

Interoperability of Learning Objects Copyright in the LUISA Semantic Learning Management System

Roberto García¹, Tomas Pariente²

¹ Universitat de Lleida. Jaume II 69, 25001 Lleida, Spain
rgarcia@diei.udl.cat

² ATOS Origin SAE – Atos Research and Innovation.
Albarracín 25, 20037 Madrid, Spain
tomas.parietelobo@atosorigin.com

Abstract. Semantic Web technology is able to provide the required computational semantics for interoperability of learning resources across different Learning Management Systems (LMS) and Learning Object Repositories (LOR). The EU research project LUISA (Learning Content Management System Using Innovative Semantic Web Services Architecture) addresses the development of a reference semantic architecture for the major challenges in the search, interchange and delivery of learning objects in a service-oriented context. One of the key issues, highlighted in this paper, is Digital Rights Management (DRM) interoperability. A Semantic Web approach to copyright management has been followed, which places a Copyright Ontology as the key component for interoperability among existing DRM systems and other licensing schemes like Creative Commons. Moreover, Semantic Web tools like reasoners, rule engines and semantic queries facilitate the implementation of an interoperable copyright management component in the LUISA architecture.

1. Introduction

The widespread adoption of e-Learning solutions across the World Wide Web has placed the focus on the interoperability requirement, specially referring to learning resources across different Learning Management Systems (LMS) and Learning Object Repositories (LOR). This interoperability is required in order to build the knowledge-intensive, open and accessible learning services that our knowledge society demands [1].

The central paradigm of such technology is the notion of learning objects (LO) as digital reusable pieces of learning activities or contents. However, transportability across platforms is only a basic step towards higher levels of automation and possibilities of delegation of tasks to software agents or modules. Such advanced technology requires richer semantics than those offered by current metadata specifications for learning resources. Semantic Web technology and the use of ontolo-

gies are able to provide the required computational semantics for the automation of tasks [2], in this case those related to learning objects as selection or composition. In addition, Semantic Web Services (SWS) provide the technical architecture and mediation facilities for semantic interoperability.

This paper concentrates on one of the issues of e-Learning systems interoperability, that of the learning contents copyright terms. Most e-Learning systems provide little support for copyright interoperability. They provide some attributes that can be used to specify the licensing terms of a given learning object but their main function is to just provide a placeholder for content licensing terms. The copyright attribute values are free text and there are not predefined terms or guides about how to build these licenses. At most, they rely on predefined licenses specialised on concrete licensing schemes like open content.

This is also a problem of other content management systems and consequently there are some initiatives, related with Digital Right Management (DRM), trying to establish standard ways to represent copyright terms. DRM languages define the terms and grammars that can be used in order to represent licensing terms.

However, most of them are more like rigid access control languages that lack flexibility, make interoperability among different DRM languages more difficult and are not able to model copyright [3].

Our proposal for interoperability at the copyright level is also based on Semantic Web technologies and methodologies [4]. This approach makes it possible to attain a greater level of expressivity while modelling licensing terms, with greater flexibility, interoperability facilities and able to represent part of the underlying copyright law notions.

The resulting Semantic DRM system is aligned with the LUISA¹ approach for e-Learning systems at large. Consequently, it is easily integrated into the LUISA reference architecture and complements it attaining semantic interoperability also at the copyright level.

This paper presents the overall platform LUISA in Section 2, then focuses on DRM and copyright issues and how they are solved using Semantic Web technologies in Section 3. The key component for Semantic DRM is the Copyright Ontology, which is presented in Section 3.1. The ontology is then used in order to model the licenses for learning objects, as shown in Section 3.2. Conclusions and future work in Section 4.

1.1. Related Work

This paper concentrates on the copyright management part of the LUISA platforms and, consequently, in this paper we just analyse related work for this part. There are many initiatives trying to improve e-Learning systems interoperability,

¹ LUISA EU FP6 Research Project, <http://luisa.atosorigin.es>

but not so much effort been devoted to learning objects interoperability at the licensing level [5,6].

The main problem of existing e-Learning systems in this respect is that they do not provide structured and formal ways to express the licensing terms of the learning objects they manage.

For instance, Sakai² defines some predefined and simple copyright status sentences that provide very limited information and little support for computerised copyright management of learning objects. It is possible to state: “Material is in public domain”, “I hold copyright”, “Material is subject to fair use exception”, “I have obtained permission to use this material” or “Copyright status is not yet determined”. Moreover, there is the “Use copyright below” option that provides a text box that allows providing a textual description for other legal status.

Something similar happens with Moodle [7], even if e-Learning metadata schemes like LOM [8] are reused. LOM provides a set of attributes for stating for learning object rights, there are the “Cost”, “Copyright and Other Restrictions” and “Description” attributes. However, there is the same problem as in the previous case, the “Description” attribute is the more informative one but there are no restrictions about its content, it is an unstructured attribute, free text, so little help can be anticipated for automated processing.

