Making Learning Objects Useful with Semantic Web Services

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Abstract: The combination of Semantic Web technology and e-Learning opens new and interesting possibilities for the applicability and reuse of learning objects (LO). Concretely, the economic promises of the widespread use of the LO reuse paradigm require high levels of automation that ease the tasks of searching, selecting and composing relevant educational resources for the given needs. This also should take place in a loosely coupled environment in which semantic metadata becomes the key resource. Still, a number of issues need be dealt with for the agile discovery and composition of LO. In this paper, WSMO, one of the most relevant public Semantic Web Service specifications is reviewed with the aim of identifying required extensions that fulfil the requirements of LO handling. Furthermore, a reference Service-oriented architecture (SOA) that uses the communication facilities of a semantically enhanced Enterprise Service Bus (ESB) is sketched, with the aim of recognizing the different main building blocks required to support e-Learning and micro learning applications.

Keywords. Semantic Web Services, learning objects, Semantic Web, Service Oriented Architecture.

1. Introduction

There have been several recent informal discussions on the Web "*ringing the death bell for learning objects*"[i]. Some of the major criticisms come from the fact that the "*promise*" of economical gains or of real reusability have still not clearly materialized, after a reasonable number of years from the inception of the concept. Others point out that the emphasis was on technical interoperability or transportability, neglecting the pedagogical aspects of reuse. These are reasonable objections, but in many cases, there is not a discussion of real technology issues, but they tend to focus on the learning object approach as a collaborative, open effort. In our view, the analysis of the gap from expectations to actual outcomes must be considered in two dimensions:

- The technology acceptance dimension, considering the issues of the degree of acceptance of the concept of learning objects and the number and quality of current deployed applications and systems – notably including learning object repositories.
- The technology research and development dimension, considering the capabilities of the software technology developed so far, in relation to the expected use requirements.

Most current criticisms address the first dimension, but from a software technology viewpoint, it is clear that the benefits of expending effort in making learning resources reusable would only be justifiable only when advanced capabilities are provided by software, and not before. Thus, our focus is that of the second dimension, since it is the critical piece that. Current technology has advanced to technical interoperability, and some specifications provide advance in other capabilities as the IMS LD[ii] that provides pedagogically-oriented workflow. Nonetheless, semantics are required to provide the infrastructure for advanced query, selection and composition capabilities. Ontologies and logics-based technology are candidates for developing advanced software that may eventually make the case and provide the value for the adoption of reuse-oriented technology [0]

Assessments of the learning object approach in the technology acceptance dimension overlook the requirement for advanced automation that arises if we want to achieve more cost-effective reuse of education, beyond what is available today (search engines, textbooks, and similar "reusable learning resources"). The promises of learning objects require technology-enhanced support with at least the following requirements:

1. The properties of learning resources should be described in computer-understandable form, as a basic requisite for the development of advanced technology.
2. Such descriptions must be expressed in a shared machine-understandable language. Such language enable the application of advanced Artificial Intelligence techniques beyond natural-language descriptions oriented to human consumption.
3. The descriptions must incorporate pedagogical information relevant to the task of learning design.
4. A mechanism should be provided to make available those descriptions on the Net to software agents. This requirement comes from the fact that reuse is of value in an environment of openness to multiple parties – companies, institutions that play different roles in e-learning activity.
5. A mechanism should be available to retrieve and sequence the objects based on those descriptions, providing more precision and added value than current mechanisms as common Internet search engines.

Current learning management systems (LMS) and learning object repositories [0] based on standards are not oriented to the strict computational semantics requirements reflected in the above requirements. While they are of course useful search tools for educators, the economic gains in reusability require the support of automation to have rapid access to the resources that are candidates to fulfil strictly formulated objectives. In fact, standards of learning object metadata as LOM[iii] arguably fail to meet requirement (1) – see [0] – since they are based on natural language text, which provides little options for automated processing based on complex need descriptions.

The kind of computational semantics expressed in requirements (1) to (3) can be provided by shared ontologies that could be used in combination with existing commonsense ontologies [0] to provide a convenient framework for the rest of the process. Commonsense ontologies allow for an extensive reuse of past knowledge engineering work, and new specific domain ontologies can be used to represent even divergent pedagogical positions on learning [0]. The expression of pedagogical information is an open problem [0] that will not be dealt with here, since it is orthogonal with the problems emphasized here, that are represented by requirements (4)-(5).

