Requirements to ensure interoperability between learning object repositories

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Abstract - There is currently a great proliferation of learning object repositories, the main objective of which is to reuse the teaching content they contain. Whether putting together the content, implementing the repository or deciding upon the search system to be used, compliance with a series of standards and specifications is necessary if these repositories are to work properly. This article analyzes the chief standards and specifications in the ambit of interoperability between learning object repositories.

Keywords: e-learning, repositories, interoperability, standards, specifications.

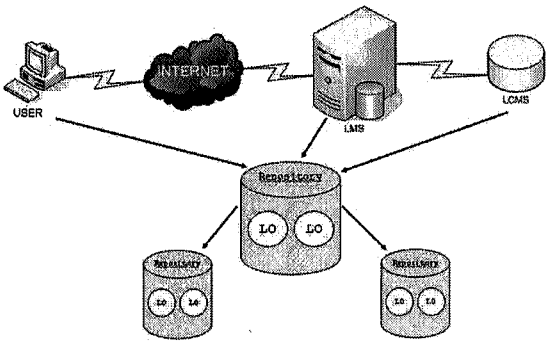

Figure 1. Repositories of learning objects.

1 Introduction

Digital repositories, in the broadest sense of the term, are used to store any sort of digital material. However, digital repositories for learning objects are much more complex in terms of what needs to be stored and how to store it. The purpose of a digital learning object repository is not simply to store and distribute learning objects, but to allow them to be shared by different users and, above all, to make it easier to reuse them in different training activities (figure 1). From the point of view of users, the advantage of these repositories consists in having access to the content deposited in them. For this to be possible, the content must be put together by means of certain procedures, norms and standards whose application is aimed at encouraging the reuse of the learning objects. Moreover, the repository itself must follow a series of specifications and standards which enable the content it stores to be searched and facilitate interoperability with other repositories.

In what follows, we describe the main standards and specifications from an interoperability perspective, as well as their classification and the relations between them. Table 1 summarizes the norms which are most important and which would be used to guarantee interoperability and the reuse of learning objects in repositories.

Table 1. Relation of standards by categories

CATEGORY	SUB-CATEGORY	STANDARD
LO		
	Metadata	IEEE LOM
	Packaging	IMS CC
	Resources	IMS RLI
	Vocabulary	IMS VDEX
SEARCHES		
	Interoperability Repositories	IMS DRI
	Query interoperability	CEN SQI
	Publication interoperability	CEN SPI
ARCHITECTURES		
	Framework	IMS AF
SERVICES		
	Data exchange	IMS LIS

	Interoperability	IMS GWS

2 Interoperability

The IEEE defines interoperability as the ability of two or more systems or components to exchange information and to use the information exchanged [1]. In the field of learning object repositories, there are specifications and standards (hereinafter "norms") which enable the exchange of the teaching contents they store and consequently achieve the reuse of those contents in different training projects.

These norms may be classified as follows:

1. Norms geared towards building and defining the learning object itself, that is to say, its content and metadata.
2. Norms geared towards the search for learning objects by making it easier to locate resources in different repositories.
3. Norms designed to assist in the design of repositories whose aim is interoperability and which therefore specify software architecture for their construction.

The following sections identify the main norms to be found in different institutions and the relation between them.

3 Learning objects

The norms in this group may be classified into two types:

1. Those designed to define the learning object's metadata.
2. Those designed to package the learning object.

The chief norm to follow when describing the metadata of a learning object is LOM [2], the standard as defined by the IEEE in 2002. This norm has given rise to various variations or adaptations for particular countries such as: CanCore [3], UK LOM [4], LOM ES [5] or Vetedata [6].

Also worth mentioning is the Dublin Core Metadata initiative [7] which uses a reduced number of fields to describe a digital resource. This concept of working with a subgroup of the most important fields is being used increasingly since in most cases not all the LOM fields are used to describe a learning object and a choice has therefore to be made of the most significant ones.

As for packaging, at present the two most widely used norms are SCORM [8] and IMS Common Cartridge [9]. These norms offer the content creator guidance as to how to group the date with the metadata in such a way that the learning object proves to be reusable.