Recently, many Learning Objects Repositories have adopted a set of more expressive and legally formal licenses defined by the Creative Commons initiative [9]. However, Creative Commons (CC) licenses are restricted to open licensing schemes, like in Open Courseware³. Although some extensions for user defined licensing schemes have been recently added to CC, called CCPlus⁴, these extensions suffer from the same limitations than in the previous cases because. The extensions are based on user defined additions and not in formalised license building blocks.

Due to the limitations of the previous approaches, there have been some attempts to adapt generic Digital Rights Management (DRM) languages for learning objects licensing [10,11]. The main DRM languages come from standardisation efforts like ISO/IEC MPEG-21 [12]. MPEG-21 Rights Expression Language (REL) is a XML schema that defines the grammar of a license building language, so it is based on a syntax formalisation approach.

Thought DRM standards are a good solution in more or less closed environments, where the involved systems adhere to one of the existing standards, they do not scale well to open environments like the Web. They cause interoperability issues like the ones identified by the Electronic Frontier Foundation [13], which are one of the main complains highlighted by DRM end-users.

Moreover, the syntax-based approach of most DRM languages makes it very difficult to accommodate copyright law into DRM systems due to its limited expressivity. Consequently, DRM standards follow a traditional access control ap-

² Sakai Project, <http://sakaiproject.org>

³ OpenCourseWare Consortium, <http://www.ocwconsortium.org>

⁴ Creative Commons Plus, <http://wiki.creativecommons.org/Ccplus>

proach. They concentrate their efforts in the last copyright value chain step, content consumption.

In fact, just Internet publishing risks are considered and the response is to look for more restrictive and secure mechanism to avoid access control circumvention. This makes DRM even less flexible because it ties implementations to proprietary and closed hardware and software security mechanisms.

The limited support for copyright law is also a concern for users. The consequence of this lack is basically that DRM systems fail to accommodate rights reserved to the public under national copyright regimes, e.g. private copy, quotes or restricted unauthorised uses in academic environments.

Our contribution tries to leverage DRM systems to copyright management systems, which support the whole value chain, from creators to consumers, and build on top of copyright law. The proposal is based on a copyright ontology, described in Section 3, which provides the building blocks and restrictions that make it possible to model licensing terms for learning objects in a flexible and expressive way.

This approach is related to other ontological approaches to DRM [14], though our proposal contributes the copyright dimension, which is commonly ignored, and support for the whole value chain, from learning objects authors to consumers. This support is difficult to attain if the underlying legal framework is not taken into account.

Moreover, our proposal is based on Semantic Web technologies and methodologies [4]. The Semantic Web has also been the technological choice for the rest of the LUISA architecture, selected in order to build an open and flexible learning management systems as it is detailed in the next section. The common technological ground makes it simple to integrate the semantic copyright management module into the LUISA architecture.

2. Semantic Learning Management System Architecture

LUISA, a project funded by the European Commission under the ICT sixth Framework Programme from March 2006 to August 2008, addresses one essential problem: the location of the appropriate learning resources for some given needs of learners, instructors or groups.

In order to achieve this objective, LUISA exploits the advantages of a Semantic Web Service (SWS) architecture to make the processes of query and specification of learning needs richer and more flexible. LUISA addresses the development of a reference semantic architecture for the major challenges in the search, interchange and delivery of learning objects in a service-oriented context.

This entails the technical description of the solution in terms of current SWS technology, and also the provision of the ontologies, facilities and components required to extend and enhance existing learning technology systems with the advanced capabilities provided by computational semantics.

The technology development objective of LUISA is put in a context of relevant learning scenarios – both academic and industrial – for evaluation and also to serve as a blueprint for technology adoption. The outcomes of LUISA are expected to make a significant contribution to the automation of learning technology systems beyond current standards, fostering the advancement of Web-based learning with an increase in the capacity to locate, search and negotiate learning resources mediated by semantic tools. Figure 1 shows the main functional blocks of the LUISA architecture, which are detailed next:

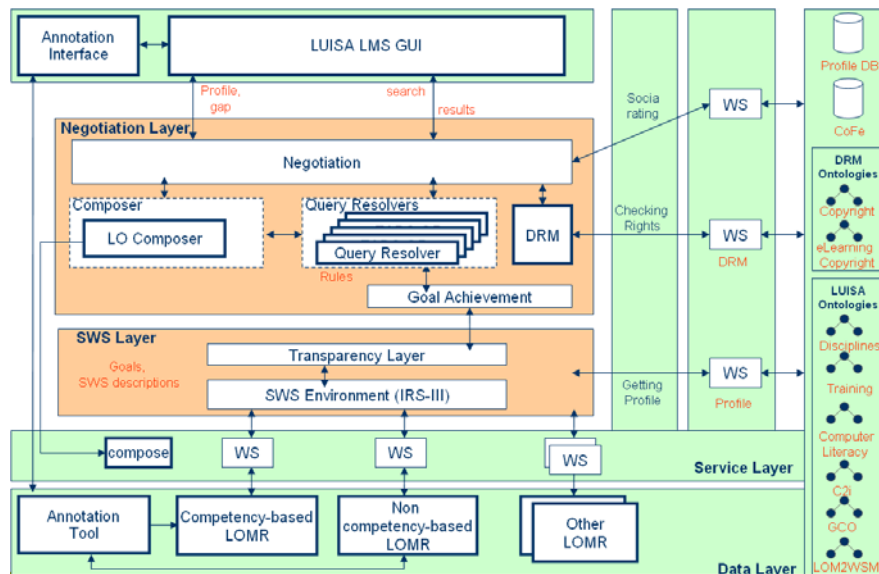


Figure 1. The LUISA architecture

- **The Interface Layer:** this layer contains all of the applications that may access the functionalities provided by the LUISA infrastructure as well as the tools that support the development of items stored within the SWS infrastructure. In particular, we distinguish two kinds of application: e-Learning and authoring. The first category represents applications that apply to end-user such as learners. The second category represents applications that apply to authors such as teachers as well as semantic developers. LUISA-specific components at this layer are: the Learning Management System (LMS) based in Moodle and learn eXact⁵ and the Metadata Annotation Tool user interface (eLUISA).
- **The Negotiation Layer:** the Negotiation Layer aims at supporting the learning objective of an end-user by using the functionalities provided by the Semantic Web Service Layer below and by implementing the organizational rules. This layer is in charge of stating the learning objective in terms of goals, abstracting

⁵ learn eXact LCMS, <http://www.giuntlabs.com/info.php?vvu=69>

the user interface from the SWS description. This involves gathering and providing data to and from the end-user application, sequencing the learning design and dealing with the negotiation of the provided results. It is important to note that the behaviour of the Query Resolver component of this layer changes according to different contexts and scenarios, i.e. domains. For this reason there can be multiple instances of this component, as it is shown at the centre of Figure 1. The composition of learning objects based on the organizational rules or driven by the user request is also performed in this layer. One of the aspects into consideration during this process is the copyright situation of the involved learning object. In order to make different rights expression languages interoperable, the DRM module infrastructure uses a Copyright Ontology, e-Learning licenses expressed using this ontology and some reasoning mechanism detailed in the next section.

- **The Semantic Web Service Layer:** this layer plays the role of SWS broker in the LUISA infrastructure. In particular, given a goal invocation, the SWS layer discovers a candidate set of Web services, selects the most appropriate, eventually mediates any mismatches at the data, ontology or business process level and invokes the selected Web services whilst adhering to any data, control flow and Web service invocation requirements. To achieve this, we use IRS-III [15], which utilises a set of SWS descriptions following the Web Service Modelling Ontology (WSMO) [16] goals, mediators and Web services.
- **The Learning Object Metadata Repositories:** this layer contains all of the possible systems that provide resources to support a learning process. For example, several LOR may be available at this layer. The resources provided by available systems are issued through specific services. These services are exposed in the Service Layer and make the infrastructure open to legacy systems. However, a LUISA-specific component at this level is the LUISA Learning Object Metadata Repository (LOMR). The metadata is stored in these LOMR using the eLUISA Annotation Tool.

3. Semantic Learning Copyright Management

The reference learning management architecture developed in LUISA is complemented with a copyright management module that is also based on Semantic Web technologies. This module, part of the Negotiation Layer, is capable of dealing with the underlying legal framework and, simultaneously, can be automated in order to benefit from computerised support.

Semantic Web technologies are chosen not just because LUISA is based on them. They make it possible to attain a greater level of expressivity for copyright licenses modelling, based on ontologies as knowledge representation tools [17]. The increased expressivity of web ontologies allows including the underlying legal framework into the formalisation. This is a key issue because, in order to build

a generic framework that facilitates interoperability, the focus must be placed on the underlying legal, commercial and technical copyright aspects.

The result of this approach is the Copyright Ontology⁶, detailed in Section 3.1. The ontology is implemented as an OWL Web ontology [18] based on the Description Logic (DL) variant, OWL-DL. This implementation facilitates DRM systems development because license checking is implemented using existing Semantic Web reasoners, as it is shown in Section 0. There, it is also shown how to model learning objects licenses based on the Copyright Ontology building blocks.

3.1. Copyright Ontology

The Copyright Ontology formalises knowledge from the copyright legal domain in order to define a more expressive and interoperable license modelling framework. It is true that copyright law diverges depending on local regimes but, as the World Intellectual Property Organisation⁷ promotes, there is a common legal base and fruitful efforts towards a greater level of copyright law worldwide harmonisation.

Starting from this legal framework, the Copyright Ontology models the primitive actions that can be performed on the creations. The actions make creations evolve through their life cycle, from abstract creations to the concrete things or events that are consumed, as it is shown in Figure 2.