Because services can randomly appear and be withdrawn, we need a framework that describes their functionality and behaviors and that can subsequently be used for location [0]. Semantic Web Services enrich the decoupled framework of Web Services with capabilities enabled by the use of formal languages. As such, they provide the required infrastructure for the delivery, search and location of reusable learning objects, exploiting logics-based metadata sentences that predicate about the contents and potential pedagogical usage of learning resources. Semantic annotations can be used as the material in which software agents can build precise resource-seeking or resource-composition activities. Even though there is a considerable literature on the application of Semantic Web techniques to learning object settings, the Service-oriented architecture that would provide the required decoupled framework for the interchange has received little attention. This paper deals with these issues, in an attempt to delineate the required architecture for providing value through technology to the learning object paradigm.

The paper is structured as follows. Section 2 presents a detailed overview of the state-of-the-art and requirements analysis for the provision of a solid framework and reference architecture that deals with the specific requirements of LOM and e-Learning. Section 3 details the proposed architectural solution depicting each one of the layers and building blocks that construct it. Section 4 briefly depicts the main characteristics of WSMO to set the basis for the description of the different extensions required to adapt the specification to the requirements of LOM. Finally, section 5 reviews the ideas presented and sketches the next steps that the authors are planning to take.

2. State-of-the-art and requirements analysis

Semantic Web Service (SWS) frameworks provide a decoupled solution to the problems described above with the provision of computational semantics. This goes beyond existing metadata schemas by exploiting the reasoning capabilities provided in modern logic languages. The WSMO framework[iv] is to date the richer SWS platform available. It provides several languages diverging in their orientation to description logics or to logic programming constructs [0]. Our approach for the adaptation of such framework to the requirements for the reuse of learning objects entails the following adaptations:

1. The reformulation of the conceptual models of metadata schemas as LOM [0]. This encompasses both the translation of the current schema and the enrichment of that schema with the axioms that will provide the added reasoning capabilities, e.g. reasoning with time, geography or competencies and its constituents [0].
2. The provision of learning object metadata repositories (LOMR) that store the instances of the descriptions in the logics-based language.
3. The integration of new annotation tools for the provision of rich metadata connected to the ontologies.
4. The provision of mediation features to resolve semantic mismatches between different schemas and also to enable the use of several distributed LOMR instances.
5. The integration of all these various elements into a flexible reference architecture able to cope with the specific requirements of e-Learning and micro learning.

In the following section the authors try to give a solution to the problems presented. More concretely, in the following section a reference architecture is depicted that tackles the different aspects of points: (2), (3), (4), (5).

3. Architectural solution

The reference architecture follows a layered model where layers are piled on top of each other building a stack (see Figure 1). Each layer comprises a number of SWS that realize the layer functionality providing support to the ones building of top. Additionally, each one of the layers is also defined as SWS that communicates with others by means of message exchanges [0]. By these means a fully-fledged SSOA is defined.

In the following the layers that comprise the architectural specification are briefly depicted:

- **Persistence layer:** Encloses a number of services that detail a light weight framework for simple storage management. In this layer the basic LO together with the semantically enhanced metadata that describes them are kept.

- **Semantic Layer:** Defines the main building blocks that implement the semantic support of the framework. It builds on top of the storage layer comprising a reasoning engine that supports mediation among heterogeneous SWS and the LO they interface.
- **SWS layer:** Depicts a number of well-defined services that put in place the functionality that enables the publication, discovery, negotiation, choreography, orchestration and execution of SWS and the LOs they interface. This layer builds on top of the basic semantic layer.
- **Communication layer:** Comprises an Enterprise Service Bus (ESB) service that provides a sharable mechanism to manage messages guarantying its delivery and mediation. It facilitates the functionality that allows the architecture to communicate with other systems and internally between the SWS that build it [0]. Every other layer in the architecture makes use of this one for service-to-service communication.

In addition to these main layers two more levels of abstraction have been added to the framework that helps realizing a fully fledged framework and reference architecture.

- **Ontologies:** In order to enriching LO-metadata with machine processable semantics the WSMO ontology has been augmented accommodating the specific requirements of LO. This architectural building block does not comprise a service by itself but rather a necessary artefact for the richer description of LO.
- **Tooling Support:** The enhancement of syntactic metadata describing LO with semantic annotations requires proper tooling support that eases the task. Thus, a LO annotation tool is made available as part of the architecture that fulfils this purpose.

