CD-LOMAS: A COLLABORATIVE DISTRIBUTED LEARNING OBJECT MANAGEMENT SYSTEM

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Abstract: Learning Objects are stored in repositories and spread through Internet. The educational sector needs to share good quality educational contents, which can be reused and adopted in several contexts. In this paper we present CD-LOMAS (Collaborative Distributed Learning Object MAnagement System) to support the sharing of contents and the collaboration on their development in a highly distributed environment. Complex Learning Objects are decomposed into simpler Learning Objects that can be distributed at different sites. In CD-LOMAS artifact management features, such as coordination of cooperative workers and versioning, are integrated with context-awareness.

1 INTRODUCTION

The growing of Internet has had as a result the rapid development of the on-line distance learning. Many faculties in the entire world are creating digital contents which are stored in Content Management Systems (CMSs) and spread through the servers of the various educational organizations. These contents are stored and handled in systems requiring different access characteristics, usually with different logins and differently structured. In this way it is difficult to retrieve and exchange contents.
Today the main challenge in the e-learning research sector concerns to let the digital contents more accessible, usable and exploitable, as stated by the European research program (eContentplus, 2005). The actual trends is to create on-line contents which are brief, last at most 20 minutes (ADL, 2006; IEEE LTSC, 2006; IMS, 2006) and including (De Lucia et Al., 2006):

- text, graphics and movies
- a navigational schema
- assessment and self assessment.

This modularization of the contents has lead to the Learning Objects (LOs), elementary members on the technological and educational plan enabling the modular composition and the reuse of the base units in the various contexts. The vision of the content fragmented in LOs requires specific units of content providers, the Learning Object Repositories (LOR). The essential functionalities of a repository are: storing, searching and maintaining LOs. In order to enable the search and the re-use of the LOs various international organizations have contributed to the definition of a standard for the Learning Object metadata (ADL, 2006, IEEE LTSC, 2006, IMS, 2006). The Advanced Distance Learning group (ADL, 2006), sponsored by the Department of the Defense of the United States, has supplied a great contribution to this objective creating a set of specifications called Shareable Content Object Reference Model (SCORM) with the aim to standardize the contents of e-learning which can be created using various programming languages and can be placed in different computers, scattered in various parts of the world. SCORM enables to classify the Learning Objects by using LOM metadata – Learning Object Metadata. In this way, it is possible to create repository of multimedia contents that can be searched through sophisticated indexing systems and exchanged between the repositories.
An additional factor to consider is that LOs have different granularity and can be aggregated until composing entire courses. Consequently, they can be the result of the cooperation of various individuals. Thus, Configuration Management is also required to handle LOs in a cooperative manner. Tools

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supporting Configuration Management for software systems, such as (CVS, 2006, De Lucia *et Al.*, 2004, RCS, 2006, Perforce, 2006, Rational ClearCase, 2006) help to coordinate the activities of the developers, supporting or avoiding the parallel development through policies of locking or assisting them in the conflict resolution through the merging. The capability to add these functionalities to a Learning Content Management System (LCMS) enables organizations to cooperate in the repository creation and in the sharing of LOs. If several organizations need to cooperate in the creation of a distributed repository, we have to manage the versioning of LOs at different granularity levels and support context awareness in such a way to know who is using or changing a LO. These problems grow together with the growing of the on-line learning community which requires ever and ever the management of the Learning Object Sharing. In this way it is pursued the goal of avoiding the duplication of the work by creating a unified content strategy (Rockey, 2002).

In this paper we present CD-LOMAS (Collaborative Distributed Learning Object MAnagement System) an on-going research project aiming at designing and developing a Web system for the management of LOs distributed on several sites. In particular, the aim is to enable the sharing of contents represented using the standard SCORM and the collaboration on their development, supporting their reuse at different granularity level. The project also aims at providing context awareness to content authors that share the learning material, as in the case when a course is articulated in two parts, such as laboratory and theory, or implicitly in case of teachers of parallel classes of the same university, of different universities, or of course at different didactic levels, such as in case of first and second degree levels. Context awareness is granted by notifying the interested people when an updating of a LO occurs, without generating an overload of messages. CD-LOMAS also supports the LO revisions for granting that the produced material is of the required quality.

