SUPPORTING COURSE SEQUENCING IN A DIGITAL LIBRARY
Usage of Dynamic Metadata for Learning Objects

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Abstract: The production of interactive multimedia content is in most cases an expensive task in terms of time and cost. Hence, optimizing production by exploiting the reusability of interactive multimedia elements is mandatory. Reusability can be triggered by a combination of reusable multimedia components and the appropriate use of metadata to control the components as well as their combination. In the same way, digital libraries comprise vast digital repositories, a wide range of services, and user's environments and interfaces, all intended to support learning and collaborative research activities. In this article, we discuss the reusability and adaptability aspects of interactive multimedia content in a digital library's learning environment. We extend a component-based architecture to build interactive multimedia visualization within digital library's learning environment with the use of metadata for reusability and customizability.

1 INTRODUCTION

The rapid advancement in computer communications and presentation technologies produce new forms of media communications than can be used to increase the quality of educational documents for visualizing complex technical problems. To help student learn difficult concepts, interactive learning software needs specific capabilities for communication, administration, visualization and real-time data collection, as well tools for analyzing, visualizing and sharing digital data. Such interactive and dynamic digital data becomes part of a vast digital repository and also part of the wide range services that the digital libraries offer, all intended to support learning and collaborative research activities. These services and digital data have to be flexibly combined in many kinds of contexts: diverse classrooms presentations, tutorials, virtual spaces and standardized assessments. To archive this goal, the standardization of so-called learning objects becomes an important issue.

As stated in the specification of the IEEE's Learning Objects Metadata (LOM) (Roschelle et al. 1999), "a learning object is defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning". Examples of learning objects include multimedia content, instructional content, instructional software and, software tools referenced during technology-supported learning. In a wider sense, learning objects could even include learning objectives, persons, libraries, universities, organizations or events. A learning object is not necessarily a digital object; however, the remainder of this article will focus on learning objects that are stored in a Digital Library.

IEEE's learning object (LO) model is characterized by the belief that independent chunks of educational content can be created to provide an educational experience. This approach assumes that these chunks are self-contained, though they may contain references to other objects and maybe combined or sequenced to form longer (larger, complex, other) educational units. These chunks of educational content may be of any type, interactive (e.g. videoconference) or passive (e.g. simple video), and they may be in any format or media type.

Another requirement for learning objects is related to tagging and metadata. To be able to use such objects in an intelligent fashion, they must be labeled as to what they contain, what they communicate and, what requirements with regard

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the use exist. Hence, a reliable and valid scheme for tagging learning objects is necessary.

The LO model provides a framework for exchange of learning objects between systems. If LOs are represented in an independent way, conforming instructional systems can deliver and manage them.

These efforts gained leverage from the rise of interactive web technology and its associated emphasis on standards-based interoperability. Although the component-based solutions developed to date are useful, they are inadequate for those building component-based interactive learning environments in which the components must respond to the meaning of the content as well as its form and presentation. We see the development of techniques for sharing semantics across components and applications as a critical research direction for the field.

The approach described in this paper addresses in the issue of developing and customizing dynamic multimedia objects within personal and group spaces using dynamic metadata.

2 CONTEXT

To explain our starting point and to communicate the motivation for our work, we first present an overview of LeComm project.

2.1 The LeComm System

The LeComm project (Morales, 2002) currently under development, is a learner-centered Digital Library CSCL environment, where the learners have the advantages of using the integration of databases and search functions within a personal or group space the Digital Library provides. These virtual spaces provide learners the capacity to arrange and structure the digital material to suit their own needs and preferences. It is possible, of course, to use all material freely available on the net or in a Digital Libraries in different contexts. LeComm effectively utilizes and manages such digital material; and also provides activities like copying, transforming, indexing, storing, and keeping references in an appropriated virtual learning environment.