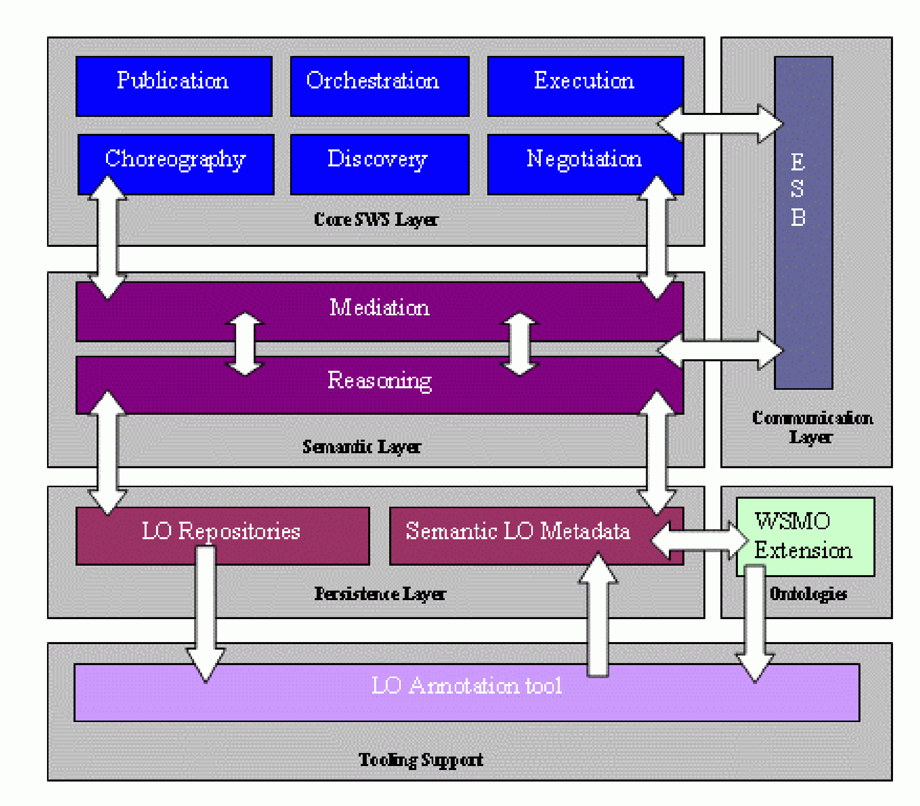

Figure 1. Layered architecture

As can be seen the proposed architecture provides a clean and flexible solution to the aforementioned problems. It facilitates the means to store LO and semantic metadata that describes them. It counts with complete support for the provision of rich ontology-based metadata. It clearly depicts a mediation layer that builds on top of reasoning support for the agile resolution for semantic mismatches among LOM schemas and instances. And finally, the architectural approach taken is flexible enough as to cope with the ubiquitous necessities of micro learning applications.

Open Source technologies has been chosen to aid in the implementation of the reference architecture. For example, Mule[v] and Open Source ESB messaging framework has been chosen as our general underlying Communication layer. Our Core SWS Layer will be built over WSMX[vi], the execution environment for WSMO. In design-time and for the tooling support we will make use of tools like WSMO Studio that are built following the Eclipse paradigm.

4. WSMO extension for LOM

In order to describe Learning Objects as Semantic Web Services we need to describe them in some formal language. There are two main initiatives in the Semantic Web Services community, namely OWL-S[vii] and WSMO. As we have mentioned before, we have chosen WSMO as the underlying infrastructure to enrich the Learning Objects as Semantic Web Services. WSMO has been created for a general purpose and therefore we will need to extend it to accommodate it to our more specific purposes. In next sections we will highlight the necessary changes and extensions that need to be undertaken to exploit the advantages of WSMO for the e-Learning community.