Both SCORM and IMS Common Cartridge have been evolving over time: the latest version of SCORM is the third edition 2004 dating from 2006; IMS Common Cartridge, which is more recent still (2008), is a group of norms defined by IMS which have been put together to form a new one known as Digital Learning Services Standards. These standards are:

- Organizing and distributing educational content (Common Cartridge – CC)
- Applications, systems and mash-ups (or hybrid Web applications) (Learning Tools Interoperability – LTI)
- Information about learning: privileges and results (Learning Information Services – LIS)

The new norm is based on pre-existing specifications:

- IEEE LOM (metadata)
- IMS Content Packaging v1.2 (content packaging)
- IMS Question & Test Interoperability v1.2.1 (assessment questionnaires)
- IMS Authorization Web Service v1.0 (access authorization)

With this standard IMS has opted to simplify as far as possible and leave aside most optional features and extensions. Thus, only the fifteen Dublin core elements are used for metadata (mapped to the corresponding LOM elements), while as far as QTI (IMS Question & Test Interoperability) is concerned, only the six types of most common questions are taken into consideration. On the other hand, new features have been added where they were thought necessary:

- A new type of resource for starting up a debate forum.
- An authorization protocol (IMS Authorization Web Service) permitting the package editor to control access to contents.

In July 2004, IMS drafted the IMS RLI (Resource List Interoperability [9]) standard. In general terms, this norm determines the optimal way to organize, describe and exchange lists of course resources, for example, bibliographies. The norm is based on an abstract behaviour service and on a data model which offers a general description of a resource at the level of an item, of a collection of resources (a list), and of the behaviour associated with an RL (resource List) administration service or RLM (Resource List Manager). It is worth emphasizing that the specification plays no part in the way resources are stored, but is only involved in the interoperability between systems with data packages. On the other hand, given the fact that a single system for bibliographical resource description will never be achieved, it is proposed that LOM should be mapped to the citation systems most common between libraries and publications.

The data model comprises a minimum group of elements for citing printed publications. It rests on the standards which already exist for specifying and exchanging such metadata:

- For metadata it uses LOM, through IMS LRM (Learning Resource Meta-data) [9], combined with ISO 690-2 for bibliographical references to electronic documents.
- As locating schemes, it proposes the use of OpenURL [10], DOI [11] or PURL [12].
- IMS CP (Content Packaging) is used for packaging and transferring lists between systems.

Finally, worthy of note is IMS VDEX (Vocabulary Definition Exchange [13]), a norms which dates from February 2004. This norm defines an XML-based format for exchanging lists of different types of values which are used as a source of the vocabularies employed for labelling metadata. In this regard, two different word categories are taken into account which are distinguished from each other by the key used to identify a concept:

- Vocabularies where the key is some kind of token, which refers effectively to some term from human language.
- Vocabularies where the key is a term from human language.

The types of data used in LOM and in most IMS specifications are tokenized terms. However, terms from human language are also used when classifying. Thus the specification carries the description of the most widespread ways of defining values for metadata labelling:

- The description of controlled vocabularies/terms which are expressed as source-value pairs.
- The description of hierarchical vocabularies or taxonomies.
- Thesauruses.

A specific IMS VDEX profile exists for each of these types of vocabulary description [14].

4 Searches

One of the basic pillars of interoperability between learning object repositories is the ability to search their contents. Recently, search systems have evolved from only working in one repository to working simultaneously in various distributed repositories; this is known as "federated search".

Into this category falls a series of norms assisting search systems which make interoperability easier. The first to appear, in 2003, was the IMS Digital Repository Interoperability [9]. This is a benchmark model, proposed by IMS, for access to different repositories. The model is made up of different types of users carrying out searches in repositories by means of the access mechanisms offered by the repositories themselves and based on different technologies and languages of consultation (for example, SQL, Z39.50, XML-XQuery, etc.), or through intermediate search systems.

But since this norm was put forward by IMS, search technology has developed fast, and today the searches in most common use are calls to Web services which deploy federated search systems. Good proof of this is to be found in the SQI norm [15].

SQI was defined in 2005 by the CEN (European Committee for Standardization). It forms part of a public initiative known as the CEN/ISSS Learning Technologies Workshop whose job it is to guarantee interoperability between learning object repositories. Thanks to these efforts, three APIs (Application Programme Interface) appeared:

- Learning Object Interoperability Framework. This is a framework which defines the form to be taken by the communication process between repositories, and the group of technologies which may be used for the purpose.
- Authentication and Session Management. This specification focuses on the definition of the process for setting up the session between repositories.
- Simple Query Interface Specification. This is an API which enables queries to be made about learning object repositories.

SQI uses XML as the language for receiving information requests and for returning the results. SQI currently accepts two languages for the purposes of queries:

- VSQL: This is the simplest language for queries and is accepted by all platforms or systems which use SQI. In a query, this language is used to send a list of terms. It does not accept logical operators or expressions of any kind.
- PLQL (ProLearn Query Language): This has been created with the specific intention of standardizing the queries made of repositories. It defines the right syntax for sending a query about a repository by defining the data format, operators (AND, OR, equals sign, etc.), and even the way to group operands together (numbers only, small letters only, vowels, etc.). It has various levels of complexity ranging from zero (equivalent to VSQL) to five; to date, only the first three levels are fully developed.

