ASIDE: An Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications

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Abstract

eLearning applications are immensely more valuable when they can use the wealth of information that exists in multimedia digital libraries. However, digital libraries and their standards developed independently on eLearning applications and their standards. It is crucial to bridge the interoperability gap between digital libraries and eLearning applications in order to enable the construction of eLearning applications that easily exploit digital library contents. We present ASIDE, an integrated architecture that supports interoperability between digital libraries and eLearning applications. The architecture is service oriented and supports multiple contexts and views of the digital objects of a library. These views can be utilized by eLearning applications of the digital library for the automatic construction of personalized learning experiences selecting learning objects from the reusable objects of the digital library.

1. Introduction

Digital Libraries are an important source for the provision of eLearning resources [1]. However, digital library metadata standards and eLearning metadata standards have been developing independently, presenting interoperability issues between digital libraries and eLearning applications. This is a complex and multi-level problem, which can be seen as a stack of conceptual layers where each one is built on top of the previous one (left part of figure 1): There are different data representations, objects, concepts, domains, contexts and metacontexts in the layer stack that should be efficiently managed in a standard way. Metadata models are languages that are used to represent the knowledge in a particular application area. Each metadata model is shown as a vertical bar on this stack to cover a specific region that represents the parts that the model tries to capture and describe in a standard way. If one places different metadata models besides this stack, (s)he may identify gaps and intersection regions so that it is apparent where the interoperability problems among these models occur.

The right part of figure 1 shows such a picture in the case of MPEG7 [2] and SCORM [3], the major metadata standards in the audiovisual and eLearning domains respectively. It is apparent from this graphical presentation that MPEG7 and SCORM are not completely overlapping. These overlapping gaps call for additional models to provide interoperability mechanisms between them. Of course, interoperability problems exist also in the overlapping areas. But in these areas solving the problem of interoperability is easier and can be solved with standard methods (e.g. by means of mappings). The major problems arise in the areas with no overlaps between the two metadata standards.

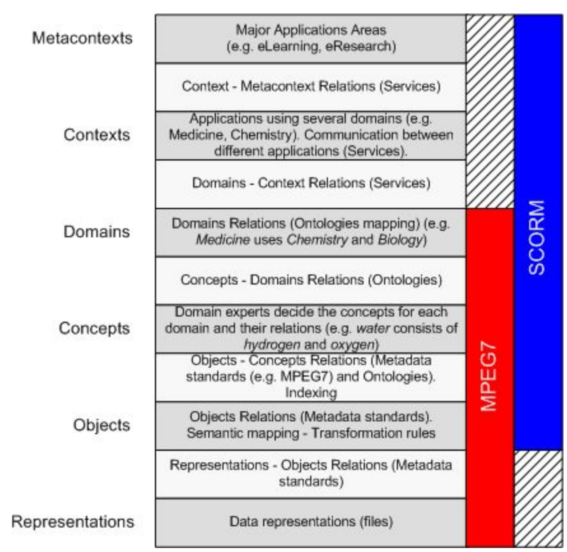

Figure 1. The multilevel problem of interoperability

In the next sections we will firstly propose a methodology for supporting multiple-contexts views of digital objects and its application in the case of A/V learning objects, without loss of important information (educational or A/V) (Section 2), and thereafter a generic architecture that overcomes the interoperability problem between eLearning applications and digital libraries will be presented (Section 3). The implementation of this architecture offers a generic framework for the automatic creation of personalized learning experiences using reusable A/V learning objects[1]. A review of the related literature is presented afterwards (Section 4) and the paper ends with some concluding remarks and future work.

2. Supporting multiple-contexts views of digital objects with METS

A digital object can be described in many ways and delivered to many applications as illustrated in the upper part of figure 2. However, performing just a transformation between the source and target metadata schemes is not always a panacea. As shown in figure 1, standards do not always completely overlap. In the non-overlapping areas the interoperability problem cannot be simply solved using mappings.

