Using Metadata Standards Represented in OWL for Retrieving LOs’ Content

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Abstract. There is a great interest on the reuse of learning materials. However, nowadays, they are structured as multimedia files and, therefore, retrieving a specific material means retrieving the whole file, even though it could be desirable to access and use only parts of these materials. So, this paper proposes an ontology based on the metadata standards LOM and MPEG-7 for LOs’ content description, in order to retrieve specific parts of content embedded in LOs. Using LOM and MPEG-7 allows describing educational and multimedia characteristics while an ontology allows retrieving through graph navigation as well as the exploration of inferred relationships.

1. Introduction

Technology enhanced learning has caught attention over the last years. However, developing high quality educational content material is still expensive and time-consuming. Therefore, in order to reduce costs and development time, there is a great interest on promoting reuse of educational content material [Moura et al. 2004] [Siqueira et al. 2007a], and the approach of developing learning objects (LOs) has been widely accepted. Actually, reusing already developed artifacts and applying them in a learning process is an alternative for the creation of new materials.

There are many authors whose works provide definitions for LOs [Downes 2001], [Sosteric and Hesemeier 2002], [Wiley 2000]. Despite the various definitions, there is a consensus regarding the basic concept of reusable portions of instructional content. The most cited definition is presented at [IEEE LTSC 2002]: “a LO is any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning”. However, although this definition is largely used, it is too broad. This paper adopts the definition provided by Polsani (2003): “A LO is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts”.

An important issue regarding LOs is the fact that they are usually structured as multimedia files and, therefore, retrieving a specific LO – and consequently reusing it - is related to the whole file. This means that although the access and reuse of only parts
of a specific LO could be desirable, nowadays it is only possible to obtain the entire LO, which limits its reuse and the return on investment of its development.

The work presented in this paper allows segmenting and describing LO’s content through an LO’s description ontology that was developed based on LOM and MPEG-7 metadata standards. These standards can be used to create and describe segments of LOs [Oliveira et al. 2008a]. Therefore, the main idea regarding to this paper is promote a description approach using both LOM and MPEG-7 represented in OWL, the W3C ontology language. This semantic LO’s description is particularly focused on the semantic relationships between different segments, constituting an important aspect to access and retrieve information.

According to Verstichel (2008), using OWL allows making inference. Thus, the work presented in this paper intends to benefit from possible inferences over descriptions of different segments of LOs’ content, discovering implicit relationships between them. This approach could support a learning process by, for example, creating a semantic network of segments in which users could apply a navigational exploration approach, learning the segments. In this case, this semantic network would comprise both the explicit relationships (defined by a user during the description process) and the implicit relationships (inferred through an inference mechanism and logic rules). This inference approach could also support a learning process by sequencing several segments in an appropriated way, guiding a learner in his/her learning process. It is important to notice, however, that different learning scenarios and pedagogical aspects could be considered and applied using the segments of LO’s content, but this paper does not intend to discuss pedagogical approaches.

The remaining of this paper is organized as follows. Section 2 discusses about metadata for LOs, presenting an overview regarding the LOM and MPEG-7 standards. Section 3 discusses some subject matters related to ontologies, the use of OWL language to represent metadata for LOs and presents an approach regarding the development of an ontology to describe LOs’ content. Section 4 presents some usage scenarios of the LO’s description ontology. Finally, section 5 presents the conclusions as well as future works.

2. Metadata for Learning Objects

There have been several global efforts to develop standards, specifications and reference models that aim at providing a standardized set of metadata in order to describe LOs. Actually, without an appropriated description, it is extremely difficult and time-consuming to search for LOs that are adequate for a particular need or interest, making difficult to reuse this material. The following subsections describe the LOM and MPEG-7, the metadata standards considered in this paper.

2.1. Learning Object Metadata

When considering the description of learning content material, the IEEE Learning Object Metadata (LOM) [IEEE LTSC, 2002] is the most used and referenced standard. It is intended to simplify the discovery, management, and exchange of LOs over the Web. An important approach regarding to the LOM is that metadata compliant with this standard provide a section of qualified object relations, which allows interconnecting
two objects in a meaningful fashion. Facing a well maintained mesh of LOs, a learning net may be presented to a learner for navigation and knowledge exploration.