Finally, the SPI (Simple Publishing Interface) norm, also devised by the CEN deserves mention. This is an API for publishing data and metadata in a repository. It provides a simple protocol which is easy to implement and integrate in already existing systems. Among its main characteristics, worth highlighting are:

- SPI is neutral in regard of meta-information standards.
- SPI defines an abstract interface which admits semantic interoperability. The Web service link point which sets out the norm's details provides a way of linking this interface with a specific implementation, thus providing as well technical interoperability.

SPI defines the following methods:

- Create Identifier: This method is to be used to obtain an identifier for a new resource in the specified protocol.
- Submit/Delete Metadata Record: These are methods for inserting or deleting object descriptions respectively.
- Submit/Delete Resource: These are methods for inserting or deleting resources respectively.

5 Architectures

In this category are to be found other norms of interest in regard of interoperable repository design, in so far as they define what the architecture of the information systems that support them should be like.

In the first place, there is IMS Abstract Framework [9]. This is a framework covering the whole range of possible e-learning architectures which could be built on the basis of a group of services based on SOA (Service Oriented Architecture). Its focus is on the support of distributed training systems, and one of its principles is interoperability.

CORDRA [17] is one of the most detailed architectures. An open, standard-based model, it allows software systems to be designed which are intended for the discovery, sharing and reuse of teaching material through interoperable repositories. This model acts as a bridge between teaching materials and repositories; it only tries to identify and specify, but not develop, the appropriate technologies and the interoperability standards in order to combine them in a benchmark model. The activities of CORDRA are coordinated between ADL (Advanced Distributed Learning Initiative), CNRI (Corporation for National Research Initiatives) and LSAL (Learning Systems Architecture Lab).

From Ariadne [18] an architecture has been proposed for repositories which implement SQI-based federated searches.

Also worth mentioning is the OKI [19] proposal which defines an service oriented architecture and some software interfaces, called Open Service Interface Definitions (OSID) for the creation of interoperable repositories.

6 Services

As we have seen both architectures and learning object packaging makes use of services which allow a series of operations to be performed on them or on the repositories which store them.

As far as architectures are concerned, the current trend is for the adoption of service oriented architectures (SOA). All those described in the previous section are examples of such services.

For some time, IMS [9] has been attempting to provide specific specifications regarding the adoption of services as a means to interoperability between repositories and learning systems. Hence this section sets out a series of service-related norms.

IMS Learning Information Services is a specification whose job is to support interactions and data exchange between learning systems and administrators, students or resource systems. Once known as IMS Enterprise Services V1.0, in its version 2.0 this specification took as its new name IMS Learning Information Services.

IMS General Web Services is a specification entrusted promoting the interoperability of the specifications of software-based Web services and different seller platforms. Its dual focus is on the specification of a group of Web services and on the most common problems encountered when implementing them. It is an attempt to manage interoperability on the level of application, more particularly, the description of types of behaviour encountered via Web services.

7 Case study

So far we have exposed the main technologies for e-learning systems standardization and for their building. In the first category the more important specifications have been developed by organizations such as IEEE, IMS, ADL and ISO. They try (1) to ensure interoperability in e-learning environments, (2) to guarantee reusability and accessibility to learning contents, (3) to offer efficient search engines, (4) to protect copyright, etc. The second category comprises specifications that define the main features of a system orientated towards the distribution and search of such content.

As a case study that conforms all the specifications and recommendations aforementioned, and summarized in Table 1, is the LORS-SC system (Learning Object Reusability System – Semantic & Composite). LORS is a system for learning object reusability developed in the Computer Science Department in the University of Alcalá. Figure 2 presents the architecture of the LORS system. This figure shows the system layers or levels (which are coincident with the SQI levels)

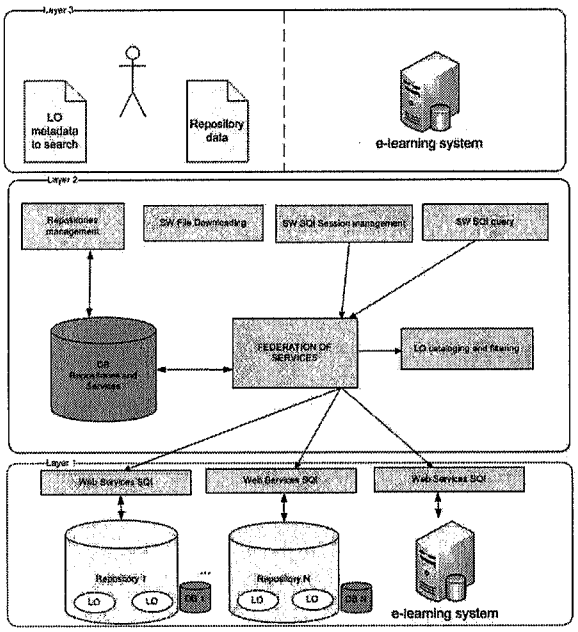

Figure 2. LORS-SC System Architecture.