In the LeComm project, we have defined knowledge base as Web-based software tools that enable access of valuable information that is organized in a systematic and pre-designed manner in the distributed Digital Library's databases. Therefore, individually structured knowledge bases are provided in the form of personal and group spaces. The learners are then able to establish their own learning environment, in which they could, for example join and link documents from different courses and different digital libraries or places on the Internet to match their own learning path and knowledge level.

The LeComm's virtual space's success depends critically on a successful knowledge management. Knowledge assets are the knowledge that the LeComm's virtual space owns or needs to own to archive its goals. Knowledge equals information, extracted filtered or formatted in some way.

In LeComm project, knowledge can be divided into two types: "*tacit virtual space knowledge*" and "*explicit media space knowledge*". Tacit virtual space knowledge consists of the hands-on skills, best practices, special know-how, heuristic, ontology, intuitions, and so on. The transfer of tacit virtual space knowledge is by tradition and shared experience, through for example, apprenticeship, job training or expertise. Explicit media space knowledge is used in the design of routines, standard operations procedures, and the structure of data records. Explicit media space knowledge enables the Digital Library to enjoy a certain level of operational efficiency and control. Those forms of knowledge can be found in any Digital Library.

The LeComm learning environment however, is continuously expanding, renewing, and refreshing its knowledge in all categories. The role of the LeComm's knowledge is to promote the learning of tacit virtual space knowledge to increase the skill and creative capacity of its learners and takes advantage of explicit media space knowledge to maximize the learning efficiency. In effect The LeComm's learning environment has acquired a third class of knowledge - meta-knowledge - that it uses to create and integrate specific lessons tailored to a targeted Digital Library's group with all its intellectual resources in order to achieve high levels of learning. These lessons are created using a knowledge base of multimedia elements within the Digital Library. These lessons are created automatically by using learner's preferences and style (course sequencing).

LeComm architecture includes part of the knowledge base of the Digital Library which is necessary to implement the course sequencing, consist of two separated knowledge spaces. The concept "*tacit virtual space*" contains a networked model of learning topics (Fischer, 2000) and uses well-known approaches from knowledge management. The media bricks stored in the Digital Library's "*explicit media space*" are atomic information units in various formats. These units are interconnected via rhetorical relations and, each media brick is described using IEEE's Learning Objects Metadata (LOM) scheme. In the following sections we refer to media bricks as "*learning* *objects"*. Although both information spaces are separate, each learning object can have a relation to one or more related topics. The separation of both spaces is the way in which LeComm generates adaptive lessons, because a set of media bricks (documents, magazines, books, articles, papers, graphics, notes, audio, video, etc.) for each topic is available. Thus, the selection of media bricks is determined by each learner's preferences.

The general functionality of LeComm, in others words the generation of lessons, depends on the knowledge base stored in the *"tacit virtual space"*. -

This approach is similar to the standardization by IEEE, in that the IEEE proposes the use of knowledge library responsible for sequencing a lesson, while the actual compilation of the lesson is done by a delivery component (see Figure 1).

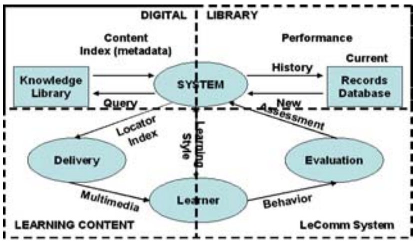

Figure 1: IEEE-LTSC adapted architecture.

To understand the automatic creation of exercises, it is essential to understand the setup of our meta-knowledge base.

The following order can be specified; taking into account the way that a teacher actually sets up a multimedia lesson:

The teacher acquires background knowledge from the Digital Library.

The teacher creates an outline for the multimedia lesson in his/her personal space.

The teacher fills the lesson's outline with the Digital Library content and, shares the virtual space.

These steps are modeled by different spaces in LeComm learning environment. The mechanisms for automatic creation of exercises are given as follows: LeComm system sends; receives and "negotiates" learning preferences and styles with the learner client.

