A Framework and an Architecture for Supporting Interoperability between Digital Libraries and eLearning Applications

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Abstract. One of the most important applications of Digital Libraries (DL) is learning. In order to enable the development of eLearning applications that easily exploit DL contents it is crucial to bridge the interoperability gap between DL and eLearning applications. For this purpose, a generic interoperability framework has been developed that could also be applied to other types of applications which are built on top of DL, although this paper focuses on eLearning applications. In this context, a framework for supporting pedagogy-driven personalization in eLearning applications has been developed that performs automatic creation of personalized learning experiences using reusable (audiovisual) learning objects, taking into account the learner profiles and a set of abstract training scenarios (pedagogical templates). From a technical point of view, all the framework components have been organized into a service-oriented Architecture that Supports Interoperability between Digital Libraries and ELearning Applications (ASIDE). A prototype of the ASIDE Framework has been implemented.

Keywords: Digital Libraries, eLearning, Interoperability, Personalization

1 Introduction

Digital Libraries (DL) are an important source for the provision of eLearning resources [9]. However, digital library metadata standards and eLearning metadata standards have been developing independently, which has as result the existence of interoperability problems between digital libraries and eLearning applications. This is a complex and multi-level problem which is often encountered between digital libraries and several types of applications that run on top of digital libraries. It can be seen as coming from the existence of a stack of conceptual layers where each one is built on top of the previous one (left part of Fig. 1): There are different data representations, objects, concepts, domains, contexts and metacontexts in the layer stack that should be efficiently managed in a standardized 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 we place different metadata models besides this stack, we may identify gaps and intersection regions so that it becomes apparent where the interoperability problems among these models occur. Interoperability problems exist also in the overlapping areas, but there the problem of interoperability can be easier 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. The right part of Fig. 1 shows such a picture in the case of MPEG7 and SCORM, 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 meaning that we need additional models to provide interoperability mechanisms between them.

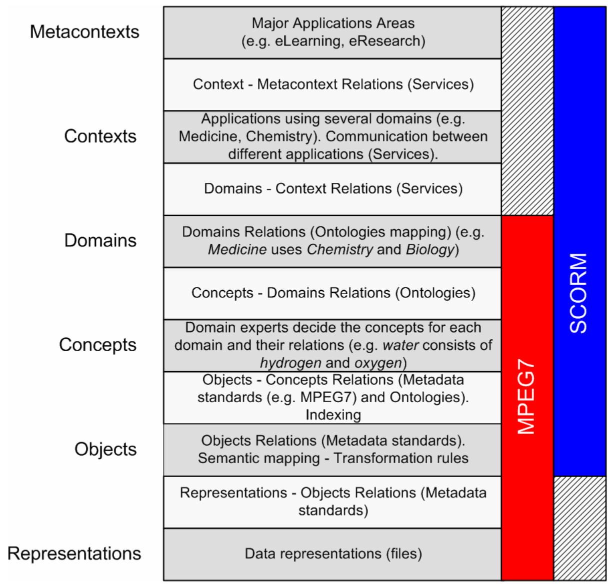

Fig. 1. The multilevel problem of interoperability

For example, SCORM contains an educational part that cannot be mapped, directly or indirectly, completely or partially, to MPEG7 elements. That is because MPEG7 does not include information about possible educational use of audiovisual (A/V) objects because it is not an application-specific context metadata standard. However, educational information is very important in the case that MPEG7 (and generally an A/V digital library) is used for educational purposes. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions, which will form the basis for applications that provide the needed effective and efficient access to audiovisual content, which can not be represented in SCORM. Modifying the above standards (e.g. mixing parts of them) is not acceptable, since they have been developed to satisfy the needs of different communities. To overcome them and fill in the gaps between SCORM and MPEG7 we have to use a higher level metadata model that is able to encapsulate both SCORM and MPEG7 in the context of a digital library.

The above considerations lead to a concrete framework and architecture that address the identified interoperability problems and offer a generic framework for the automatic creation of personalized learning experiences using reusable audiovisual learning objects. 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 supports interoperability problem between eLearning applications and digital libraries will be presented (Section 3). The implementation of this architecture also offers a generic framework for the automatic creation of personalized learning experiences using reusable A/V learning objects which is also presented. A review of the related literature is presented afterwards (Section 4) and the paper ends with some concluding remarks.

