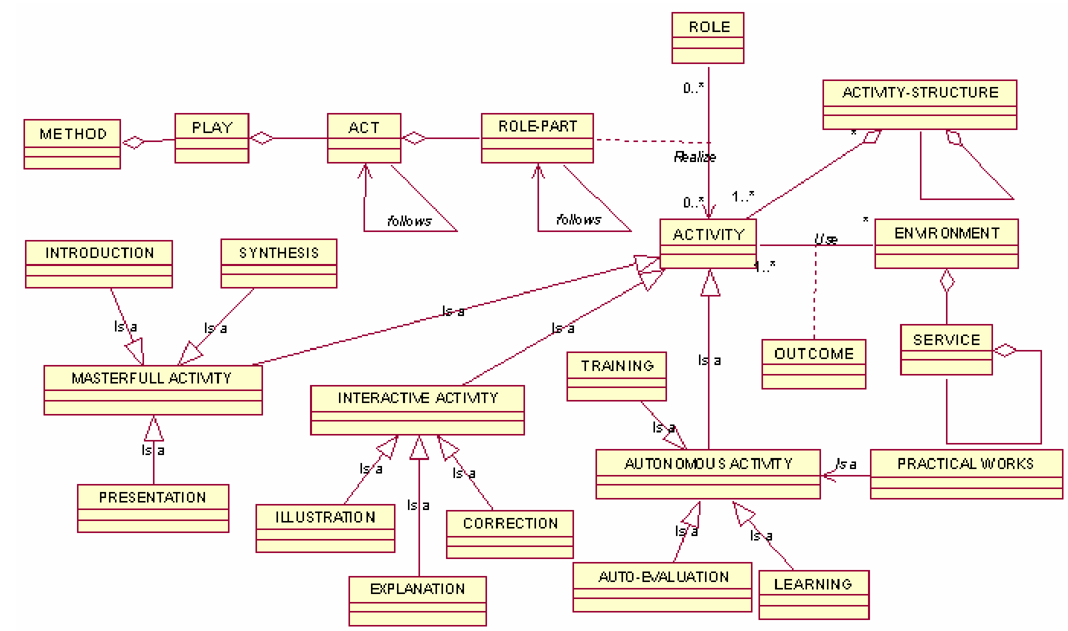

Figure 5: Model of description of a teaching scenario (Learning design).

The global model

The different facets we developed in the previous section are integrated in a single model as described in figure 6. The various activities of the lessons and their organization as well as the learning objects used are represented thanks to the link between *Activity* and *Learning object* classes. The use of an *object* in various *activities* is specified in the *Context* class. The prerequisites for activities are considered through the pre-necessary notions (concepts from the theme ontology) and pre-necessary competences. This corresponds to a relationship between *Activity* and *Notion*.

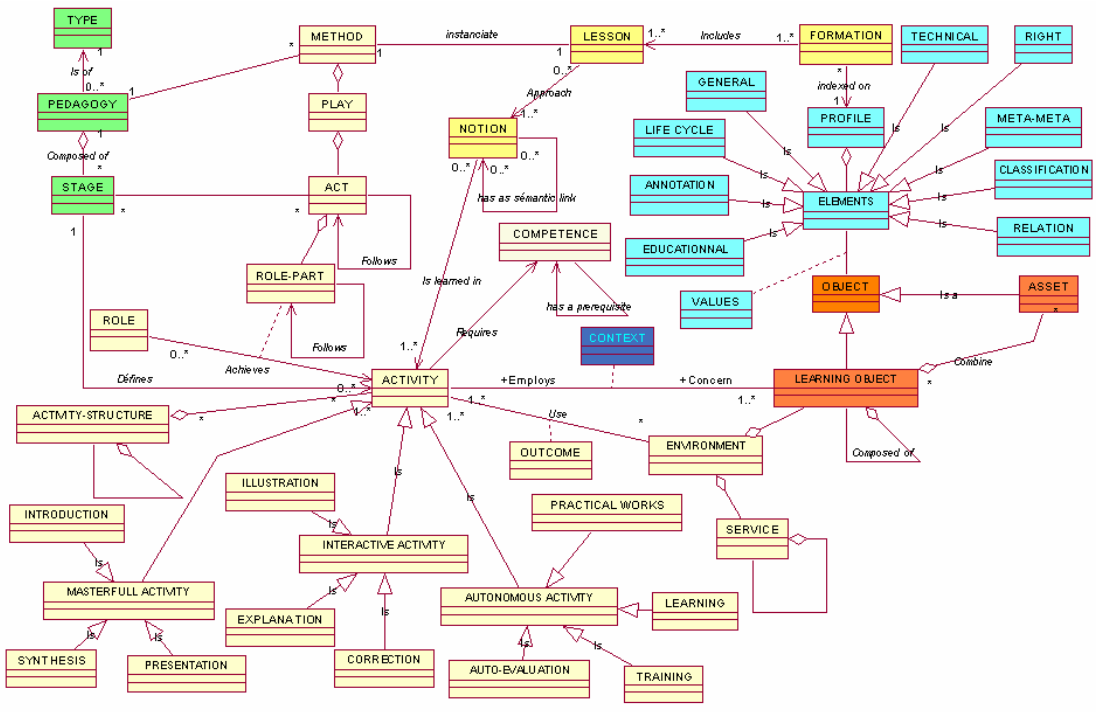

Figure 6: Complete model integrating the various aspects of representation of a learning object in its context of use.