The remainder of this paper is organized as follows. Section 2 discusses related work. Section 3 presents an overview of CD-LOMAS, while Section 4 describes the proposed architecture. Section 5 presents how CD-LOMAS supports cooperation and collaboration, while Section 6 discusses concluding remarks and future work.

2 RELATED WORK

Many Learning Object repositories are available on the Web. In particular, the Multimedia Educational Resource for Learning and Online Teaching (MERLOT, 2006) repository is one of the first (1997) and famous management system of LOs. It is managed from the University of the State of California and has links with thousand of LOs of several types, such as interactive applications, presentations, and examples. The use of MERLOT is free and the inclusion of a Learning Object is subordinated to a peer review phase before being accepted. MERLOT stores only the metadata associated to a Learning Object and not its contents. Another important repository is the Campus Alberta Repository of Educational Objects (CAREO) created by three American universities: the University of Alberta, the University of Calgary and the University of Athabasca. Differently from MERLOT, it also stores the contents of LOs. Both MERLOT and CAREO do not enable to recombine Learning Object at various levels of granularity. The (eduSource, 2006) project, currently ongoing, aims at creating a net of interoperable learning object repositories. It involves several universities, governmental institutions and industries. The repositories communicate through the eduSource Communication Layer (ECL) (Eap et Al., 2004). The initial phase has concerned the definition of the Web services and of the protocols necessary to enable the various institutions to communicate.

Features for generating and managing LOs in SCORM compliant format are provided by two open source tools, such as (RELOAD, 2006) and its web version, (WELOAD, 2006). Both systems handle a centralized repository.

(Hossain et Al., 2004) proposed a three-tier architecture which enables the 3D navigation of distributed learning object repositories. No collaboration among multiple users is provided. Single users can author LOs aggregating them in SMIL format. LOs do not follow a specific standard.

(De Moura et Al., 2005) use Web Services for integrating heterogeneous Learning Object repositories. The proposed approach is based on mediators and wrappers. Data sources are autonomous and heterogeneous (RDBMS, OODB, XMLDB, files, etc.). Ontologies are used to represent the mapping rules between a global common schema and the local schemas.

3 CD-LOMAS OVERVIEW

CD-LOMAS is a distributed environment supporting the cooperative handling of learning objects. It allows the distribution of LOs among different sites. In this way it is possible to create a virtual community which cooperates in the production of the learning material and interact as all authors were in the same place. In particular, CD-LOMAS supports content authors in the creation of LOs using cooperation or collaborative authoring. The first approach enables authors to interact only during the revision process and each authors produces its own individual content. Differently, in collaborative authoring the concept of ownership becomes irrelevant and authors work together.

CD-LOMAS enables the composition of a LO, supporting the reuse of existing LOs spread among the various repositories. Authors are assisted in creating and updating LOs following the standard SCORM and in sharing information.

The proposed system has been designed starting from two open source applications, (RELOAD, 2006) and its Web version, (WELOAD, 2006). In particular, CD-LOMAS reuses the features offered by these applications for composing LOs, for inserting the associated metadata and for browsing LOs. These features have been extended with the capability of performing these operations also when the component objects are scattered on different CD-LOMAS repositories of the network.

CD-LOMAS emphasises the LO life cycle by associating the users with the different operations they can perform on each LO. This feature, together with the resource permissions definition and management, enables to reuse existing LOs and to cooperate in the creation of new materials. The owner of a Learning Object can describe the permissions related to it, and provide different kind of usage for several users.

Quality management is also supported by associating each LO with a standard template and an inspection checklist to be validated during the review process. Each template can be customised for a specific LO.

The support for cooperation is provided through typical configuration management features. In fact, CD-LOMAS enables groups of people to work on the same LO, depending on their roles. Different users can access the same LO according to a lock-based policy or concurrently, if branch versions of the same LO are allowed by the LO owner.

Moreover, the system has been enriched with features to deal with some of the most common problems faced by cooperative environments, in particular context awareness and communication among users. A first context-awareness level is given by the possibility to see at any time the people who are working/using a LO. Context awareness is supported through event notifications: teachers using a LO are notified whenever relevant events happen to such LO. An example of such events is the creation of a newer version.