2 Supporting Multiple-Contexts Views of Digital Objects

In general, a digital object can be described in many ways and delivered to many applications (upper part of Fig. 2). Usually, digital objects have a source metadata description that is appropriately transformed to a target metadata description when this object should be delivered to an application. However, performing just a transformation between the source metadata scheme and the target metadata scheme is not always applicable as standards do not always completely overlap.

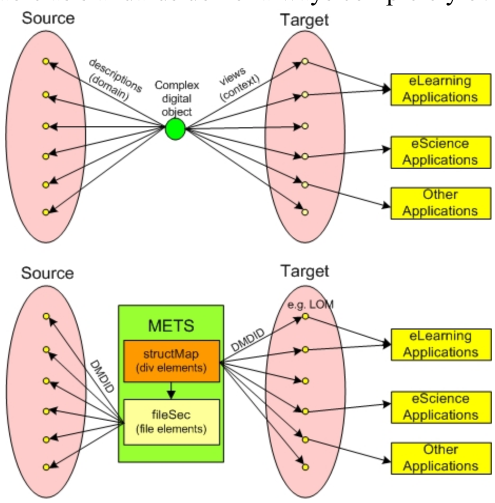

Fig. 2. Supporting multiple-contexts views of a digital object using METS

For example, an audiovisual digital object that resides in a digital library and is described with MPEG7 can be used in eLearning or eScience applications. However, the pure MPEG7 description does not say anything about the educational use (e.g. learning objectives) of the digital object nor contains any information useful for eScience applications. Performing just a transformation between the source metadata scheme and the target metadata scheme does not solve the problem. So, we need a way to incorporate in a digital object description both source metadata (domain) and target metadata (context). We should 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 above domain information.

A flexible model that satisfies the above needs is the Metadata Encoding and Transmission Standard (METS). METS is a widely-accepted digital library standard that is intended primarily as 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 a comprehensive system of internal identifiers. The metadata (any preferred scheme) itself may be held inline in the METS file or in external files and referenced from within the METS document.

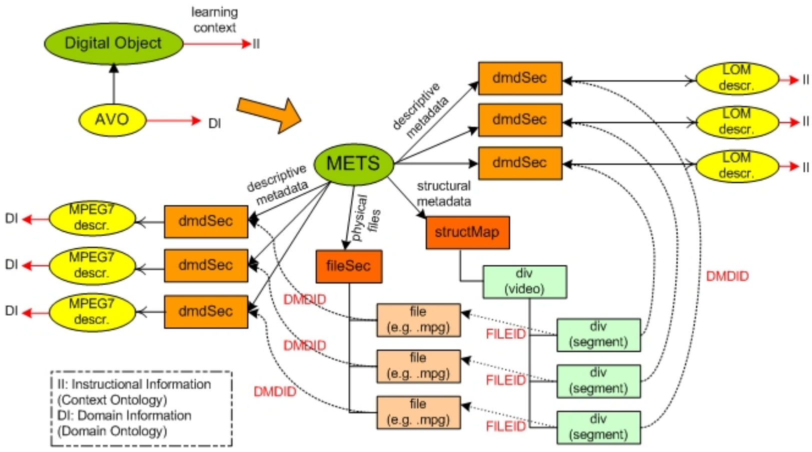

Fig. 3. Combining METS, LOM and MPEG7 to build audiovisual learning objects

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 [2]. The methodology is illustrated in the lower part of Fig. 2. Using the DMDID attribute of the <div> elements of the structMap section where the structure of the digital object is described we can point to an appropriate metadata scheme creating a context (view) of this object and its parts (e.g. using LOM). In parallel, using the DMDID attribute of the <file> elements of the fileSec section, where all files comprising this digital object are listed, we can point to a source metadata scheme that describes the lower level features or the semantics of this object (e.g. using MPEG7). This is useful when applications want to further filter the resulted objects according to their multimedia characteristics. Here, we combine METS, MPEG7 and LOM to give to the audiovisual objects and their parts educational characteristics constructing this way audiovisual learning objects (Fig. 3). The DMDID attribute of the <file> element is used to reference the MPEG7 metadata (domain metadata) describing the audiovisual object referenced by FLocat element. In an upper level we put the Context Metadata (in our case educational metadata) using the DMDID attribute of the div element to reference LOM metadata. The video decomposition to segments is described through the METS document (as a complex object) and there is no need to be described in a MPEG7 document using for example the TemporalDecomposition element.