By using these four facets (as summarized in figure 1) the suggested model improves reusability of an object. Its description by metadata and especially on its contents (the concepts it treats of) as well as the definition of its structure make it possible to implement mechanisms for accessing and searching learning objects and elementary components. Object use in scenarios of training also can help a designer to understand better a learning object and help him to consider it as a component of a new course. Lastly, the interoperability and durability are ensured thanks to the conformity of the model with the standards.

Implementation

We implement the ideas that are presented through the model using the Reload CP Editor; we also used the Protégé software.

Ontologies

Ontologies are implemented using OWL (Web Ontology Language) (W3C, 2004) using the Protégé resource (Stanford Medical Informatics). Regarding the domain ontologies, they are manually built (meaning that we choose the concepts to include). However, we have also developed a method that helps a designer to build ontologies, based on texts on the domain (Aussenac et al., 2000), (Mothe et Hernandez, 2007).

LOM and Application Profile

Parameters from Reload CP Editor have been set in order to take into account the application profile. For doing this, we modify two files: the profile file and vocabulary file.

The application profile we defined is composed of the LOM metadata enriched by the vocabulary associated to the « *Learning object type* » metadata considering the pedagogical functions. This metadata implements the link between the ontology of the educational theories and learning objects.

The metadata we added is the « *Notion* » which takes its values in the domain ontology. Thus, this metadata implements the link between the domain ontology and learning objects.

Both the « *Learning object type* » and the « Notion » are defined as mandatory in the application profile. Figure 7 is an extract of the application profile vocabulary description.

```
<!-- RELOAD Metadata Profile -->
<!-- This is the default Profile - do not edit or delete! -->
<profile vocabfile="EMIAGE_Vocab.xml" schemahelperfile="EMIAGE
Helper.xml">

<group name="General">
<element name="Identifier" path="lom/general/identifier"/>
<element name="Title" path="lom/general/title/langstring"/>
      <group name="Catalog Entry">
      <element name="Catalog" path="lom/general/catalogentry/catalog"/>
      <element name="Entry"
path="lom/general/catalogentry/entry/langstring"/>
</group>
<element name="Language" path="lom/general/language"/>
<element name="Description" path="lom/general/description/langstring"/>
<element name="Keyword" path="lom/general/keyword/langstring"/>
<element name="Coverage" path="lom/general/coverage/langstring"/>
<element name="Structure"
path="lom/general/structure/value/langstring"/>
<element name="Aggregation Level"
path="lom/general/aggregationlevel/value/langstring"/>
</group>

<group name="Life Cycle">
<element name="Version" path="lom/lifecycle/version/langstring"/>
<element name="Status" path="lom/lifecycle/status/value/langstring"/>
<group name="Contribution">
<element name="Role"
path="lom/lifecycle/contribute/role/value/langstring"/>
      <element name="VCard"
path="lom/lifecycle/contribute/centity/vcard"/>
      <element name="Date"
path="lom/lifecycle/contribute/date/datetime"/>
</group>
</group>
```

Figure 7: Extract of file profile EMIAGEProfile.xml

Scenario

Reload Learning Design Editor has also been used to implement and handle units of learning, associated with the IMS-LD standard. These units can be interpreted by the LD Players.

Illustration within the framework of a course

In this section, the proposed model is illustrated on a course on computer science (database lesson). We consider a learning object which is an exercise on data file indexation. The object is composed of three elementary objects: two images of B-trees in jpg and an examination statement.

We illustrate in the following subsections how our model allows the learning object to be reused according to various pedagogical purposes.

Learning objects reuse according to LOM Metadata

The learning object "exercise" and each of its elementary elements are indexed using LOM metadata. These metadata help the learning system users reuse the different elements easily.

For example, the metadata *right* of the two images is defined as public, so any teacher or learner may reach it and use it. On the other hand, for the "Examination statement", the metadata *right* is defined as private to the people following the course. This implies that the examination statement as well as the learning object "exercise" can be reused only by teachers of the course and be consulted by learners registered on this course. Teachers can thus reuse the exercise in other lessons, while students can only reuse the B-trees images for making revision notes for example.

The metadata pedagogy-*level* related to "the exercise" is set at *initiation*. This indicates that the exercise is addressed to students who have not studied file indexing methods. The exercise can be used by teachers for designing any module addressed to a public having this level.