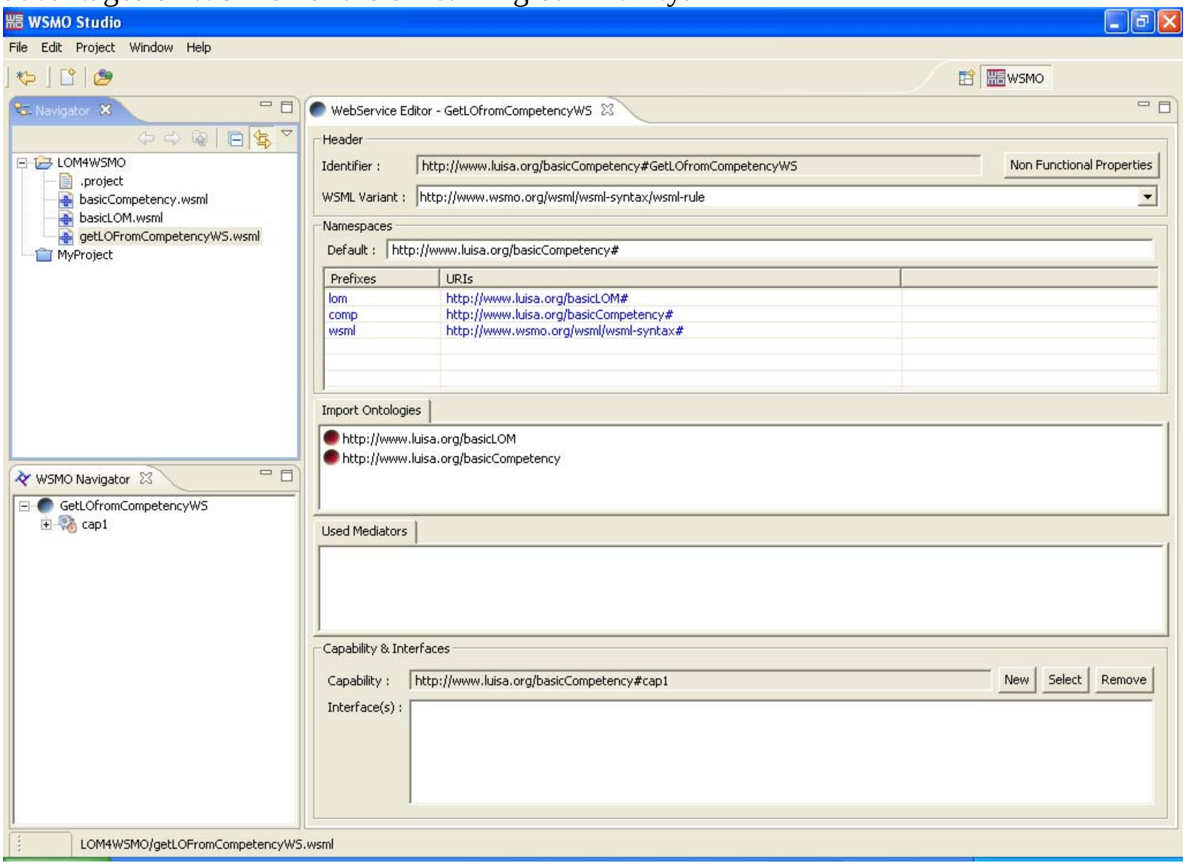

Figure 2. Using WSMO Studio for the formalization of Ontologies

4.1 Learning Object Metadata (LOM)

A number of specifications and standards that describe or make use of the learning object concept have evolved in the last years. The basic metadata elements associated to learning objects have been described in the IEEE LOM standard[viii], which organizes its conceptual metadata schema in nine categories: General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification. These cover basic description – title, coverage, etc. – and general purpose annotations (*General* and *Annotation*), contributors, change control and property matters (*Lifecycle* and *Rights*), technical characteristics of the Web contents (*Technical*), and the metadata record itself can also be described (*Meta-metadata*). The *Educational* category describes the envisioned educational characteristics of the object, including type of interactivity, typical educational context, typical age of intended learners and the like. The *Relation* category describes relations between learning objects, which could be viewed as a form of “linking” able of specifying also characteristics related to the educational, e.g. related learning objects that constitute prerequisites or that cover semantically related elements. Finally, the *Classification* element serves several different purposes, including stating the objectives of the learning object, the prerequisites of the learner and the overall classification of the contents inside taxonomical schemes or ontologies.

4.2 Web Service Modelling Ontology (WSMO)

The Web Service Modelling Ontology (WSMO) [0] is a formal ontology and language for describing the various aspects related to Semantic Web Services.