3 The ASIDE architecture

The previous section presented a framework for the representation and description of digital objects that reside in a digital library in order to support multiple-context views so that these objects can be retrieved from different applications (in this case eLearning applications). This section presents an Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications (ASIDE).

The architecture addresses the identified interoperability problems in a layered manner where eLearning (and other) applications are built on top of digital libraries and utilize their content. ASIDE [2] also offers a generic framework for the automatic creation of pedagogy-driven personalized learning experiences using reusable A/V learning objects. It is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification, which provides recommendations for the interoperation of the most common repository functions: search/expose, submit/store, gather/expose and request/deliver.

Fig. 4 illustrates the architecture components, which are the following:

- The *Digital Library*, where digital objects are described using METS integrating LOM (eLearning context), and MPEG7 (A/V descriptions) thus building interoperable A/V learning objects, which can be transformed to SCORM and exploited by eLearning applications. Regarding the MPEG7 descriptions, the methodology described in [11] is used for extending MPEG7 with domain-specific knowledge descriptions expressed in OWL (*domain ontologies*).
- *Learning Designs* are abstract training scenarios (pedagogical templates) in a certain instructional domain built according to an *instructional ontology*, which can be applied to the construction of learning experiences.
- The *Middleware* consists of the following parts:
  - The *METS/SCORM transformation component*, which is responsible for the transformation of the METS integrated descriptions to SCORM Packages [6]. The 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).
  - The *Personalized Learning Experiences Assembler (PALEA)*, which, taking into account the knowledge provided by the Learning Designs (abstract training scenarios) and the Learner Profiles, constructs personalized learning experiences and delivers them in the form of SCORM Packages. 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).
- *Applications* (Agents in terms of IMS DRI, like Learning Content Management Systems, Learning Management Systems) that discover, access and use the A/V content of the digital library through appropriate services (resource utilizers).
- The *Learner Profiles* constructed using the vocabulary given in a Learner Profile Ontology.