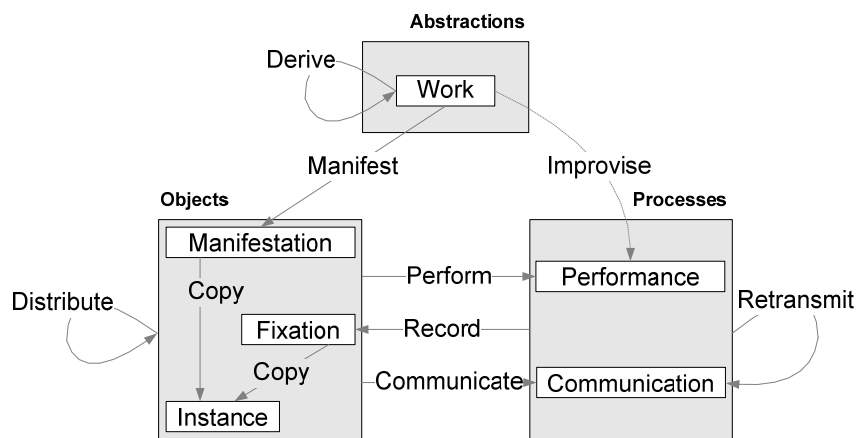


Figure 2. Relations between action and creation

A Work is a distinct intellectual or artistic creation. It is the original idea behind many possible expressions based on it. For instance, some pedagogical ideas and methodologies for a concrete subject that are realised into physical things that might be perceived.

⁶ Copyright Ontology, <http://rhizomik.net/ontologies/copyrightonto>

⁷ WIPO, World Intellectual Property Organization, <http://www.wipo.int>

One kind of physical realisation of a Work is a Manifestation, its materialisation in a concrete medium, a tangible or digital object. For instance, a learning object. There might be many copies of that learning object, called Instances.

On the other hand, there are Performances, the expression in time of a Work. For instance, a teacher's dissertation in a classroom, which might be directly based on some ideas (improvisation) or based on some previously written teaching guides (Manifestation).

The Performance might be recorded into a Fixation, which then can be copied and physically distributed (e.g. a CD copy of a learning object) or communicated, the process when the public is not present at the place and or time where the communication originates. Examples of Communication are a broadcast of the teaching session or a Web streaming of the same session.

The previous set of primitive actions and kinds of creations makes it possible to build licenses for all the different forms that a learning object can take as long as copyright law is concerned during its life cycle. These actions are regulated by the rights in the Rights Model. For the economic rights, these are the actions:

- **Reproduction Right:** to reproduce, commonly speaking *Copy*.
- **Distribution Right:** *Distribute*. More specifically *Sell*, *Rent* and *Lend*.
- **Public Performance Right:** *Perform*; it is regulated when it is a public performance and not a private one.
- **Fixation Right:** to fix something, *Record*.
- **Communication Right:** generically *Communicate* when the subject is an object or *Retransmit* when communicating a Performance or previous Communication, e.g. a re-broadcast. Other related actions depending on the intended audience are *Broadcast* or *Make Available*.
- **Transformation Right:** *Derive*. Specialisations are *Adapt* or *Translate*.

The action concepts are complemented with a set of relations that link them to the action participants. This set is adopted from the linguistics field. It is based on case roles [19] and shown in Table 1.

Table 1. Action Model case roles

	initiator	resource	goal	essence
Action	agent, effector	instrument	result, recipient	patient, theme
Process	agent, origin	matter	result, recipient	patient, theme
Transfer	agent, origin	instrument, medium	experiencer, recipient	theme
Spatial	origin	path	destination	location
Temporal	start	duration	completion	pointInTime
Ambient	reason	manner	aim, consequence	condition

The roles are categorised on four main types of roles, the columns. *Initiator* corresponds to a participant that determines the direction of the process from the beginning while *Goal* determines it for the end. *Resource* points to a participant that must be present at the beginning of the process, but does not actively control what happens, while *Essence* must be present at the end of the process. The roles also depend on the aspect of the verb they are related to, the rows. For instance, if the verb has a transfer aspect, something changes its “location”, or if it has a temporal aspect, how does it evolve along time. Their use is illustrated in the next section while modelling licenses in the e-Learning domain.

3.2. Copyright Licenses for Learning Objects

As it has been shown, the Copyright Ontology defines a set of primitive building blocks, inspired by the underlying copyright legal framework. They are combined in order to model licenses. Licenses should capture the obligations, permissions and prohibitions that make sense in the copyright domain.

First of all, action patterns are introduced as the way to state what is obliged, permitted or prohibited by a license. The previous actions and case roles are used to model action patterns in the copyright domain. Patterns are implemented as OWL classes made up from the combination of classes for actions, e.g. *Copy* or *Access*, and a set of OWL restrictions.