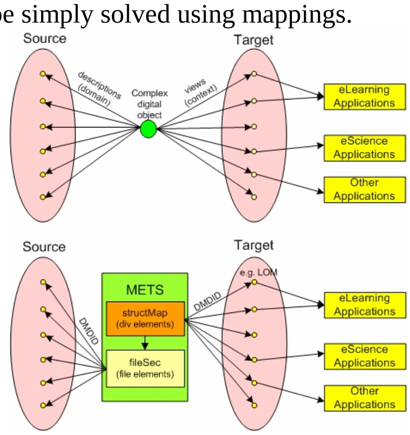

Figure 2. Using METS to support multiple-contexts views of digital objects

For example, SCORM contains an educational part that cannot be mapped to MPEG7 elements. Very often we want A/V digital objects that reside in a digital library and are described with MPEG7 to be used in eLearning applications. However, the MPEG7 descriptions do not say anything about the educational use (e.g. learning objectives) of the digital objects. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools, which can not be represented in SCORM. In order to overcome these shortcomings we have to use a higher level metadata model that is able to encapsulate both SCORM and MPEG7 metadata descriptions in the context of a digital library. This model should be essentially a wrapper that will allow for the use of MPEG7 metadata of existing A/V objects and parts of them together with the necessary LOM [4] metadata to specify the educational characteristics of these objects and their parts.

In general, we need a way to have multiple descriptions (source metadata (domain), target metadata (context) pairs) for a digital object showing possible views of the object. Context and domain information should reside in different levels, where context information is described using domain information.

A flexible model that satisfies the above needs is the Metadata Encoding and Transmission Standard (METS) [5]. METS is a widely-accepted standard designed specifically for digital library metadata. METS is a flexible, but tightly structured, container for all metadata necessary to describe, navigate and maintain a digital object: Descriptive, Administrative and Structural metadata. Each type of metadata is described in a separate section, which is linked to its counterparts by internal identifiers. These metadata (any preferred scheme) may be held physically within the METS file, or in external files and referenced from within the METS document.

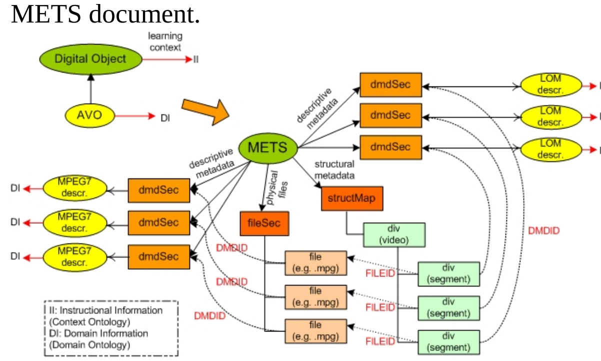

Figure 3. Combining METS, LOM and MPEG7 to build audiovisual learning objects

Using METS we can create different views of a digital object pointing to both source metadata description and target metadata description (context) in different levels. The methodology is illustrated in the lower part of figure 2. Using the DMDID attribute of the <div> elements (structMap section describing the structure of the digital object) we can point to an appropriate metadata scheme creating a context (view) of this object and its parts. E.g., we can use LOM to describe the educational characteristics of each object and its parts, so that being able for them to be searched and retrieved by eLearning applications (learning context) (figure 3). In parallel, using the DMDID attribute

[1] Although A/V objects are used in the implementation of the architecture, this does not restrict its generality.

of the <file> elements (fileSec section, where all files comprising this digital object are listed, we can point to a source metadata scheme that describes the low features or the semantics of this object (e.g. using MPEG7).

3. The ASIDE architecture

The architecture presented here addresses the identified interoperability problems in a layered architecture where eLearning (and other) applications are built on top of digital libraries and utilize their content. The ASIDE architecture offers a generic framework for the automatic creation of personalized learning experiences using reusable A/V learning objects. It is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification [6]. The IMS DRI specification provides recommendations for the interoperation of the most common repository functions enabling diverse components to communicate with one another: search/expose, submit/store, gather/expose and request/deliver. These functions should be implementable across services to enable them to present a common interface. Figure 4 illustrates the architecture components, which are the following:

- The **Digital Library**, where digital objects are described using METS+LOM (eLearning context), and MPEG7 (A/V descriptions) building this way interoperable A/V learning objects, which can be transformed to SCORM and delivered to eLearning applications (METS/SCORM transformation component). Some important elements used in the LOM descriptions are: educational objectives expressed as {verb (Bloom's Taxonomy [7])+subject (term from a Domain Ontology)} using the *classification* part of LOM, *context*, *typicalAgeRange* and *difficulty*. Regarding the MPEG7 descriptions, the methodology described in [8] is used for extending MPEG7 with domain-specific knowledge descriptions expressed in OWL[9](domain ontologies).
- **Applications** (Software Agents in terms of IMS DRI, like Learning Content Management Systems, Learning Management Systems etc.) that discover, access and use the content of the A/V content of the digital library through appropriate services (resource utilizers). The generated personalized A/V learning experiences are delivered to the applications in the form of SCORM packages. Any SCORM-compliant system can recognize and "play" these packages.
- The **Middleware**, which is responsible for the assembly of personalized learning experiences. The middleware consists of the following parts:

a) The **METS/SCORM transformation component**, which is responsible for the transformation of the METS descriptions pointing to LOM and MPEG7 descriptions to SCORM Content Packages [3]. This includes not only simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Moreover, the mime-type of the files is taken into account and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files).