LeComm system receives current assessment information, preferences, and performance information (history and objectives) for future learning experiences; It makes queries to the knowledge library and search for the appropriate material; the knowledge library returns the catalog info in the form of content index metadata as found learning content, extracts the locators index from the returned catalog info in the form of content index metadata; and makes a choice (a lesson plan) by invoking learning content. And finally, locators index are sent to delivery process to identify but not transfer learning content.

Here is very important to note that the delivery process is not responsible for retrieving learning content, and the knowledge library is responsible for transferring learning content.

The tacit virtual space contains ontology in terms of keywords, which is necessary for creating the outline of a lesson. After sequencing the outline (equally applicable to the creation of a table of contents), the real content like documents, magazines, books, articles, papers, graphics, notes, videos, their complements, and their links) are filled into the outline using elements of the second space, the Digital Library's explicit media space.

The general idea of LeComm in this point is that is necessary to employ different relations within the *"tacit virtual space"* and the *"explicit media space"* to model the different goals in both spaces.

When working with media bricks and the necessary educational metadata, an important disadvantage becomes obvious. Due to the way in which the history of metadata developed, static resources such images or text documents can be described properly; but an appropriate description of dynamic resources, for example multimedia objects like video and audio, are feasible only to a limited extend. The reason is that dynamic multimedia objects can process input parameters, generate output parameters, and also work internally with data that cannot be described with traditional metadata schemes.

2.2 Multimedia Content

Learning systems enriched with multimedia elements can be divided into two categories:

Learning objects are relatively simple, but are described by metadata in detail. A learning system operates on the metadata with intelligence.

Learning objects are very smart in that they change their behavior. A learning system has to pass on specific information, and each learning object has to adhere to a specific stipulated set of inputs and outputs parameters.

An example of the first category is the use of IEEE's LOM in the LeComm project to describe multimedia content (see Figure 2). However, multimedia content as part of a learning system can be text, graphics, audio, video and, Digital library's services.

In LeComm learning environment, we can identify learning objects as follows:

Multicode: Use of various symbols, for example, images, pictographs, texts.

Multimode: LOs make use of text, images and continuous media like video and audio.

Dynamic: LOs realize to some extend the interaction between learner and LeComm.
Interactive: LOs can address various senses: visual, aural, or both ate the same time.

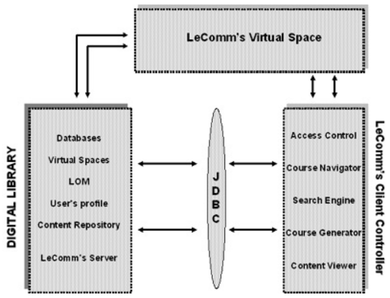

Figure 2: LeComm's lesson architecture

Figure 3 illustrates the above characteristics and their relationships. For example, an active map object belongs in the intersection between multicode and multimode. The common denominator of all these characteristics is what we refer to as *"smart learning object"* (SLO). Digital material such as audio and video that visualize complex procedures dynamically and interactively belong to the group of SLOs. Animated graphics, videos and audio are much closer to real life than still flat documents or graphics. Complex procedures can be experienced, understood and, learned by experimenting in the virtual environment offered by LeComm learning environment.

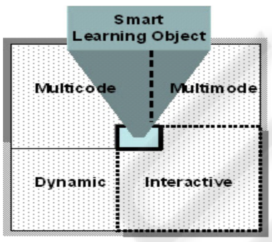

Figure 3: Learning object's characteristics

The behavior of smart learning objects can be changed, as well as adapted, according to parameters passed by the system. In the reminder of this article, we detonate interactive visualizations as *"SLOs"*.
One of the key problems in developing e-learning infrastructures in general and interactive instructional visualization units in particular is the integration of learner requirements that change over time. Learning systems must be flexible to adapt easily to new and changing user requirements.