Each restriction defines a constraint on how members of the class, the domain, are related through the specified property to other ones, the range. Restrictions are combined using the intersection, union and complement logical operators in order to compose action patterns. For instance, Figure 3 shows the conceptual model for a license that combines commercial and open access terms.

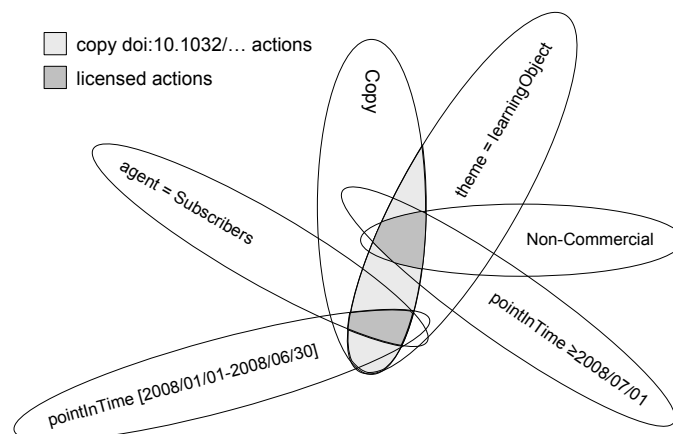


Figure 3. Building an action pattern as an intersection of restrictions

Table 2 shows the OWL-DL logic notation for the class definition that models the commercial copy pattern in Figure 3, called Pattern. Each intersected restriction reduces the initial set of actions, which corresponds to all the *Copy* actions (1). First, (2) models the time range as a restriction on the *pointingTime* case role to a custom datatype. The last constraints, (2) and (3), restrict the range of *agent* to one or more instances of the “Subscribers” class and *theme* to just the instance “learningObject”.

Table 2. OWL-DL Class for the commercial copy action pattern

Pattern \equiv Copy \sqcap	(1)
$\forall \text{pointingTime} . \geq 2008-01-01, \leq 2008-06 \sqcap$	(2)
$\exists \text{agent} . \text{Subscribers} \sqcap$	(3)
$\exists \text{theme} . \{\text{learningObject}\}$	(4)

From this point, it is possible to implement pattern matching using DL reasoners, which are specially suited for classifying individuals into classes. They can answer if an individual, considering its relations to other individuals and attribute values, satisfies all the restrictions of a class pattern and, thus, can be classified as an instance of that class. This functionality is used to check if a particular action, modelled as an individual, is included by an action pattern, modelled as a class.

Action patterns are then used in order to state what is permitted by a license. Permissions are modelled by a new action, *Agree*, and the permitted pattern is linked using the *theme* case role. Following with the example in Table 2, in order to authorise the pattern that it models, an instance of the *Agree* action is connected to the class pattern as it is shown in Table 3 Pattern through the *theme* case role.

Table 3. Agreement example using N3⁸ notation for RDF metadata

@prefix co: <http://rhizomik.net/ontologies/2008/05/copyrightonto.owl#>
:agreement_01
a co:Agree;
co:agent :owner;
co:theme :Pattern.

Conditions are also modelled using patterns that must be satisfied in order to activate the evaluation of another event pattern. The *condition* case role is used to associate the condition pattern with the conditioned pattern and the *aim* case role to state that a concrete action satisfying a condition pattern is geared towards fulfilling the specified action pattern.

For instance, Table 5 shows the metadata that states that Pattern is conditioned by the pattern in Table 5. This statement is not part of the pattern modelled in Table 2, i.e. it is not part of the restrictions of the class modelling the set of copy ac-

⁸ Notation 3, http://en.wikipedia.org/wiki/Notation_3

tions, because we do not want to impose that all concrete actions are modelled having in mind which is the license that might authorise it. In fact, a concrete action, e.g. an attempt to copy a piece of content, might be authorised by more than one license. This is why the condition property is associated to the action pattern at the annotation level. This information is used at check time in order to know which condition pattern must be checked once we know that a concrete action satisfies a licensed pattern, as it is shown later.

Table 4. The licensed pattern is associated with its condition pattern at the annotation level

<pre> :Pattern co:condition :Condition. </pre>
--

On the other hand, Table 5 shows the condition pattern required to exercise the copy actions authorised in Table 2. The condition is that the “owner” agent (3) receives a 3 Euros (4) transfer (1) from the “consumer” agent (2). The condition pattern is linked to the conditioned one using the *aim* case role as shown in (5).

Table 5. Commercial copy action pattern plus economic compensation condition

Condition \equiv Transfer \sqcap	(1)
\exists agent.Subscribers \sqcap	(2)
\exists recipient.{owner} \sqcap	(3)
\exists theme.{3EurosAmount}	(4)
\exists aim.Pattern \sqcap (≤ 1 aim)	(5)

The combination of the patterns in Table 2 and Table 5, in conjunction with the statements in Table 3 and Table 4, builds up a simple license for a learning object based on Copyright Ontology terms. Table 6 shows an example copy action *copy_01* that is included by Pattern action pattern. This pattern is authorised as stated in Table 3 and conditioned by the Condition pattern, shown in Table 5, as stated in Table 4. Therefore, there should be a transfer like *transfer_01* that fulfils the required Condition pattern. Consequently, the copy action should be authorised.