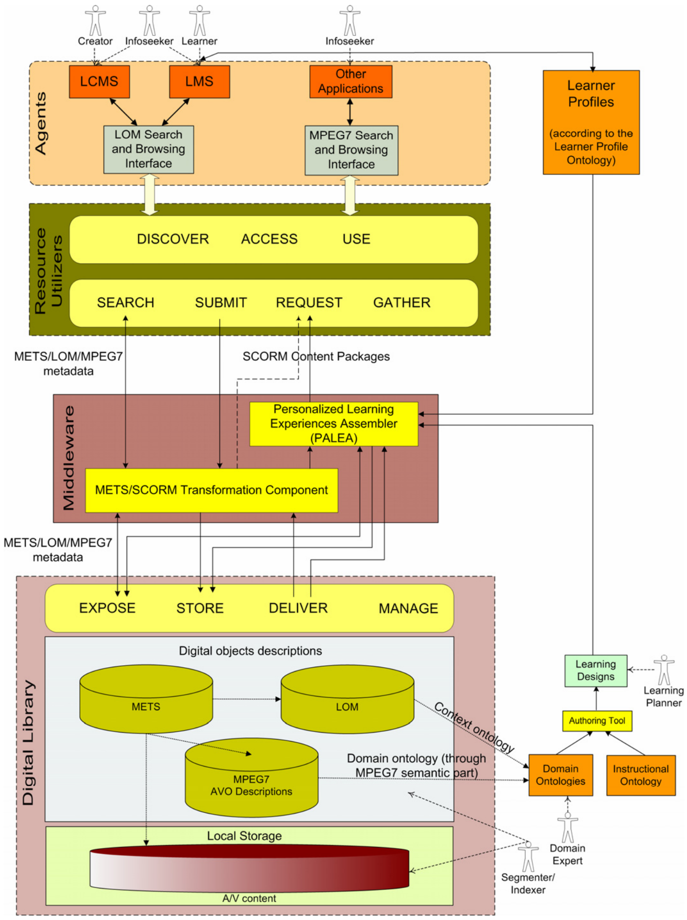

Fig. 4. The ASIDE architecture

3.1 Learning Designs and the Instructional Ontology

Learning Designs are abstract training scenarios that are constructed according to an instructional ontology coded in OWL (Fig. 5). This ontology has the important characteristic that learning objects are not bound to the training scenarios at design time, as in current eLearning standards and specifications (e.g. IMS Learning Design 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 taking into account several parameters of the Learner Profile. This is possible, since the model makes possible to specify in each Activity the learning objects' requirements, instead of binding the learning objects themselves.

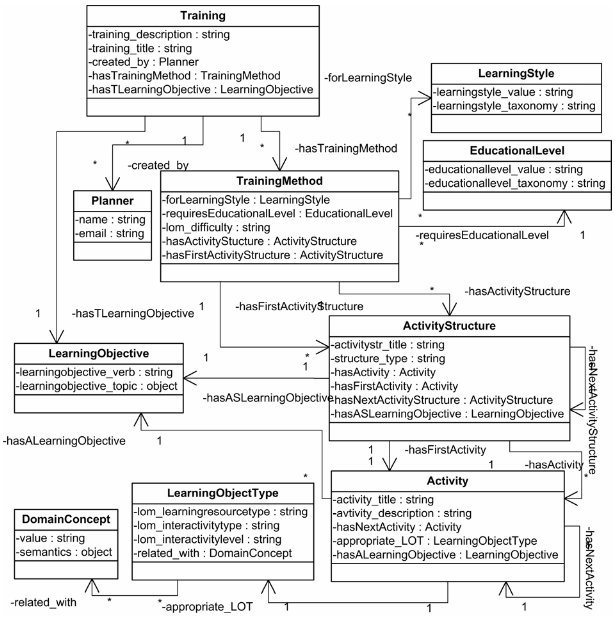

Fig. 5. The instructional ontology

A *Training* is a collection of *TrainingMethods* that refer to the different ways the same subject can be taught depending on the *LearningStyle*, the *EducationalLevel* of the Learner and the preferred *difficulty*. 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 reusable *ActivityStructures* built from reusable *Activities*. Each *Training*, *ActivityStructure* and *Activity* has a *LearningObjective*. Each *LearningObjective* is defined in a formal way[1] composed of: a) a *learningobjective_verb*, taken from Bloom's Taxonomy [3]) and b) a *learningobjective_topic* that indicates the topic that the Learning Objective is about, referencing a concept or individual of a domain ontology. The *LearningObjectType* is used to describe the desired learning object characteristics without binding specific objects with Activities at design time. Via the *related_with* property we can further restrict the preferred learning objects according to their constituent parts (if they are semantically annotated) connecting them with *DomainConcepts* which refer to concepts or individuals from a domain ontology.

3.2 The Learner Profiles

Our intention here is to focus on the elements that should be included in a Learner Model in order to support pedagogy-driven personalization within the framework

[1] In learning objects descriptions expressed in LOM we also incorporate Learning Objectives info this way exploiting its classification element.

presented in this paper. These elements could be mapped in appropriate elements of the IEEE PAPI and IMS LIP learner profiles standards using extensions.

A Learner can have many *LearnerGoals*. A *LearnerGoal* is expressed in terms of *LearningObjectives* using the structure that was presented above in the instructional ontology. A *LearnerGoal* has a *status* property (float in [0, 1]) indicating the satisfaction level of the goal (0 represents no satisfaction, 1 fully satisfied). Using this information one can also infer the previous knowledge of the Learner. The Learner can also define a *priority* for each *LearnerGoal*. The Learner can have several types of Preferences: *EducationalLevel* and *LearningStyle* matching with the corresponding elements of the instructional ontology, *Language*, *LearningProvider* (the author or organization making available the learning objects), *LearningPlanner* (the person that develops Learning Designs) and *Technical* preferences. These parameters affect both the construction of an appropriate learning path for a specific Learner according to existing Learning Designs and the selection of learning objects that are thereafter bound at run-time to the learning path to form the resulting learning experience.

