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TOWARDS INTEROPERABLE LEARNING OBJECT REPOSITORIES: THE ARIADNE EXPERIENCE

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ABSTRACT

In this paper, we present an approach for producing interoperable metadata by mapping metadata structures of application profiles into standard metadata structures. As a study case, we map the ARIADNE metadata structure into the LOM structure. We use XSLT to transform ARIADNE XML instances into IEEE LOM Instances. Finally, we validate the resulting LOM XML instances. The major contribution of this paper is that it explains how mapping and transforming metadata between different metadata specifications is not always a simple one-to-one process. We present and analyze different kinds of complications involved in such mappings. This work increases the interoperability between ARIADNE and other Learning Object Repositories that rely on IEEE LOM.

KEYWORDS

Interoperability, Learning Object Repositories, Metadata, Metadata Mappings, Application profiles

1. INTRODUCTION

Nowadays, more and more systems face the problem of mapping and representing metadata according to some metadata standard [Rehak, D., 2003]. This mapping allows to share and to exchange learning objects as well as their metadata. Metadata is defined as "information about an object; be it physical or digital" [Duval, E., 2001], it is used to facilitate search, evaluation, acquisition and use of learning objects. Typically, Learning objects and their associated metadata are located in distributed Learning Object Repositories (LOR's). However, there is more than one approved standard used to describe the properties of learning objects, for example the Learning Object Metadata (LOM) standard [IEEE, 2002] and the Dublin Core standard [DCMES, 1999].

Different Learning Object Repositories try to address different needs. Therefore, metadata designers may select a number of metadata elements as well as their related value sets from one or more metadata standards [Heery, R., 2000]. The specification of these metadata elements and value sets is called an "application profile". For simplicity, we will use the term 'Profile' instead of 'application profile' in this paper. Profiles are used to adapt metadata specifications to the requirements of the local community such as multilingual and multicultural requirements [Duval, et al., 2002]. Therefore, each of the Learning Object Repositories uses a different profile to define learning objects. Examples of such profiles are the metadata sets of CanCore [CanCore, 2002], SingCore [SingCore, 2002], SCORM [ADL, 2001] and ARIADNE [ARIADNE, 2001].

Learning Object Repositories aim to share and reuse metadata. Therefore, syntax and semantics of metadata elements, as well as their value sets, should be represented according to a particular metadata standard. To do so, we need to conceptually map data elements of different profiles and their related values into elements and values of a standard schema, and represented in a semantically interoperable [Euzenat, J., 2001] and technically sharable representation such as XML or RDF.

In this paper, we introduce our approach, which aims to increase the interoperability between ARIADNE and other Learning Object Repositories that rely on IEEE LOM. To achieve this goal, we map the ARIADNE profile into the LOM structure. We use XSLT to transform ARIADNE XML into IEEE LOM XML. Finally, we validate the resulting LOM XML instances.

More generally, we provide guidelines for mapping metadata of profiles, we discuss different important issues related to mapping, transforming and validating metadata. This will help other Learning Object Repositories to map, transform and validate their metadata.

The paper is structured as follows: In section 2, the ARIADNE and LOM specifications are described. In section 3, we discuss the different kinds of metadata mappings used to map profiles into metadata standards. Finally, a conclusion is given in section 4.

2. ARIADNE METADATA SPECIFICATIONS AND LOM

The ARIADNE Knowledge Pool System is a distributed repository for learning objects [Duval, et al., 2001]. It encourages the share and reuse of such objects. An indexation and query tool uses a set of metadata elements to describe and enable search functionality on learning objects.