b) The **Personalized Learning Experiences Assembler (PALEA)**, which, taking into account the knowledge provided by the Learning Designs (abstract training scenarios) and the Learner Profiles described later, constructs the personalized learning experiences and delivers them in the form of IMS Content Packages. Before transforming the resulted learning experience to a SCORM package, it is stored as METS+LOM+MPEG7 description in the digital library according to the interoperability framework, being ready and available in an interoperable way for later requests. The dashed arrow in the left side of PALEA indicates that using this component is optional, and that digital library services can be directly accessed (e.g. a teacher wants to find appropriate learning objects to construct manually a learning experience).

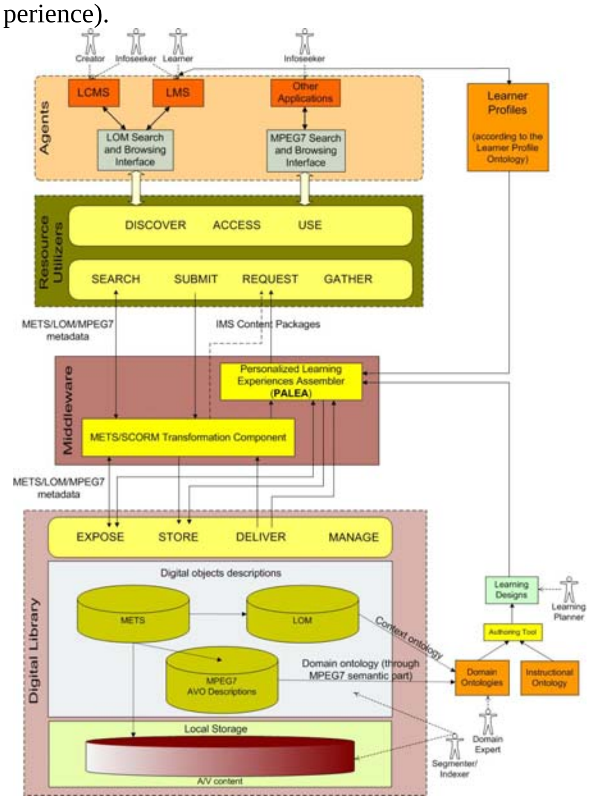

Figure 4. The interoperability architecture

- **Ontologies** providing knowledge to the PALEA for the automatic construction of personalized learning experiences:

a) **Domain Ontologies** that provide vocabularies about concepts within a domain and their relationships.

b) **Instructional Ontology** (see section 3.1) that provides a model for the construction of abstract training scenarios. These are pedagogical approaches (instructional strategies/didactical templates), which can be applied to the construction of learning experiences.

- **Learning Designs** are abstract training scenarios in a certain domain built according to the model given in the instructional ontology.

- The **Learner Profiles** constructed using the vocabulary given in the **Learner Profile Ontology**, which represents a learner model for the creation of learner profiles. Elements from IEEE PAPI [10] and IMS LIP [11] specifications have been also used in this model. Some important elements of this model are: learner goals, competencies, previous knowledge, educational level and learning style.

The interoperability architecture has been implemented using the following technologies: Web services, JavaTM 2 Platform, Standard Edition, v1.5, Berkeley DB XML, Jena API [12], SPARQL RDF Query Language [13] and XQuery for querying the XML-based metadata descriptions of the digital objects stored in the digital library.

3.1. The instructional ontology

We present here a model for the construction of abstract training scenarios which is represented in an ontology coded in OWL that has the important characteristic that learning objects are not bound in the training scenarios on design time, as in current eLearning standards and specifications (e.g. IMS Learning Design (IMS LD) [14] and SCORM). Whereas, pedagogy is separated and independent from content achieving this way reusability of learning designs or parts of them that can be used from the systems for the construction of “real” personalized learning experiences, where appropriate learning objects according to the learner profile are bound to the learning experience at run-time. This is possible, since the model gives the opportunity to specify in each Activity the learning objects’ requirements, instead of binding the learning objects themselves, as IMS LD and SCORM impose. This ontology borrows some elements and ideas from IMS LD and LOM.