Although the LOM is the most used metadata for LOs’ description, the evolution of information and communication technologies provides the development of audiovisual LOs, making LOM insufficient to adequately describe the multimedia characteristics because it does not include all the necessary elements to describe audiovisual LOs. Moreover, even considering the non audiovisual LOs, LOM does not present, for instance, a mechanism for describing a hierarchical segmentation of learning content. So, MPEG-7 standard is considered in order to improve the LOs description.

2.2. MPEG-7

Several standards have been developed for the representation of metadata for audiovisual content description, among which the dominant one is MPEG-7 [Martinez, 2004], which is an ISO/IEC standard developed by MPEG (Moving Picture Experts Group). Formally named "Multimedia Content Description Interface", MPEG-7 provides a rich set of standardized tools to describe multimedia content. In fact, it offers a comprehensive set of audiovisual Description Tools to create descriptions, which will support applications enabling an effective and efficient access to multimedia content.

Moreover, MPEG-7 provides a number of tools for describing the structure of multimedia content in time and space. The Segment Description Scheme describes a spatial and/or temporal fragment of multimedia content. A number of specialized subclasses are derived from the generic Segment Description Scheme. These subclasses describe the specific types of multimedia segments, such as video segments, moving regions, still regions and mosaics, which result from spatial, temporal and spatiotemporal segmentation of the different multimedia content types. In other words, this standard enables to define specific parts of instructional content. This approach could allow defining descriptions over specific parts of LOs’ content. In this way, for instance, instead of executing searches over a description related to a LO as a whole, it is possible to perform searches over descriptions related to parts of the LOs content. Furthermore, using this standard, it is possible to retrieve specific parts of LO’s content, instead of retrieving an entire LO.

3. Ontologies in LO’s Describing Approach

In spite of all standards that aim to provide a standardized description of LOs, using metadata as recommended is not sufficient to solve the problems of reusability and accessibility of LOs [Zarraonandia et al, 2004]. In fact, LOs must provide semantic information in order to facilitate their discovery, retrieval and reuse. So, an important idea that has been discussed by researchers in order to improve the LOs reusability is the use of ontologies. Among other reasons, they are adopted in order to perform navigations between concepts [Siqueira et al. 2007b] and due to the fact that they can be used to perform inference tasks, discovering new facts from an existing knowledge base [Oliveira et al. 2008b].

According to Fensel (2003), ontologies provide an explicit conceptualization that describes data semantics. Ontologies are formal and explicit representations of a knowledge domain, typically expressed with linguistic terms that include concepts,
concept properties, and relationships between concepts. For humans, ontologies enable better access to information and promote shared understanding. For computers, ontologies facilitate the interpretation of information and more extensive processing. Noy and McGuinness (2001) indicate that ontologies define a common vocabulary, interpretable by machines, for studies that need to share information about a domain, including definitions about basic concepts of a domain and their relationships.

3.1. Multimedia Ontology

As the main focus of this paper is on LOs that incorporate multimedia, it is important to present a general outline regarding the development of ontologies for this specific kind of learning materials. Multimedia ontologies are created because the concepts and categories defined in traditional ontologies are not rich enough to fully describe the characteristics intrinsic to multimedia objects. Multimedia ontologies are used for content visualization, content indexing, knowledge sharing, learning and reasoning. They could be designed to, for example, annotation (e.g. summarization of multimedia content), analysis (e.g. ontology driven semantic analysis of multimedia content), reasoning (e.g. application of reasoning techniques to multimedia content), personalized filtering (e.g. delivery of multimedia content according to user preferences) and retrieval (e.g. context-based retrieval and recommendations) [Seremeti and Kameas 2007].

The construction of multimedia ontologies is difficult, because different specifications of the same domain are possible and many decisions have to be made, which depend on the domain, the purpose of the multimedia ontology, the complexity of content and structure that characterize the multimedia objects, and the user’s knowledge, need or interests. The users can, for example, build a multimedia ontology simultaneously for all media. For each concept, all media specific concepts are encoded into the nodes of the ontology simultaneously. Alternatively, the users can develop a separate ontology for different media and create a link between nodes for every cross reference. Multimedia ontologies should be able to represent the structure of a multimedia document. They need to describe and represent knowledge for either one, or even more of the following top-level hierarchical types of multimedia documents: image, video, 3D graphics, audio, audiovisual and multimedia presentation. In fact, considering the work presented in this paper, they should be rich enough to describe the spatiotemporal relationships between the objects.