2.3 Metadata for Dynamic Learning Objects

The existing technologies, standards and, ongoing initiatives for multimedia educational metadata are the starting point for our research. The Alliance of remote instructional authoring and distribution networks for Europe (ARIADNE, 2001), Dublin Core metadata element set (Dublin Core, 2002), Educom's instructional management system (IMS) (Educom, 2002) and, the IEEE's learning object metadata working group 12 are the most important initiatives dealing with metadata for computerized learning. These initiatives are closely related to the resource description framework (RDF, 2003), the warwick framework (Warwick, 2001), and to other activities of the world wide web consortium.
All the methods specifying metadata make use of it in the traditional sense of describing static data:
To summarize the meaning of the data. (what the data is about);
To allow learners to search for data;
To allow learners to determine if the data is what they want;
To prevent some learners (children) from accessing data, and;
To instruct us on how to interpret the data (format, encoding, encryption).
That is, the metadata descriptors are associated with the data sets in a fixed way. Their granularity is defined by the original metadata author.
A great drawback is that the application of metadata is mainly limited to content. Our first observation is that such metadata cannot adequately describe smart dynamic LOs. Metadata cannot influence the multimedia content itself, because metadata usually contain universal and widely applicable descriptions of objects. From our point of view, the use of dynamic multimedia LOs such audio and video objects require a new sort of metadata, which must be dynamic in order to facilitate the I/O behavior of a dynamic LO.

3 LEARNING EXAMPLE

Figure 4 shows the overall architecture of LeComm's SLOs tagging and customizing architecture. Digital Library's learning resources are tagged using LeComm's personal space (see section 3.1). For the storage of static and dynamic metadata, we use a relational database (see Figure 2). To access the data stored in the Digital Library, we developed a three-tier architecture using JDBC.

LeComm's learning environment allows modify interactive visualizations with the use of dynamic metadata. This *"customizer"* is used to modify smart learning objects for a lesson; we are then able to use these visualizations several times in the personal or group spaces, depending on the context, which is described in detail in Section 3.2. In Figure 4, smart learning objects are reused in different scenarios with different metadata sets to show various scenarios of the same topic.

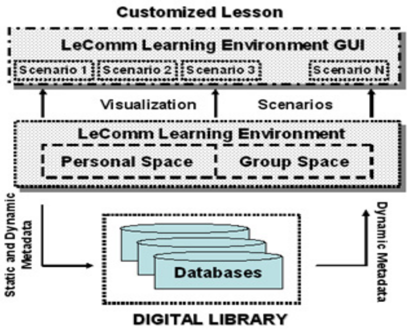

Figure 4: SLO tagging and customization process

3.1 Personal and Group Spaces

LeComm includes a concept that we call personal and group spaces, these areas are generated owned and maintained by learner persistently keep resource objects, or references to resources which are relevant to a task or set of tasks the learner needs to perform in the learning processes (Morales, 2000). In the following we describe the creation of static and dynamic metadata within personal and group spaces. These virtual spaces can also be used to publish metadata records for various Digital Library resources, e.g. documents, images; audio clips, video clips and interactive exercises. Figure 5 shows the relationship between the Digital Library's explicit media space and the LeComm's tacit virtual environment using metadata.

A metadata record consists of a set of elements that describes a multimedia resource. Examples of these elements are: creation date, type, author, format, title and publication of the resource.

To enable easy access and discovery of multimedia information resources, LeComm provides mechanisms to store and create LOM records based on the IEEE-LOM scheme version 4.0 in a relational database and can also be used to search the Digital Library's databases and to navigate the resulting metadata set. While working with personal and group spaces and using the base LOM scheme, LeComm quickly turned out that SLO can be described to only a limited extend. We extended this feature by adding an extra category showed in the (Table 1) for dynamic metadata that is not included in IEEE-LOM 4.0 scheme. This extra category includes specific parameter configuration of visualization; used to adapt the content of and object and/or to change the behavior of a learning object.