3.3 The Personalized Learning Experiences Assembler (PALEA)

The Personalized Learning Experiences Assembler (PALEA) takes into account the knowledge provided by the Learning Designs and the Learner Profiles and constructs personalized learning experiences that are delivered next to eLearning applications in the form of SCORM packages. The goal is to find an appropriate Learning Design that will be used thereafter to construct a learning experience adapted to the Learner's needs. Learning objects are bound to the learning scenario at run-time.

The procedure of constructing an adaptive learning experience is the following:

1. At the beginning, the component tries to find an appropriate Learning Design (Training in terms of the instructional ontology presented) taking into account the Learner's Learning Objectives, Learning Style, Educational Level, preferred Difficulty, and preferred Planner (optional).
2. When an appropriate Learning Design is found its structure is retrieved (Training(T), Activity Structures (AS), Activities(A)) and an appropriate Training Method of this Learning Design is selected, according to the Learner's Learning Style, Educational Level and preferred Difficulty.
3. The structure of this Training Method is further refined, by removing from it Activity Structures and Activities with Learning Objectives that have been satisfied by the Learner (the Learner can define a threshold value t, so that Learning Objectives with satisfaction value>t are considered as satisfied).
4. Finally, appropriate learning objects are retrieved and bound to each node (Activity) of this structure constructing the learning experience. Here, the Learning Object Type describing the characteristics of appropriate learning objects for each Activity is taken into account along with other learner's preferences (e.g. content provider, technical preferences). The resulted learning experience is transformed to SCORM (Transformation Component) and delivered to the Learner.

4 Related Work

Efforts trying to integrate or use in cooperation eLearning standards and A/V standards include the Video Asset Description (VAD) Project [4] the MultImedia Learning Object Server [1] and the Virtual Entrepreneurship Lab (VEL) [8]. Most of these approaches [1, 8] use mappings between standards (e.g. MPEG7 and LOM) or propose adding MPEG7 elements to SCORM elements [4]. As already discussed, using mappings is not enough to solve the interoperability problem between DL and eLearning applications. Extending SCORM is again not acceptable as a general interoperability solution. It results in a model that is not standard and cannot be interoperable with standard SCORM compliant applications and systems. The approach proposed here is more general and provides and interoperable framework of educational and application specific metadata so that eLearning applications can easily use and reuse DL objects in multiple contexts.

Automatic construction of personalized learning experiences is also supported, using and reusing learning designs and learning resources. In [5] a similar approach is followed to represent pedagogy in order to support run-time resource binding. Our approach differs in that it takes into account the learning style, the educational level and learning goals of the learners, supporting the representation of different learning paths (Training Methods) for training in a specific subject. In [10], although the need for supporting different training methods for the same subject is recognized, these methods are not connected as in our approach with the learning styles and educational levels of the learners. Moreover, description of appropriate learning objects characteristics beyond semantics is not supported. An alternative approach is presented in [7] regarding automatic course sequencing, where learning paths are not constructed based on pedagogical models, but are extracted from a directed acyclic graph that is the result of merging the knowledge space (domain model) and the media space (learning objects and their relation) using minimum learning time as an optimization criteria. However, since this approach is highly based on the domain model that does not necessarily imply an instructional model and on the relations of learning objects and their aggregation level, the result of the sequencing process may be not always "pedagogically-right" adapted to the learners' needs.

5 Conclusions

We have presented a framework for the representation and description of digital objects that reside in a DL in order to support multiple-context views so that these objects can be retrieved from different applications (in this case eLearning applications). We have also presented ASIDE, an architecture that supports interoperability between DL and eLearning applications so that eLearning applications can easily use and reuse DL objects in multiple contexts and outlined the various aspects of its implementation. Special emphasis has been placed in the definition and implementation of a software engineering framework for supporting personalization in the ASIDE architecture that performs automatic creation of personalized learning experiences using reusable (audiovisual) learning objects, taking into account the learner profiles and a set of learning designs. This work provides the basis of a generic architectural framework for integrating diverse application classes on top of DL so that DL objects are also reused across application classes that have been built on top of digital libraries.

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