3.2. Creating a LO’s Description Ontology

The construction of ontologies is usually a manual, iterative process that consists of the selection of concepts to be included in the ontology and the establishment of properties for the concepts and relationships between concepts in the ontology. There are many ontology languages available with different expressiveness and reasoning capabilities. The main criteria for the selection of an ontology language are its knowledge representation mechanism and the inferencing/reasoning support needed by the application. Thus, considering that the high complexity of multimedia materials requires a representation language with high semantic expressiveness and since the Ontology Web Language (OWL) is a W3C recommendation and comprises the OWL DL – which makes possible consider an inference approach through Description Logic -, this paper adopts OWL (specifically the OWL DL) for LO’s description representation.
OWL [McGuinness and van Harmelen 2004] emerges as a standard that is supported by W3C for defining ontologies in the semantic web. OWL aims at providing a language that can be used for describing classes and their relationships, which are inherent in web documents and applications. This language can be used for formalizing a domain through the definition of classes and their properties, to define individuals and assert properties about them, and prove logic reasoning about these classes and individuals according to the degree allowed to the formal semantics of OWL. In this paper, it is proposed to describe LOs through metadata standards represented in OWL.

![Figure 1. Example of an ontology for MPEG-7](image)

Several researches provide ontologies for LOM or MPEG-7 [Hunter, 2001] [Harit, 2006] [Arndt, 2007] as a whole or in part using OWL. However, the combination of both standards represented in OWL to describe learning resources and also explore possible logic inferences is still under research and development, and it is explored in this paper. The OWL representation of LOM is not considered a problem since its set of metadata is well defined and limited. However, as MPEG-7 is too large and generic, it is difficult to represent all its features in greater details in a single ontology. Therefore, it is generally considered a core subset of the MPEG-7 specification. Particularly, the work presented in this paper concerns to Multimedia Description Schemes (MDS), which comprises one of the parts of MPEG-7 specification containing the metadata related to the segments’ definition process. Figure 1 - shown above - presents an example of an ontology for MPEG-7.

It is important emphasize that there is a proposal for representing LOM as RDF [Nilsson et al 2003]. However, while RDF and RDFS are commonly used Semantic Web standards, neither is expressive enough to support formal knowledge representation that is intended for processing by computers. Most notably, it doesn't allow expression of constraints and it has few descriptors to make extensive inferences. OWL is based on description logics (DL), which are a family of class-based (concept-based) knowledge representation formalisms and this is an important propriety which makes OWL an appropriated language to allow inference tasks.
For the particular case of this paper, the main objective of a LO’s description ontology is to enable the creation of semantic representations of the LOs’ content in order to allow the retrieval of specific parts of this content. Once there are already developed ontologies comprising parts of the LOM and MPEG-7 metadata standards, in order to create a LO’s description ontology the first step is to select, from LOM and MPEG-7 ontologies, the necessary concepts to describe a specific LO’s content, according to an user need or interest. The idea is to provide both the LOM and MPEG-7 ontologies and make possible to an user to choose, from each one, the necessary elements in order to create his/her LO’s content description. So he/she will create a LO’s description regarding to his/her particular need through a friendly interface application. Figure 2 presents an example of a LOs’ description ontology created by a user. For diagram simplification, only some elements are represented.

According to figure 2 it is possible to see the metadata elements that were select by a user in order to describe a video’s content. This semantic representation is important since it is used to increase the effectiveness in content’s retrieval. The objective of this ontology is to provide a vocabulary that makes possible to explicit the content of a video asset as well as to describe it. In order words, it provides a way to define segments of the video’s content and describe these segments through educational metadata. Moreover, this ontology provides – through the LOM - a set of meta-relationships that could be used to specify relationships between different video’s semantic segments, allowing an inference mechanism to perform logic inferences in the
segments’ knowledge base. It is extremely important, however, that the LO’s description regarding to the LOM part refers the MPEG-7 part of this description. This could be accomplished through the “Location” metadata attribute considered in the “Technical” LOM metadata category.

4. Usage Scenarios of the Proposed Ontology

This section presents some situations in which the LOs’ content description ontology could be applied. The main objective is to demonstrate the advantage of using OWL to represent the semantic description of segments obtained from LOs. For this purpose, a general outline regarding the semantic structuring approach, which was proposed and demonstrated in [Oliveira et al. 2008a], is presented. Basically, this semantic structuring proposes a segmentation of LOs’ content, creating semantic segments. Figure 3 presents a general outline of this approach, considering a segmentation of a video content.