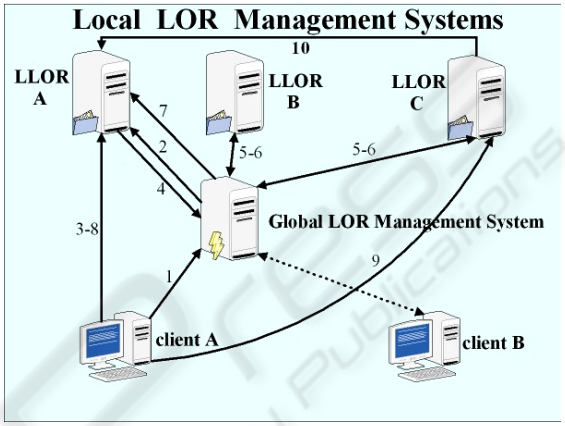

Figure 1: The CD-LOMAS architecture.

Events notification provides a solution to the isolation problem for resources working on the same LO in different workspaces (De Lucia *et Al.*, 2004). In fact, context awareness allows to identify potential conflicts before they occur, because the system is able to notify interested resources as soon as a LO is checked-out and potentially before substantial modifications have been applied to it.

4 THE PROPOSED ARCHITECTURE

The CD-LOMAS architecture, as depicted in Figure 1, is composed of two kinds of systems: the *Global LOR Management System* (GLOR) and the *Local LOR Management System* (LLOR). This two level architecture allows the access to learning materials distributed among several LLORs by referring only to a GLOR. Hiding to the user the structure of the network enables to easily add new nodes, obtaining scalability by distribution.

The basic functionality of a LLOR is to store learning objects in a SCORM format.

The GLOR assigns to each teacher a workspace, an area reserved to him/her, where (s)he manages the contents to create courses in a cooperative or

standalone way. The workspace is allocated on the nearest or less overloaded LLOR.

The GLOR supervises the access to the resources stored at LLOR level. In particular, the GLOR system manages the LOs lifecycles basing on events generated during the cooperative or standalone LOs creation process. It also enables users to search the distributed repository and to access, depending on the user permissions and role, to the required LOs.

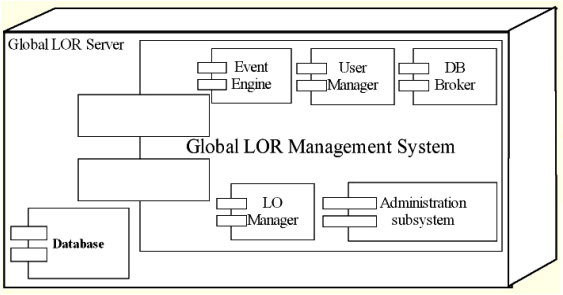

Figure 2: The CD-LOMAS Global LOR Management System.

In particular, as depicted in Figure 2, the Global LOR Management System is decomposed into five subsystems:

- The *LO Management subsystem* which poses a great emphasis to the LO life cycle by associating to the user the different operations that can be performed on a LO and the role assignment, such as *content creator*, *reviewer*, *approver*. It is responsible of the critical functionalities needed to perform effective collaboration in authoring and using LOs: access to shared information, check-in and check-out, locking and version control. Moreover, the LO Management subsystem provides support for the definition of LO types with related standard templates and for a checklist-based inspection and review phase of the LO life cycle.
- The *Event Engine* has in charge of collecting and dispatching events concerning a LO. Users can subscribe particular events concerning LO and courses (such as the production, updating or deletion of a LO, or the publication of a LO on a given subject), thus increasing the context-awareness level. The Event Engine notifies interesting events to the subscribed users of the CD-LOMAS system.
- The *User Management subsystem* manages users, their access permissions on different LOs and their roles in accessing CD-LOMAS services.
- The *Administration subsystem* provides several administration features, such as adding or deleting a LLOR, security and reporting.
- Access to the database is achieved through the functionalities offered by the *Database Broker*, which accepts queries from each client, forwards these queries to the databases on the LLORs, collects the results and returns a ranked list to the user.

The *Local LOR Management System* stores LOs and courses and contains the teachers workspaces. When a LO is ready to be published it is transferred in the course repository of the teacher, locally handled, and is available to be deployed.