To ensure simplicity, understandability and adaptability for the ARIADNE community, data elements are grouped into six categories:

- General: groups the general information that describes the learning object such as document title, document language, etc.
- Semantics: groups elements that describe the semantic classification of the learning object like the science type, main discipline, sub discipline etc.
- Pedagogical: groups elements that describe the pedagogic and educational characteristics of the learning object such as semantic density, interactivity level, etc.
- Technical: groups elements that describe the technical requirements and characteristics of the learning object like OS version, required disk space, etc.
- Indexation: groups elements that describe the general information about the metadata itself of the learning object such as the identifier of the metadata instance, metadata creation date, creator, etc.
- Annotations: groups elements that describe people or organizations notes about learning objects like annotator, language of annotations, and date of annotation.

These specifications together with similar specifications contributed by IMS [IMS, 2001] served as the starting point for the IEEE LTSC LOM standard. LOM has a wide set of globally agreed metadata elements. Metadata data elements of LOM are grouped into nine descriptive categories: General, Life cycle, Meta-metadata, Technical, Educational, Rights, Relation, Annotation, and Classification. These specifications have been defined and agreed on by a global community to enable share and reuse.

The IEEE LTSC has developed a LOM XML representation for metadata exchange so that different Learning Object Repositories can be interoperable. This LOM XML representation standard is based on LOMv1.0 base schema. Therefore, metadata information of these Repositories should be semantically represented according to LOMv1.0 and technically represented according to the LOM XML binding.

The current ARIADNE Educational Metadata Specification is a profile of LOM. It is fully compatible with LOM and it also adapts the structure of LOM to the specific requirements of the multicultural and multilingual ARIADNE community.

To increase the interoperability of ARIADNE with other repositories within the LOM community, we represented the ARIADNE metadata according to the LOM standard, which enables other repositories to share this metadata. The work was done in three phases as illustrated in Figure 1.

First, the ARIADNE metadata structure was conceptually mapped into the LOM structure (the reverse mapping is planned as future work). Secondly, using XSL transformations, we transformed the ARIADNE XML binding into the LOM XML binding. Finally we validated the produced LOM XML instances using the LOM XML schema (XSD).

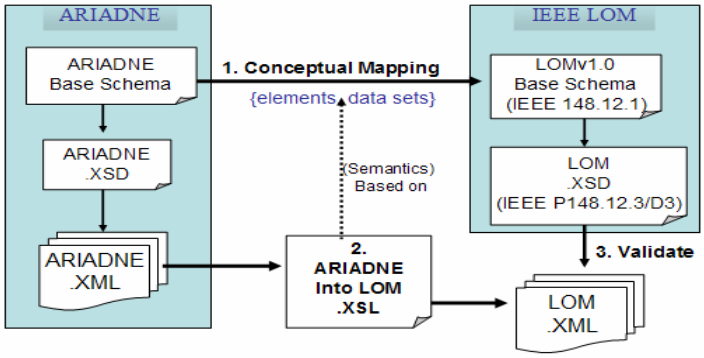

Figure 1. An approach to generate interoperable metadata instances

In the next section we will discuss some specific issues in the mapping of the ARIADNE profile into LOM. Also, we will present XML bindings of the technical transformations related to these cases. Finally, we will discuss the validation process that was used to automatically validate the produced LOM XML instances.

3. MAPPING PROFILES INTO METADATA STANDARDS

Different learning communities have different metadata "profiles" as well as associated value spaces and data types. This makes the exchange of metadata information between these communities very difficult if not impossible [Rehak, D., 2003]. Hence, we need a common standard to map the different metadata profiles.

To map a profile into this common standard, the following actions can be performed depending on the meaning and syntax mismatch between the metadata profile and the standard. This mapping process involves complicated actions as well as simple ones.

I. Mapping of data elements: Mapping of profile elements into their equivalent elements in the standard.

1. Mapping of independent data elements. Mapping of regular data elements (Section 3.1.1).
   - 1-to-1: Mapping one profile data element into one data element in the standard.
   - 1-to-N: Mapping one profile data element into more than one data element in the standard.
   - N-to-1: Mapping more than one profile data elements into one data element in the standard. Due to the fact that a profile has more details than the standard; an N-to-1 mapping can cause a huge loss of information; whereas in the earlier cases, all information is reserved.
2. Mapping sets of dependent elements. Data elements have a dependency relationship with other elements. For example, mapping set of elements of formal classification scheme into LOM taxonomy system which is based on a set of different classification purposes (Section 3.1.2).