Tagging the Digital Library's source material with LeComm's personal and group spaces turned out to be an interesting experience. Most elements of a lesson apply the same basic metadata such as the author's name, copyright and, the targeted user group within the Digital Library. So it would be useful to have a set of templates to tag the Digital Library's material. With templates we can avoid filling a lot of fields over and over. For example, the owner fields, library's classification, browser requirements, object's representation and many others. In out current prototypical implementation, templates are used to stored information, which is then only typed once but can be applied multiples times.

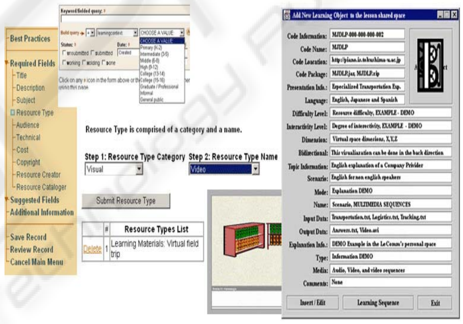

Figure 5: Publishing metada records in LeComm's personal and group space

Table 1: SLO proposed dynamic metadata

Property	Description
Code information	Digital Library SLO's code
Code name	Digital Library code
Code location	Where is located the SLO
Code package	Package name
Presentation Info.	How is presented the SLO
Language	Language of the SLO
Difficulty level	SLO degree of difficulty
Interactivity level	SLO degree of interactivity
Dimension	SLO visual dimension XYZ
Bidirectional	If the visualization can be done in the back direction or not.
Topic information	Topic to be shown in the SLO
Scenario	Scenario to be visualized
Mode	Teacher's intention
Name	Name of the scenario
Input data	SLO's parameters to start properly
Output data	SLO's output file
Explanation Info.	Kind of explanation required for the SLO
Type	List of possiboe explanation types
Media	Possible media types to be used
Comments	Teacher's comments

3.2 Usage Example

To be able to reuse the same content in different scenarios that is the basic functionality that enables dynamic metadata to operate; the LeComm learning environment requires that both LOM and SLO proposed dynamic metadata schema exist concurrently, as they are both involved in the learning process. Indeed, whereas in the explicit media space's LOM receives, processes and sends the original request negotiation to the LeComm, the LeComm's tacit virtual space gets the actual metadata to its extended metadata schema and creates the meta-knowledge that we called SLO. Here the SLO's description plays an important role due that each SLO contain all necessary information for a specific lesson in different scenarios.

4 CONCLUSIONS AND FUTURE WORK

In this article we discuss the reusability aspects of multimedia content in a Digital Library's web based e-learning system. We highlight the necessity for developing component-based interactive multimedia visualization units within personal and group spaces. We suggest the use of metadata for reusability issues. The main contribution of this article is an extension a component-based architecture (IEEE's learning objects metadata) to enable it to describe dynamic multimedia learning objects in a Digital Library, which we refer to as meta-knowledge - "smart learning objects" -. Traditional metadata that describe learning objects are well suited for describing static elements (text and images), but do not take the dynamic nature of multimedia element into account (specially audio and video objects). Hence, we compare various learning metadata standards and derive an extension to solve the problem.
The LeComm's metadata-based framework in our article also addresses the customization of smart learning objects by metadata. Having explained dynamic metadata, we described our implementation in the LeComm's personal and group space for tagging, storing and, customizing smart learning objects. As a Digital Library prototype, we implemented visualizations artifacts dealing with the teaching of the english language in the supply chain management area in an specific company provider explanation. We currently use our framework to develop other language teaching lessons within our Digital Library, for example, Japanese, English and Spanish multimedia lessons to explain specific problems in the area of computer sciences.
The research described here differs from other related work, in that the set of dynamic metadata items in the Digital Library's personal and group spaces can be defined for smart learning objects is open-ended and not fully predefined. When the learners add new metadata or schemas, the changes are automatically reflected through the LeComm learning system. Predefining all attributes would hinder the support of multiple applications as we already mentioned. Instead, learners are allowed to create whatever metadata records are necessary to support the object customization process, together with a necessary base set of predefined parameters in the virtual space describe dynamic resources.

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