Table 6. Instance data examples: copy and transfer actions satisfying the conditions imposed by the license in Table 3, and consequently authorised

<pre> :copy_01 a co:Copy ; co:agent :consumer ; co:theme :learningObject . co:pointInTime "2008-06-19"^^xsd:date ; :consumer a :Subscriber. </pre>	<pre> :transfer_01 a co:Transfer ; co:agent :consumer ; co:recipient :owner ; co:theme :Amount3Euros ; co:aim :copy_01. </pre>
--	--

The pattern matching part of the previous license checking is implemented using an OWL-DL reasoner like Pellet [20]. For instance, Pellet is capable of determining that the previous instance actions, *copy_01* and *transfer_01*, satisfy the restrictions imposed by the patterns modelled by the classes Pattern and Condition respectively.

However, this is not enough to implement license checking. The main limitation of the OWL-DL implementation is that it is not possible to restrict the agent in the Pattern and the Condition to the same instance because there are not explicit variables in OWL-DL. In order to overcome this limitation, we have used the Semantic Web query language SPARQL [21].

For instance, Table 7 shows the SPARQL query required in order to check if *copy_01* is authorised by some license, this is a template query that can be used to check if any action is authorised. First, it is checked if the action is classified in some pattern (4). If it is so, it is checked that the pattern is authorised, (2) and (3).

Then, if the pattern is conditioned (6), it is also checked that there is some action satisfying it (7). Finally, a common SPARQL variable is used in order to assure that the agent of the licensed action and the condition one is the same individual, (5) and (8), and that the aim of the condition action is to satisfy the authorised action (9).

Table 7. SPARQL query that checks if an action is authorised and the condition met

ASK {	(1)
?agreement rdf:type co:Agree;	(2)
co:theme ?pattern.	(3)
:copy_01 rdf:type ?pattern;	(4)
co:agent ?consumer;	(5)
co:condition ?conditionPattern.	(6)
?condition rdf:type ?conditionPattern;	(7)
co:agent ?consumer;	(8)
co:aim :copy_01.	(9)
}	

The combination of the DL reasoner and SPARQL queries makes it possible to implement license checking based on the copyright ontology by reusing existing Semantic Web tools. There are other limitations of OWL-DL that require some additional processing of the licenses, particularly the Open World Assumption [22] which is overcome by some transformations of the licenses and negation-as-failure, which is implemented using SPARQL optional patterns and the BOUND condition⁹. More details about this concrete issue are available from [23].

⁹ SPARQL in a Nutshell, http://www.slideshare.net/fabien_gandon/sparql-in-a-nutshell

4. Evaluation

The copyright management approach proposed in this paper has been evaluated in the context of the LUISA research project. Concretely, a range of licensing schemes concretised from the requirements posed by the project partners have been considered.

These licensing schemes are basically based on textual descriptions of the licensing terms in the case of commercial licenses, which are completely dependent on each partner internal policies and requirements, and open licensing schemes based on Creative Commons licenses.

The latter, much more partner independent because they are all based on the same building blocks defined by the Creative Commons initiative, can be easily mapped to the Copyright Ontology following a basic mapping from Creative Commons concepts to the Copyright Ontology equivalent ones [24].

On the contrary, mapping commercial licenses available in textual form has been much trickier. First of all, we analysed the characteristics of the commercial licenses they employ and consider relevant in the context of the project. From this analysis, it was possible to define a set of license templates that were then modelled using Copyright Ontology concepts and relations.

For instance, Table 8 shows a template license between EADS and University Henri Poincaré (UHP) modelled using the ontology. The license allows copying EADS learning objects to the UHP repository, which is managed by the EHP learning objects managers. The condition is a credit transfer to EADS.

Existing licenses have been adapted in order to involve just project partners and economic transfers have been replaced by “credit” transfers that allow keeping track of the transactions and controlling the “credit” revenues generated by each learning object.

Table 8. Example license from the LUISA EU Project

CopyEadsLotoUhp \equiv	(1)
Copy \sqcap	(2)
$\forall \text{pointInTime} . \leq 2008-12 \sqcap$	(3)
$\exists \text{agent.UhpLoManager} \sqcap$	(4)
$\exists \text{theme.EadsLo}$	(5)
	(6)
CopyEadsLotoUhpCondition \equiv	(7)
Transfer \sqcap	(8)
$\exists \text{agent.UhpLoManager} \sqcap$	(9)
$\exists \text{recipient.}\{Eads\} \sqcap$	(10)
$\exists \text{theme.}\{1\text{Credit}\}$	(11)
$\exists \text{aim.CopyEadsLotoUhp} \sqcap (\leq 1 \text{ aim})$	(12)

The previous model for the patterns associated to this kind of licenses, the action and condition patterns, is complemented with the instance data, shown in Table 9, stating that the action patterns is authorised by EADS and that the patterns of actions authorised is conditioned by the condition pattern.