The above mapping cases are arranged from the simplest types into the most complex ones.

II. Mapping values of data elements: mapping element values that don't match their corresponding values in the standard.

1. Mapping vocabulary values from a profile value space into values of the standard (Section 3.2.1).
   - 1-to-1: Mapping one profile vocabulary value into one equivalent value in the standard.
   - 1-to-N: Mapping one profile vocabulary value into more than one value in the standard. This means that profile vocabulary values for this element are much narrower than the values of the standard.
   - N-to-1: Mapping more than one profile vocabulary value into one equivalent value in the standard. This means that the profile vocabulary values are much wider than the values of the standard.
   - N-to-Null: One vocabulary value or more don't have any equivalent value among values of the standard.

The above mappings are arranged from the simplest types into the most complex ones.

2. Mapping values from one data type into another data type identified by the standard (Section 3.2.2).
   - Mapping the LangString data type into a vocabulary data type.

- Mapping the vocabulary data type from one token format into another.
- Mapping the string data type into a vCard data type.
- Mapping one string data type format into another format.

Concerning the mapping of the ARIADNE metadata structure into the LOM structure:

- 27 data elements of the 43 ARIADNE elements have been mapped directly into their correspondent LOM data elements (LOM has 45 2nd level data elements).
- 16 data elements have been mapped into more than one LOM data element.
- In addition, value sets/spaces of ARIADNE data elements are the same or a superset of LOM value sets.

This high degree of compatibility is found because ARIADNE data elements with their associate values have formed the basis for LOM standard. In the case demonstrated above, we believe that the mapping of ARIADNE metadata into LOM will increase the semantic interoperability of LOM.

Based on the above mentioned mapping types, in the coming sections we will discuss in detail the mapping process used to map the ARIADNE metadata into LOM. However, when it's necessary, we provide a conceptual mapping, real instances and XML binding illustrations for the different mapping types.

3.1 Mapping of Data Elements

In this section, we will discuss in more detail the different types of data element mappings in the framework of ARIADNE.

3.1.1 Mapping of independent data elements

- **1-to-1 Mapping**: Data elements of a profile have the same characteristics as its interrelated data element in the standard. Therefore, each data element is mapped directly into exactly one corresponding data element in the standard.

In Figure 2, we illustrate an example of mapping "title" instances from ARIADNE structure into instances of LOM.

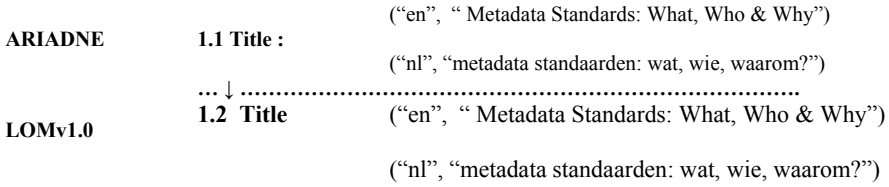

Figure 2. The ARIADNE element maps directly into the LOMv1.0 element

In Figure 2, we map the "1.1 Title" ARIADNE data instances directly by 1-to-1 procedure into instances of LOMv1.0 "1.2 title". Note that, the assigned data type for the element in both sides is the same, which is LangString data type. This mapping process is illustrated in the following XML bindings.

ARIADNE	LOMv1.0
1.1 general.title <titles type="langString"> <title entry=" Metadata Standards: What, Who & Why " lang="en" type="langStringItem"/> <title entry=" metadata standaarden: wat, wie, waarom?" lang="nl"type="langStringItem"/> </titles>	1.2 general.title <title> <string language="en" > Metadata Standards: What, Who & Why </string> <string language="nl" > metadata standaarden: wat, wie, waarom ? </string> </title>

Note that due to the fact that the data elements at both sides have the same characteristic and meaning, we only need to transform the name labeling and the binding structure of the ARIADNE element into the LOM name labeling and structure.