The main features of the LORS-SC system are:

- It is a fully interoperable with all other systems and repositories. This means not only that the LORS system can launch searches over other SQI-compliant systems or repositories, but these repositories or systems may also launch searches over LORS-associated repositories. This enables to make content accessibility and reusability as wider and complex as desired.
- It expedites the learning content search process. Only ARIADNE[18] and ADL-R [20] specifications present two kinds of searches (which are associated with the implemented PLQL levels-- ProLearn Query Language). This enables a finer search level, because the system allows key field-based searches (PLQL level 0) and metadata-based searches (PLQL level 1).
- It makes it possible to adapt the downloaded learning contents to the metadata specification used in the target system, so a learning object fully compliant and ready to be used is obtained.
- It is also possible to adapt it to any set present or future set of metadata. In LORS will only be required to change a configuration to virtually adapt the system to any set or subset of metadata. This feature is not available in any other system and it is critical for the system interoperability.

The layers of the LORS system were presented in figure 2. In the rest of this section each of these layers is described. Standards and/or recommendations employed on each layer are specially stressed. A summary of them is presented in Table 2.

Table 2. LORS-SC System Employed Standards

STANDARD	LAYER 1	LAYER 2	LAYER 3
IEE LOM	X		
IMS CC	X		
IMS RLI	X		
IMS VDEX	X		
IMS DRI	X	X	X
CEN SQI	X	X	
CEN SPI	X		
IMS AF	X	X	X
IMS LIS	X	X	
IMS GWS	X	X	

7.1 Layer 1

This layer comprises all the web services associated to every repository. To build this layer the IMS GWS (General Web Services) recommendation was employed. It determines the way in which web services are developed and the way in which they interact with each other. This web services enable the access to learning objects which are described by the IMS LOM (Learning Object Metadata) and packaged with according to IMS CC (Common Cartrigde). In order to access to this data the SQI (Simple Query Interface) and the SPI (Simple Publishing Interface) are employed. SQI defines the web methods to be developed. These methods enable the system to access to the learning data stored. SPI defines the set of methods to define the way to publish the learning objects in a repository.

Moreover, semantic techniques are used to search data. To tag this metadata and to create vocabulary categories the IMS VDEX (Vocabulary Definition Exchange) specification has been adopted. IMS RLI (Resource List Interoperability) is used to arrange, describe and interchange resources lists included by every learning object. And finally IMS LIS (Learning Information Services) has been used to make every data interchange effective.

7.2 Layer 2

This level comprises the federated search services. They use the services provided by layer 1 to get and handle the data provided by them, consequently they also use the SQI specification. Because they are also Web services, they were also developed according to IMS GWS. This layer will also handle all the information provided by the repositories, so it is also required to use the IMS LIS specification. Besides the services that call the SQI methods, another set of services have been developed in order to catalog and filter information, and to manage the repositories associated with the search engine.

It should also be stressed that this layer may be called upon by other search systems, so it can also be the target of outside calls.

7.3 Layer 3

This final layer represents the presentation layer of the application. All the interfaces that offer access to the system will be found here.

Besides all the aforementioned specifications, IMS DRI (Digital Repositories Interoperability) and IMS AF (Abstract Framework) have been also adopted for this layer. IMS DRI defines the features that a repository must offer in order to be interoperable and enable the access to its hosted content. IMS AF (Abstract Framework) presents and abstract representation of the set of services that should be used to build an e-learning system in its broader sense, so this specification was the main source to determine the required service.

8 Conclusions

As we have seen in the preceding sections, the proliferation of standards and specifications focused on the interoperability of learning object repositories is very wide-ranging, which is why we decided to carry out a survey of the most important and recent ones, and then to classify them and indicate the relations between them.

In the light of our study we are in a position to say that the building of a totally interoperable repository of learning objects, which will consequently allow the learning objects it contains to be reused, must comply with a series of very clear norms. In line with the norms set out above, the steps to be followed in order to achieve an interoperable repository may be summarized as follows:

1. When analyzing and designing the system software that will house it, a service-oriented architecture should be used.
2. In order to integrate the repository in a federated search system, the SQI specification should be adopted.
3. Steps 1 and 2 complement each other since, as they both use an SOA architecture, it is extremely easy to integrate the services offered by SQI or SPI [21].

Packaging learning objects using the norms set out in section 3 and describing their metadata will make those objects reusable. It will also be necessary for all their resources to be suitably linked through the use standards which guarantee their proper accessibility, as also stated in section 3.

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