Table 9. Instance data for the previous license

```
@prefix co: <http://rhizomik.net/ontologies/2008/05/copyrightonto.owl#>
@prefix luisa: < http://luisa.atosorigin.es/uhp-eads-p2.owl#>
luisa:agree_copy_eads_lo_to_uhp
    a co:Agree;
    co:agent luisa:Eads;
    co:theme luisa:CopyEadsLotoUhp.
luisa:CopyEadsLotoUhp
    co:condition luisa:CopyEadsLotoUhpCondition.
```

Finally, in order to check if a concrete attempt to copy a learning object is authorised, the SPARQL query template presented in 3.2 has been directly reused. It is just required to set the action that is being checked when generating the query to be sent to the metadata repository, in the case of the SPARQL query shown in Table 10 the action to check is “luisa:copy_eads_lo_to_uhp_01”.

Table 10. SPARQL query that checks if an action is authorised and the condition met

```
PREFIX co: <http://rhizomik.net/ontologies/2008/05/copyrightonto.owl#>
PREFIX luisa: < http://luisa.atosorigin.es/uhp-eads-p2.owl#>
ASK {
    ?agreement rdf:type co:Agree;           (1)
    co:theme ?pattern.                       (2)
    luisa:copy_eads_lo_to_uhp_01 rdf:type ?pattern; (3)
    co:agent ?consumer;                     (4)
    co:condition ?conditionPattern.         (5)
    ?condition rdf:type ?conditionPattern;   (6)
    co:agent ?consumer;                     (7)
    co:aim luisa:copy_eads_lo_to_uhp.       (8)
}                                             (9)
```

A part from mapping existing licenses from the project partners to the Copyright Ontology, the resulting licenses have been put into practice following the license checking implementation principles introduced in Section 3.2. A description logic reasoner, concretely Pellet [20], has been used in order to provide the reasoning capabilities that implement checking intended uses against the available action and condition patterns.

In order to manage a great volume of licensed learning objects, Pellet has been combined with a semantic metadata repository that provides database persistence.

Jena [25] has been the choice at this development stage. The combination of Pellet and Jena makes it possible that just the classes defining the action and condition patterns, together with the Copyright Ontology and the relevant facts for the reasoning at hand, are loaded into memory. This makes the solution more scalable as the main part of the data to be managed corresponds to facts, i.e. users, actions, learning objects, etc., while the classes modelling licenses patterns are just a small part of it.

In any case, Jena is not recognised as one of the more scalable semantic data repositories [26], though it has been chosen as it has facilitated the development process and the integration with Pellet, the priority during the prototype development. Consequently, the objective now is to develop more intensive tests and to evaluate existing alternatives for semantic data storage that show greater scalability.

5. Conclusions and Future Work

This paper presents the European project LUISA, a reference architecture for Learning Content Management, and concentrates on the DRM module responsible for learning objects licensing terms integration, copyright management and license checking. This module, as the whole LUISA architecture, is based on Semantic Web technologies and methodologies.

In the case of the copyright management module, this choice makes it possible to develop a Copyright Ontology that captures copyright terms in an interoperable and flexible way. Moreover, it is possible to take profit from Semantic Web tools, reasoners and semantic query engines, in order to easily implement license checking.

This approach has been evaluated in the context of the research project. Different licensing schemes from different project partners have been formalised using Copyright Ontology concepts and relations. It has been possible to capture the semantics of commercial licenses from these partners, most of them based on textual representations. Then, it has been possible to develop a DRM module based on Semantic Web tools that manages a set of licenses and instance data from different project scenarios, i.e. facts about users, learning objects, the actions carried out by the users on the learning objects, etc.

The current deployment has been tested with a limited size and quite synthetic dataset. Future work concentrates now on modelling a greater range of licensing schemes detected in the LUISA project and performing a detailed test of the copyright management module in order to test the scalability of this solution. This test will be performed on a mix of commercial licenses like the ones currently evaluated together with licenses based on open access terms. The latter, though easier to generate, will allow generating a much bigger dataset and to test the integration of open and commercial terms in a semantic DRM module.