A *Training* is a collection of abstract training scenarios regarding one domain. The same subject can be teached in several ways (*TrainingMethods*) depending on the *LearningStyle* and the *EducationalLevel* of the Learner. There are several categorizations of Learning Styles and Educational Levels, thus these elements are flexible so that being able to point to values of different taxonomies. A *TrainingMethod* consists of a hierarchy of *ActivityStructures* built from *Activities* (elements taken from IMS LD) forming an arbitrarily complex structure of activities (sequence or selection). Since this model is RDF-based (OWL), existing *ActivitiesStructures* or paths of *ActivitiesStructures* can be reused in many Learning Designs. Each *Training*, *ActivityStructure* and *Activity* has a *LearningObjective*. Learning Objectives are treated here in a more formal way (as in [15]), than pure text descriptions. The *LearningObjectType* class is used to describe the desired Learning Object characteristics (requirements) without binding specific objects with *Activities* on design time. If more than one entries are used per *Activity*, the interpretation is “OR”. Via the *related_with* property we can further restrict the preferred learning objects connecting them with *DomainConcepts* or individuals from a domain ontology.

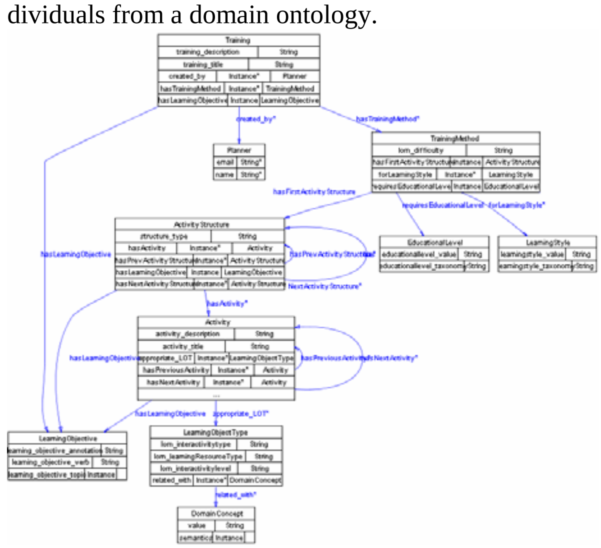

Figure 5. The instructional ontology

4. Related work

Efforts trying to integrate or use in cooperation eLearning standards and A/V standards include Video Asset Description (VAD) Project [16], MultImedia Learning Object Server [17] and Virtual Entrepreneurship Lab (VEL) [18]. Most of these approaches ([17],[18]) use mappings between standards (e.g. MPEG7 and LOM) or propose adding MPEG7 elements to SCORM elements [16]. As explained in Sections 1 and 2, using mappings is not enough to solve the interoperability problem between digital libraries and eLearning applications. The framework proposed here is more general and does not depend on the strict use of MPEG7 and LOM.

Web services implementations based on IMS DRI include the EduSource Canadian Network of Learning Objects Repositories [19], the Learning Objects Network (LON) [20] and the Campus Alberta Repository of Educational Materials (CAREO) [21]. Our approach differs in that it provides an interoperable framework of educational and application specific metadata so that eLearning applications can easily use and reuse digital library objects in multiple contexts. Moreover, intelligent construction of personalized learning experiences is supported, so that courseware creation and reuse of educational resources (including learning designs) may be automated.

5. Summary

We have presented ASIDE, an architecture that supports the integration of eLearning applications on top of digital libraries. The architecture supports interoperability between digital libraries and eLearning applications so that eLearning applications can easily use and reuse digital library objects in multiple contexts. The architecture is generic and it provides a framework for integrating in eLearning applications material selection and personalization of the material selected from the digital libraries. We have outlined the various aspects of the implementation of the ASIDE architecture.

The architecture presented and its implementation provide the basis of a generic architectural framework for integrating diverse application classes (like eLearning and eScience applications) on top of digital libraries so that digital library objects are also reused across application classes that have been built on top of digital libraries. We are currently investigating interoperability issues and generic architectural support for this environment.

6. Acknowledgements

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