In the following section, we will show how we can map and transform elements that are interrelated to more than one element in the standard.

- **1-to-N Mapping:** One data element of the profile maps into more than one data element in the standard schema. Therefore, data elements can be mapped into their interrelated elements without losing metadata information and without providing ambiguity to this information. Thus, issues like instance multiplicity, order and string -data type- constraints should be considered very carefully during the mapping process. For example, it is possible to map an element of '1' instance multiplicity into an element that has "N" instance multiplicity. On the contrary, it's not possible to map information of data elements that have "N" instance multiplicity into elements of "1" instance multiplicity, because this will cause a huge loss of metadata information.

In Table 1, we present an example of conceptually map "1.7 version information" data element from ARIADNE metadata profile into LOM standard.

Table 1. One ARIADNE data element map into two LOM data elements

ARIADNE				LOMv1.0			
Element	Multiplicity	Ordered	Lang String		Multiplicity	Ordered	Lang String
1.7 Version information (Based On)	1	-	YES	7.2.2:Relation.Resource.Description with 7.1:Relation.Kind='isversionof'	N	NO	YES

In table 1, we conceptually map the "1.7 version information" ARIADNE data element using the 1-to-N procedure into "7.2.2 Description" and "7.1 Kind" LOM data elements. As shown, this element has the data type LangString at both sides, so there is no conflict in instance multiplicity, order or data type constraints. Therefore, this element map into elements of LOM without any loss of metadata information.

In Figure 3, we show an example of mapping "1.7 version information" instances of ARIADNE into instances of LOM.

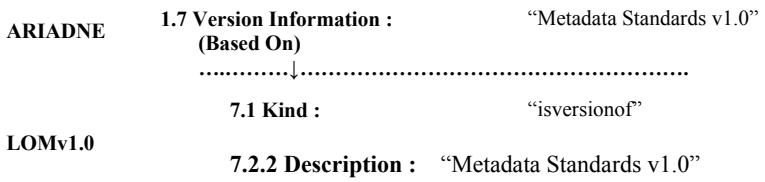

Figure 3. Instances of one ARIADNE elements map into instances of more than one LOM elements

In Figure 3, we map the "1.7 version information" ARIADNE data instances into instances of "7.2.2 Description" and "7.1 Kind" that are two data elements of LOM.

This mapping process is shown in the following XML bindings.

ARIADNE

1.7 Version Information (Based On)

```
<Sources type="multiValued">
  <Source type="container">
    <title entry=" Metadata
     Standards v1.1"type="string"/>
  </Source>
  <Source type="container">
    <title entry=" Metadata
     Standards v1.2"type="string"/>
  </Source>
</Sources>
```

LOMv1.0

5.5 Educational.IntendedEndUserRole

```
<relation>
  <kind>
    <source>LOMv1.0</source>
    <value>isversionof</value>
  </kind>
  <resource>
    <description>
    <string>Metadata Standards
              v1.1</string>
        <string>Metadata Standards
              v1.2</string>
          </description>
     </resource>
</relation>
```

Notice that since the ARIADNE element is related to two LOM elements, we transformed the ARIADNE binding structure into the binding structure of LOM; also we added the "isversionof" value to the "kind" data element in the LOM binding. By doing so, we reserve the full meaning of the metadata information.

In the next section we will present a special case of data elements mapping; we will show how to map a group of data elements that have a strong semantic dependency relationship between each other.

3.1.2 Mapping a set of dependent elements

In this case we have special kind of data elements; these data elements have a hierarchical relationship or a parent-child relationship. These elements should be mapped in away that reserve the semantic relationship between elements in order to preserve the metadata contained in these elements. An example of this mapping case is illustrated below.