Learning objects reuse according to their content

Learning objects are also represented by the concepts that they are dealing with. An extract of the ontology of the theme of data processing is presented in figure 8.

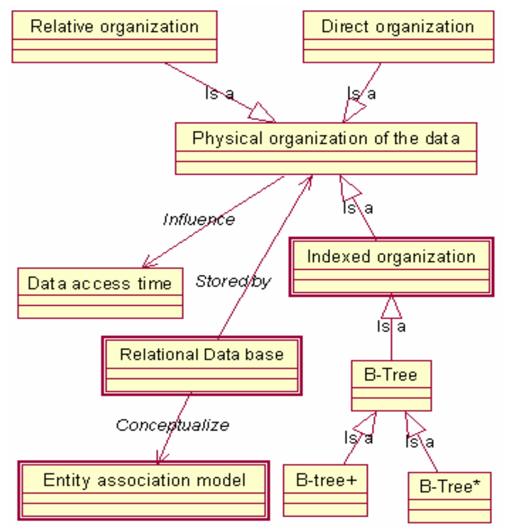

Figure 8: Extract of the theme ontology of the data processing.

This extract corresponds to the ontology related to the database domain. The concepts are represented by rectangles containing the various labels or terms, the captioned arrows represent the semantic relations between concepts. In the extract presented here, the doubly-framed concepts represent the concepts to be studied within the framework of the module "Relational Data Base".

One of the images represents a B-tree +, and the other a B-tree *. In our model, the two images are thus represented by these two concepts of the ontology of data processing. The exercise approaches the concepts of "indexed organization" of the data, starting from "B-trees" while insisting on the "access time" to the base. These three concepts of the ontology are thus used to index it. The advantage of specifying these concepts is that a teacher will be able to reuse this exercise when s/he wants to work on the concepts previously quoted. Moreover, as the notions are represented within an ontology, different teachers can interpret the same meaning associated to the notions by visualizing the different concepts and relations stated in the ontology.

Learning design

Learning scenarios are also considered in our model. Learning objects are represented according the acts and plays in which they have already been used. Let us consider the following scenario composed of different acts.

Act 1: The teacher presents the notions to be studied by students by providing a written document.
Act 2: The students read the corresponding resource and require explanations from the teacher.
Act 3: The teacher gives explanations, using examples, and waits for a new reaction of the students. Possibly s/he gives additional explanations if the students request some.
Act 4: When the time limit is reached, the teacher gives the exercises which the students must do.
Act 5: The teacher corrects the exercises while providing precise explanations on each point which is not mastered by the student, by e-mail, by on-line dialogue or on forum. In order to ensure the comprehension and memorization of the concepts to be learnt, self-assessment and some exercises to evaluate the students are provided to them.
Act 6: Finally, the teacher gives a summary of the most important points on the studied notions.

When this scenario is chosen, the system will be able to propose our learning object “exercise” and its elementary elements for different acts. The exercise can be used in both the acts 4 and 5. When preparing these two acts, the teacher will have access to all the exercises that have been indexed with the notions considered and that have already been used in such kind of acts. The images of the B-tree + and B-tree * can be proposed during act 1 to help the teacher design the written document, in act 3 to help the teacher give examples and in act 4 and 5 to prepare exercises. Representing learning objects with our model enables the reuse the objects according to how they have previously been integrated in a scenario.

Conclusions

The proposed model can be applied to any electronic document which has an educational objective. It can be integrated into any model of learning (synchronous or asynchronous distance learning…). It also presents the possible use and adaptation on any type of course because it was not conceived within the framework of a specific training.

The model is based on a multi-facet representation of documents by using three ontologies: ontology of theme, ontology of the tasks, ontology of the educational theories and a LOM/SCORM description. The proposed ontologies are represented in OWL (Web Ontology Language) (W3C, 2004) and based on the syntax RDF / XML. It makes it possible to explicitly represent the significance of the terms of vocabularies and the relations between the associated concepts.

One of the key points of the model is that the ontologies enable all the life cycle of a learning object to be covered: from its conception by the teacher to the search for pieces of information on a given notion by learners. It makes it possible to develop a system including the users’ assistance from the conception of the resources. The different actors of the system (teachers, learners) and their various tasks are considered. The model supplies the flexibility of a semantic representation and search for relevant learning objects by the use of the LOM application profiles. Respect the standards of on-line courses guarantees interoperability with other systems.

To further our study, we intend to set up a system allowing on the one hand automatic indexing of learning objects and on the other hand searching for learning objects matching a need (expressed by a learner or a teacher). The mechanisms will be based on the theme ontology. The first aspect will be based on the work of (Hernandez, 2005) which proposed this type of mechanism in another context (scientific documents). Another aspect relates to the automated construction of theme ontologies which must be produced for each domain of teaching. Work of the IRIT laboratory in this field (Aussenac et al., 2000) could be reinvested here.

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