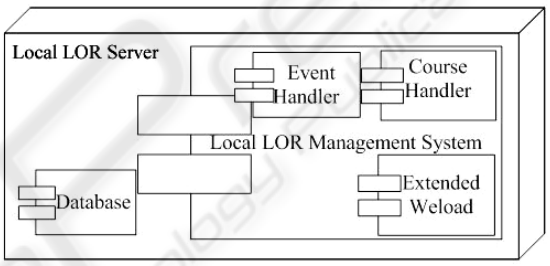

Figure 3: The Local LOR Management System.

This system provides two web services: the retrieval of some LOs, the browsing of the LO catalog. The access of a logged user to its workspace is performed using http protocol.

As shown in Figure 3, it includes the *Extended Weload* component which has been obtained extending RELOAD and its Web version, WELOAD, as described in Section 3.

Each user can compose LOs into a personal workspace, using the LO Editor offered by the Extended Weload component. This editor enables the composition of a SCORM LO using local assets, local LOs or existing LOs spread trough the network.

Figure 4 shows the screenshot of the Extended Weload feature enabling to compose a SCORM package. The required standard Metadata are manually added to the object description.

The *Event Handler* subsystem is responsible of generating and dispatching events about LOs. Events are used to signal the GLOR about the life cycle of a LO, and to enforce the user context awareness about interesting LOs.

The LLOR also includes the *Course Handler* component, providing simple LMS features to

compose a course by selecting LOs available in the user workspace or hosted on other LLORs.

An example of a scenario of the system usage is the following, referring to Figure 1:

1. the client A logs in the GLOR;
2. the GLOR, depending on the user permission, gives to it the access his/her workspace on the LLOR A;
3. The user composes a LO using the extended Weload Editor and asks to access to a LO on a selected subject;
4. the LLOR address the query to the GLOR Database Broker;
5. the GLOR Database Broker forwards the query to the databases on the LLORs;
6. the GLOR Database Broker collects the results;
7. GLOR Database Broker returns a ranked list to the user LLOR;
8. the user selects a LO hosted on LLOR C;
9. the user plays the selected LO by using the LO player of the LLOR C;
10. The user download the LO in its workspace hosted by the LLOR A.

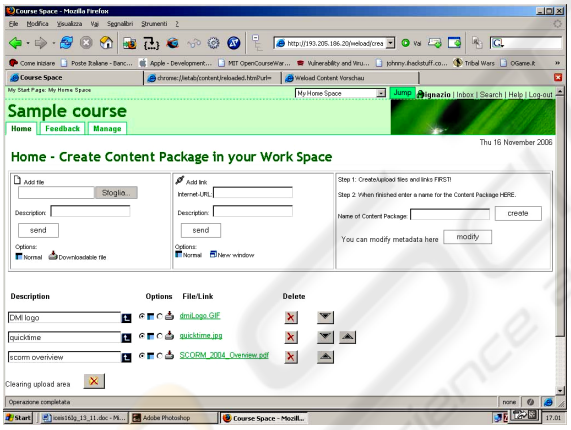

Figure 4: SCORM Content Package creation.

5 SUPPORTING COOPERATION AND COLLABORATION

The administrator of a learning organization can define several LO types according to the standards provided by CD-LOMAS. This enables the content authors of an organization to produce the same kind of LOs. Besides a standard template, a checklist can be associated to a LO type and used during the review phase of a LO of that type. The adoption of a review phase assures that the repository contents are only LOs having good instructional value. Reviewers can be assigned manually by the GLOR administrator or automatically by selecting them from a reviewer list depending on the LO subject. The subject of a LO is taken from a thesaurus.

Critical factors to effective collaboration includes check-in, check-out, locking and version control.

CD-LOMAS LOs follow the general life cycle depicted in Figure 5. The owner of the LO uploads the template and the checklist selected by the administrator of the learning organization. He /she defines permissions of resources to work on the LO and activates it.

Once a LO is *activated*, several draft versions of this LO can be created and maintained. When a LO is *scheduled*, the LO owner can decide if branches are allowed during its production. If branches are not allowed, each resource can lock the LO (*check-out*) and work on it until a new version is uploaded and *checked-in*. Otherwise, different *branches* can be produced and worked independently by each resource, which can also produce different versions of each branch. When all branches are closed, they can be merged in a new version of the LO. Completed non-branch versions of a LO undergo the revision process and are either *approved* generating a baseline or sent back to the *draft* state.