- **Mapping elements of the ARIADNE classification system into the LOM taxonomic set:** The ARIADNE hierarchical classification system consists of 6 data elements: "2.1 Science type", "2.2 Main Discipline", "2.3 Sub discipline", "2.4 main Concept", "2.5 concept synonyms" and "2.6 other important synonyms". Values of these elements depend on the parent or child values. This means that mapping each of these related elements needs to be accomplished very carefully to preserve the meaning and to provide complete classification information of learning objects.

In Table 2, we conceptually map the"2.4 main concept" data element together with its other related data elements into LOM taxonomic set that has a "discipline" classification purpose.

Table 2. Mapping of ARIADNE classification elements into LOM

ARIADNE				LOMv1.0			
Element	Multiplicity	Ordered	Lang String		Multiplicity	Ordered	Lang String
2.1 science type 2.2 main discipline 2.3 sub discipline **2.4 main concept**	1	-	YES	9.2.2.2:Classification.TaxonPath.Taxon[4].Entry, with 9.1:Classification.Purpose='discipline' and 9.2.1:Classification.TaxonPath.Source='ARIADNE' and 9.2.2.2:Classification.TaxonPath.Taxon[1]=2.1 science type and 9.2.2.2:Classification.TaxonPath.Taxon[2]=2.2 main discipline and 9.2.2.2:Classification.TaxonPath.Taxon[3]=2.3 sub discipline	1	-	YES

In Table 2, we notice that there is no conflict in elements multiplicity, order and data type constraints, so this element and its related elements map also without losing their meaning.

In Figure 4, we illustrate an example of mapping "2.4 main concept" data instances together with instances of its upper and lower related elements into instances of LOM taxonomic set.

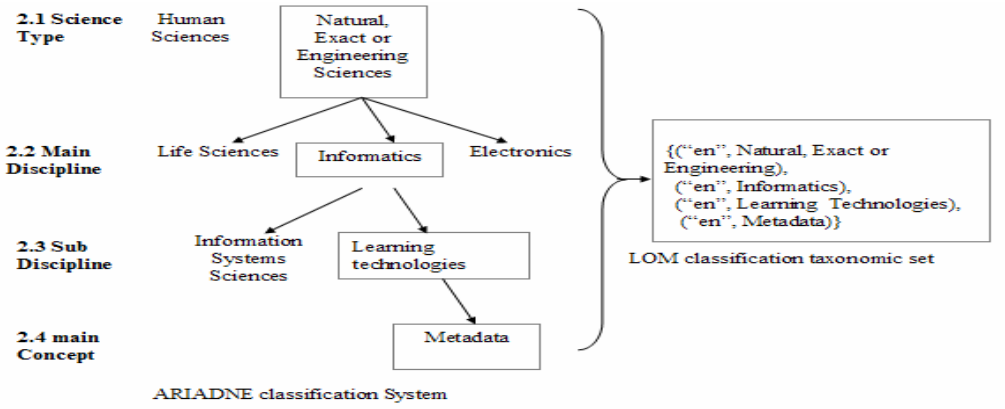

Figure 4. Mapping instances of the ARIADNE classification system into LOM

In Figure 4, we use this special mapping procedure to map related data elements that bear very sensitive information about learning objects.

In the next section, we will show how values of data elements from a profile value space can be mapped into value space of a standard.

3.2 Mapping values of data elements

In this section, we consider mapping of values of a profile data elements into the values of the standard. In case the data types don't match, the aim is to represent vocabularies and other data types of profile values according to the value space and data type of the standard. Value sets mapping in one way or another is similar to data elements mapping, since vocabulary values also map by 1-to-1, 1-to-N and N-to-1 mapping procedures. In addition, we map values of data elements from one specific data type into another (data type mapping).