Reference

1. Vargas-Vera, M., Lytras, M.D.: Exploiting semantic web and ontologies for personalised learning services: towards semantic web-enabled learning portals for real learning experiences. *Int. J. of Knowledge and Learning* 4(1), 1-17 (2008)
2. Collazos, C., García, R.: Semantics-Supported Cooperative Learning for Enhanced Awareness. *International Journal of Knowledge and Learning* 3(2/3), 59-66 (2007)
3. Rosenblatt, B.: 2005 Year in Review: DRM Standards. *DRM Watch*, January 2, (2006) <http://www.drmwatch.com/standards/article.php/3574511>
4. Lytras, M., García, R.: Semantic Web Applications: A framework for industry and business exploitation - What is needed for the adoption of the Semantic Web from the market and industry. *International Journal of Knowledge and Learning* 4(1), 93-108 (2008)
5. Porter, D.: Bringing Customer Value to the Learning Ecosystem. *Proceedings of the 2nd Canarie eLearning Workshop*. Montreal, Quebec, (2003)
6. Kang, M., Kim, S., Park, G.-C., Lee, G., Kil, M.: Design of DRM-LMS Model in M-Learning Environment. In: B. Gabrys, R.J. Howlett, L.C. Jain (eds.): *KES 2006, Part III*, LNAI vol. 4253, pp. 1075-1082 (2006)
7. Cole, J., Foster, H.: *Using Moodle: Teaching with the Popular Open Source Course Management System*. O'Reilly Media (2007)
8. Harman, K., Koohang, A.: *Learning Objects: Standards, Metadata, Repositories, and LCMS*. Informing Science Press (2006)
9. Lessig, L.: *The Future of Ideas: The Fate of the Commons in a Connected World*. Vintage (2002)
10. Liu, Q., Yang, Z., Yan, K., Jin, J., Deng, W.: Research on DRM-enabled learning objects model. In: *Proceedings of the International Conference on Information Technology: Coding and Computing, ITCC'05*. IEEE Computer Society, vol. 2, pp. 772-773 (2005)
11. Iannella, R.: On-line Trading of Rights-Enabled Learning Objects. *International Journal of Electronic Commerce*. 8(4), 99-113 (2004)
12. de Walle, R.V., Burnett, I.: *The MPEG-21 Book*. John Wiley & Sons (2005)
13. Doctorow, C.: Critique of NAVSHP (FP6) DRM Requirements Report. *Electronic Frontier Foundation* (2005). Available from <http://www.eff.org/IP/DRM/NAVSHP>
14. Pease, A., Rust, G.: Formal Ontology for Media Rights Transactions. In: García, R. (ed.) *Semantic Web for Business: Cases and Application*. IGI Global, in press (2008)
15. Cabral, L., Domingue, J., Galizia, S., Gugliotta, A., Norton, B., Tanasescu, V., Pedrinaci, C.: IRS-III: A Broker for Semantic Web Services based Applications. In: *Proceedings of the 5th International Semantic Web Conference (ISWC 2006)*, Athens, USA (2006)
16. Mocan, A., Cimpian, E.: An ontology-based data mediation framework for semantic environments. *International Journal on Semantic Web and Information Systems* 3(2), 66-95 (2007)
17. García, R.: "A Semantic Web Approach to Digital Rights Management". PhD Thesis, Universitat Pompeu Fabra, Barcelona, Spain, 2005. Available from <http://rhizomik.net/~roberto/thesis>
18. McGuinness, D.L., van Harmelen, F.: *OWL Web Ontology Language Overview*. W3C Recommendation 10 February 2004. Available from <http://www.w3.org/TR/owl-features>
19. Sowa, J.F.: *Knowledge Representation. Logical, philosophical and computational foundations*. Brooks Cole Publishing Co. (2000)

20. Sirin, E., Parsia, B., Grau, B., Kalyanpur, A., Katz, Y.: Pellet: A practical OWL-DL reasoner. *Journal of Web Semantics* 5(2), 51-53 (2007)
21. Prud'hommeaux, E., Seaborne, A.: SPARQL Query Language for RDF. World Wide Web Consortium Recommendation (2008). Available from <http://www.w3.org/TR/rdf-sparql-query>
22. Grimm, S., Motik, B.: "Closed World Reasoning in the Semantic Web through Epistemic Operators". In *Proceedings of the OWL Experiences and Directions Workshop* (2005)
23. García, R., Gil, R.: "An OWL Copyright Ontology for Semantic Digital Rights Management". In Meersman, R.; Tari, Z.; and Herrero, P. (eds.) "OTM Workshops 2006". Springer, LNCS Vol. 4278, pp. 1745-1754 (2006)
24. García, R., Gil, R.: "Copyright Licenses Reasoning using an OWL-DL Ontology". In Breuker, J., Casanovas, P., Klein, M., Francesconi, E. (Eds.): *Law, Ontologies and the Semantic Web*, IOS Press, in press, (2008)
25. McBride, B.: Jena: a semantic Web toolkit. *IEEE Internet Computing* 6(6), 55-59 (2002)
26. Bizer, C., Schultz, A.: Benchmarking the Performance of Storage Systems that expose SPARQL Endpoints. In *Proceedings of the 4th International Workshop on Scalable Semantic Web knowledge Base Systems (SSWS2008)*. Karlsruhe, Germany (2008)