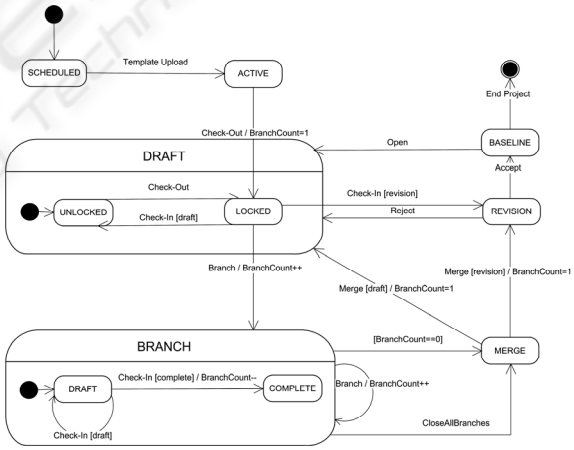

Figure 5: Learning Object lifecycle.

In Figure 6 the LO card is shown, describing information concerning the LO name, its status, whether branch are allowed and the number of branches currently active. During the Check-In operation it is possible to import a LO from the user workspace, from the distributed repository, or to upload a new object in standard SCORM from the local computer. Whether the imported file does not respect the standard SCORM an alert message is provided.

Figure 6: LO Card and Check-In source selection.

5.1 Handling Object Permissions and Composition

When a LO is checked-in the LO owner decides the permission (s)he gives to other systems users. In particular, (s)he can decide to globally share a LO with all other users, or only with a specific subset of global roles (i.e., teacher or students) or (s)he can fix local users roles that can access the owned LO (i.e., students frequenting his/her course). The LO owner can also assign to each role several reuse capabilities, such as *locked reuse*, the LO is reused unchanged, *derivative reuse*, the LO can be downloaded in the user workspace and modified, and, finally, (s)he can allow only to receive the description of the object in a ranked list. In the last case the system provides support to the interested user in asking the permission to use or reference LOs to the LO owner. The LO owner finds the request in a Feedback section of its workspace.

It is important to point out that the system offers several permission possibilities, but to success in applying a unified content strategy (Rockley, 2002) authors should work together and no own any part of an object. When several authors decide to cooperate in the creation of an entire course with other authors, a course project is created by one of them and a collaborative workspace is associated to the team. All members can create LOs in this space. In this environment authors work together aiming at ensuring that content is not written more than once by more authors. Check-in, check-out, event notification, locking and versioning are still applied, but all the users have the same permissions on the objects of the team.

Concerning the hierarchical composition of a LO, several fine grained configuration management systems have been proposed in literature, such as Coop/Orm (Magnusson and Asklund, 1996), CoEd (Bendix et Al, 1997) and ADAMS (De Lucia et Al., 2004). Similarly to ADAMS, we handle composite LOs by using hierarchical dependencies.

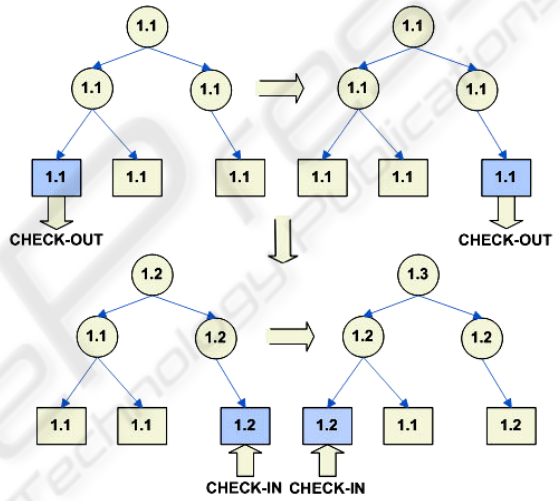

Figure 7: Versioning of composite Los.