![Figure 3. LO's segmentation approach](image)

The segmentation approach uses the LOM and MPEG-7 standards. Through the first one it is possible to describe the educational characteristics of each segment. On the other hand, through the second one it is possible to, explicitly, define the initial and final point of the segments. Using the LO’s description ontology proposed in this paper, an user could navigate over the elements which composes the ontology, in order to perform both the segmentation of LO’s content and description of the segments. When navigating over the elements that compose the ontology, it is possible to see the description (comment) of each element, the vocabulary (recommend list of appropriated values) associated to the element (when this vocabulary exist) and also the relation between the various classes presented in the ontology, supporting the user in his/her description process. It is important to emphasize, however, that although some elements provide a defined vocabulary with recommend values, others values – not presented in the list – may be used as well, but just for some elements (e.g. LOM relation).

Although it is desirable to perform this description in a semi-automatic approach, in this paper it is considered only a manual process. However, future works have been planned regarding to the use of data mining in order to provide semi-automatic filling in metadata. This approach could represent an important support to the users in their description process by suggesting description data. Moreover, although this section presents a scenario using a video asset, the ontology was created in order to support the description of others different types of LOs (images, audio, etc.). The idea is to allow each user chooses the description elements according to his/her needs or interest.
Differently of the work present in [Oliveira et al. 2008a], this paper proposes to use both LOM and MPEG-7 represented in OWL. In fact, the main focus regarding to this paper is related to the relationships (which can be defined through the LOM metadata) that could be specified between different semantic segments. Describing these relationships using OWL is essential in order to allow performing inferences over different segments, making possible to discover implicit relationships between them. Actually, only describing LO’s content using OWL is not sufficient to perform inferences. In fact, it is necessary to use a set of logic rules which should be applied over the LO’s description in order to make possible discovering new facts, as presented in [Oliveira et al 2008b]. In this paper, the major interest is on discovering possible relationships between different semantic segments obtained through the segmentation structuring approach.

As a consequence of using the proposed LO’s description ontology, through a search application, users can perform searches for segments, according to their particular needs or interests and this application can use an inference mechanism (including a reasoner engine as well as logic rules) in order to perform inferences trying to discover segments that are semantically related to those presented as searches’ results. So, the OWL representation of LOs’ description allows a search engine not only to return segments according to the search’s parameters, but also to return other segments that are related to these ones.

Figure 4 illustrates some explicit and implicit relationships between different segments. The relationships represented through full lines stand for relationships that were explicitly defined during the segments’ description. On the other hand, those ones represented through dotted lines are relationships implicitly obtained through some inference mechanism in the course of an inference process – using both the explicit relationships and also a set of logic rules previously defined by an expert. A more detailed discussion regarding an inference mechanism is found in [Oliveira et al. 2008b]. In some situations, this inference approach could be desirable. This approach can, for example, support user’s learning process by presenting segments in a meaningful sequence that enables an exploratory navigation approach between the segments returned through the users’ searches.

5. Conclusions

This paper presents an ontology for describing content embedded in LOs. Moreover, discusses that, through an LO’s description ontology, it is possible to describe parts of LO’s content, making possible to retrieve these parts. In fact, nowadays, LOs are structured as multimedia files, which unable to retrieve only specific parts of LOs’ content. This means that, although the access and use of only parts of a specific LO
could be desirable, nowadays it is only possible to obtain an entire LO. Some usage scenarios of the proposed ontology were discussed. Through an ontology developed to describe LO’s content, a user can perform a segmentation process and create an OWL LOM/MPEG-7 description for each defined segment. Using the ontology development approach presented in this paper, an user can navigate over the classes and subclasses of LOM and MPEG-7 ontologies, choosing the relevant elements, according to his/her needs or interest, in order to describe LO’s content.

In relation to future works, some proposals are considered. An interesting approach refers to creating more detailed descriptions, considering pedagogical aspects, probably not considered in LOM standard. Another proposal is using ontologies regarding to IMS Learning Design in order to define a complete learning environment based and supported by ontologies. Other approach comprises the use of natural language processing in order to make the LOs’ description as automatic as possible.

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