3.2.1 Mapping vocabulary values from a profilevalue space into the value space of the standard

As mentioned before, vocabulary values of ARIADNE map into values of LOM using three mapping procedures. In each mapping type, we bind metadata information in away that guarantees the stability of their meaning and increases the semantic interoperability with LOM.

- In case of vocabulary values that have a 1-to-1 relationship with values of LOM: in the LOM XML binding, we only provide the LOM vocabulary values, since the ARIADNE vocabulary values are exactly the same as the values of LOM.
- In case of vocabulary values that have no equivalent value within LOM: in the LOM XML binding, we only provide the ARIADNE vocabulary values. This way, we introduce new values for LOM instances.
- In case of vocabulary values that have N-to-1 relationship with values of LOM: in the LOM XML binding, we provide both the ARIADNE and LOM vocabulary values. By doing so, we also add new values to LOM instances, which increases the semantic interoperability. This mapping process is shown in the following XML bindings.

ARIADNE	LOMv1.0
3.9 Pedagogical .Granularity <granularitys type="langString"> <granularity entry="Raw Media" lang="en" type="langStringItem"/> <granularity entry="Roh Media" lang="de" type="langStringItem"/> </granularitys>	1.8 General.aggregationLevel <aggregationLevel> <source>ARIADNE</source> <value>Raw Media</value> </aggregationLevel> <aggregationLevel> <source>LOMv1.0</source> <value>1</value> </aggregationLevel>

Note that the ARIADNE data element "3.9 granularity" includes more than one vocabulary value that is equivalent to a corresponding vocabulary value in LOM. For example, the "raw media", "fragment" and "Document" vocabulary values of this element mapped into the "1" vocabulary value of the LOM element "1.8 aggregationLevel". In addition to that, ARIADNE vocabulary values have the langString data type, which allows providing different translations of the same vocabulary. However, we map all those semantically equivalent translations of this vocabulary into the LOM vocabulary value "1". By doing so, we map the vocabulary value from the LangString data type into a numeric token vocabulary that is assigned by LOM.

In the next section, we will show how we can map values from one value data type into another value data type that is assigned to by a standard.

3.2.2 Mapping values from one data type into another one identified by the standard

Here, we map values of data elements from one data type into another. This mapping type is required in the case of a data type of a profile's element that doesn't match the data type of its corresponding element in the standard. For example, mapping values from one *date* string format into another string format or transforming personal information represented by the regular string format into a *vCard* data type. This mapping type is illustrated in the following example.

ARIADNE	LOMv1.0
3.6 Pedagogical .Duration (minutes) <pedagogicalDuration entry="124" type="string"/>	5.9 Education.typicalLearningTime <typicalLearningTime> <duration>PT2H4M</duration> </typicalLearningTime>

Notice that due to the data type mismatch in the value of pedagogical duration information with corresponding data elements in the standard, we transformed this value from the ARIADNE minutes string format into the LOM duration format ("124" MINUTES become "PT2H4M").

4. CONCLUSION

The presented approach aims to enable exchange of metadata by relying on standards. In this work, the ARIADNE application profile has been mapped into IEEE LOM, and valid exchangeable LOM XML metadata instances for ARIADNE metadata have been produced. This work will increase the interoperability between implementations based on the LOM standard.

The LOM XML Schema was used to validate the LOM XML instances that have been generated from the ARIADNE metadata. This schema provides the formal specification of names, values and ordering of data elements. Therefore, we customized this common schema to accept multiple instances and vocabulary values of ARIADNE when it is appropriate.

As future work, we are planning to map IEEE LOM metadata into the ARIADNE KPS structure, and to represent ARIADNE metadata into other bindings like LOM RDF [IEEE RDF, 2002] which is currently under development. Also, build tools that support automatically mapping different metadata schemas, this work requires us to consider different issues during the automatic mapping process such as the elements labeling mismatch, metadata language, cultural differences, validation and etc.

More information about our completed work is available online at: http://rubens.cs.kuleuven.ac.be:8989/ariadne/.

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