When a LO is created, it can be composed using existing LOs spread on the various LLORs. Following the definition of LOs described in the standard SCORM, leaves are associated with assets, while internal nodes define LOs. Therefore, operations that can be performed on internal LOs just aim at modifying the LO composition (adding/deleting sub-LOs). Operations on internal LOs cannot be performed in branch mode; rather, each time an internal LO is locked for an updating operation, sub-LOs are locked too as well as higher level LOs. As shown in Figure 7, each time a new version of a sub-LO is created, a new version of higher level LOs is created too, to maintain consistency and record the operations made on each LO.

This approach enables the cooperative development of learning contents. Indeed, each user is able to access a LO component without locking the entire LO or using superfluous branches.

CD-LOMAS also supports LO reuse when a LO is checked-out from a user different from the owner

with the permission of derivative reuse. When the object is checked-in the user of the new object can create a *variant* of the original object whether there exists a small number of differences between the two objects and metadata do not have been substantially modified. Differently, if the modifications are substantial a new object is created with a new owner.

Let us note that a SCORM LO is packed in *zip* format. To reuse and compose LOs structured as zip packet is complex. Thus, we decide to entirely apply the standard, but to store the LOs without pack them. The components of a LO are stored in the local Database and the packet is created only when the LO is exported.

5.2 Supporting Context Awareness

One of the most common problems faced by cooperative environments and distributed development teams concerns the context awareness. Even when supported by configuration management tools, such teams quickly suffer of the isolation problem occurring when different people are involved in the development of the same (or correlated) LOs within different workspaces. CD-LOMAS supports context awareness to enables the teacher community to create shareable contents. In particular, context awareness is mainly supported through event notifications: i.e., messages generated in response to specific events triggered by one of the subsystems of CD-LOMAS.

Event notification in CD-LOMAS adopts a publish-subscriber paradigm: as soon as an event concerning a LO occurs, the users who subscribed such event are notified. CD-LOMAS increases the context awareness without overloading a teacher or a learner with useless event messages. To this aim, a user can selectively specify the events concerning a LO (s)he needs to be notified of. In particular, (s)he can require to be informed about events having a direct impact on the LO (s)he is working on, or events concerning all the LO referring to a specific topics, as well as on specific LOs. (S)he can also requires to be informed when variants of a LO is checked-in. To avoid a message overloading CD-LOMAS offers the possibility to select the right level of notification needed by the users.

As an example, in order to prevent the isolation problem, a teacher can choose to be notified as soon as LOs (s)he is interested in are allocated or checked-out, but (s)he can also be only interested on meaningful changes applied to other teachers LOs, or in changes that impact on object referred in his(her) course space.

In this way the notifications are targeted on the specific user needs still minimizing the number or subscription requested to the learning content authors/users and the number of unimportant messages they receive, resulting in a good compromise between an adequate context-awareness level and an endurable quantity of messages received.

By default, all the LOs allocated to a content author are intended to be fully subscribed (all events concerning the LO are notified), whereas all the other LOs are intended as unsubscribed. However each author can override such behaviour specifying for each LO the most appropriate notification level.

6 CONCLUSION AND FUTURE WORK

In this paper we have presented CD-LOMAS, a system for the management of distributed Learning Object Repository. The main feature of the system is the possibility of cooperate in the creation complex Learning Objects choosing the elements to be composed by searching the didactic material available on other CD-LOMAS sites. Event-based notification provides support to the teachers that want to be informed on modification made on user interesting learning objects, improving context-awareness.

A CD-LOMAS prototype has been implemented using PHP and Mysql. A configuration composed of one Global LOR and two Local LOR on different PCs is going to be experimented. In particular, we are adopting CD-LOMAS during the three parallel classrooms of the Software Engineering course offered by the Computer Science Program of the University of Salerno. Two of them have been located on the same Local LOR.

The adopted distribution strategy depends on the frequency and locality of references to LOs. The preliminary experience reveled that updating of local LOs are more frequent than searching or downloading of LOs on different LLOR. We plan to experiment the proposed system on a more large scale, involving other universities as users and content providers and to verify the network workload.

Because the LMS features offered by the system are very simple, we are going to integrate the CD-LOMAS in Moodle (Moodle, 2006) by creating an ad hoc plug-in. In this way the community of user and the production of contents will grow more

quickly. We also plan to enhance the searching capabilities by using more advanced information retrieval models and techniques.

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