The objective of WSMO and its surrounding efforts is to define a coherent technology for Semantic Web Services. Means for semi-automated discovery, composition, and execution of Web Services shall be based on logical inference-mechanisms, because of the well-known competences of suchlike techniques, and its appropriateness for the purpose.
WSMO defines the modelling elements for describing several aspects of Semantic Web Services. The conceptual grounding of WSMO is based on the Web Service Modelling Framework (WSMF) [0], wherein four main components are defined:

- **Ontologies** provide the formal semantics to the information used by all other components.
- **Goals** specify objectives that a client may have when consulting a Web Service.
- **Web Services** represent the functional part, which must be semantically described in order to allow their semi-automated use.
- **Mediators** used as connectors provide interoperability facilities among the rest of components.

In order to allow suitable logic-based reasoning on Semantic Web Service, the description language has to provide reasonable expressiveness for describing relevant aspects of the Services, together with well-defined formal semantics that support effective reasoning. WSMO counts with WSML [0] for the description of ontologies, goals, Web services and mediators. WSML provides a coherent framework that brings together Web technologies with different well-known logical language paradigms (Description Logics [0], Logic Programming [0], and fLogic [0]), as starting points for the development of a number of WSML language variants, based on existing Web standards such as XML Schema and RDF.

4.3 WSMO extension for LOM

One of the main differences from the semantics of WSMO and the needs of the Learning Objects is the way in which the user is described. Although the user preferences can be expressed in terms of Domain Ontologies, there isn’t any possibility to describe and use the stored record of interactions of the user. However, in e-Learning, the profile of the user is very important in order to find and use the most appropriate Learning Object for the user. In a WSMO Web Service, a capability can be described to serve one or more Learning Objects. However, the desire of the user willing to obtain those Learning Objects should provide not only the functional content of the Learning Object but also the already acquired skills of the user. The current semantics of a WSMO goal can determinate the functional requirements of the user, but there is no place in which the user can customize the matching with his own profile.

The fulfilment of the objective [1] of this paper needs that an extension of WSMO in which the user profile is taken into account (by means of the goal's precondition section) defining what the user already *knows* and what are his own *competencies*. In this way, the matching of the user's desires (characterized by a WSMO goal) and what the Learning Object provides (characterized by one or more WSMO Service) will be more efficient, allowing the adaptation and evolution of the own profile by means of their use.

An initial version of the ontologies in WSML was described in [0]. However, that initial work can be extended in horizontal or vertical ways – i.e. extending the learning-object describing or covering specific domains. Semantic Web Services serve as the point of interaction of the above described components. The following WSML fragments, designed and validated using WSMO Studio[ix], a tool developed for the definition of WSMO elements, are provided as an illustration of the nature of such interfaces and the capabilities provided.

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-rule"
namespace { _"http://www.luisa.org/basicCompetency#" }

ontology _"http://www.luisa.org/basicCompetency"
     nonFunctionalProperties
     _"http://purl.org/dc/elements/1.1#title" hasValue "Basic Competency"
     _"http://purl.org/dc/elements/1.1#language" hasValue "WSML-rule"
     _"http://purl.org/dc/elements/1.1#contributor" hasValue {"Miguel
Angel Sicilia", "Ozelin Lopez"}
     _"http://www.wsmo.org/wsml/wsml-syntax#version" hasValue "0.1"
     _"http://purl.org/dc/elements/1.1#date" hasValue "04/05/06"
     endNonFunctionalProperties

concept CompetencyComponent
concept CompetencySpec
     title impliesType  (1 1) _string
     hasConcept transitive  impliesType CompetencyComponent
concept attitude subConceptOf CompetencyComponent
concept skill subConceptOf CompetencyComponent

instance compSpec1 memberOf CompetencySpec
     title hasValue "CompetencySpec1"
```

Table 1 Basic Competency Ontology

```
ontology _"http://www.luisa.org/basicLOM"
     importsOntology
        _"http://www.luisa.org/basicCompetency"

concept LearningObject
     title impliesType  (1 1) _string
     LomClassCompetency impliesType comp#CompetencySpec
     LomRelationHasPart inverseOf(LomRelationPartOf) impliesType
LearningObject
     LomRelationPartOf inverseOf(LomRelationHasPart) impliesType
LearningObject
     LomCost impliesType  (0 1) _decimal
     LomTypicalLearningTime impliesType  (0 1) _duration

instance lo1 memberOf LearningObject
     title hasValue "LearningObject1"
     LomClassCompetency hasValue comp#compSpec1

instance lo2 memberOf LearningObject
```

Table 2 Basic LOM Ontology

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-rule"
namespace { _"http://www.luisa.org/basicCompetency#",
     lom _"http://www.luisa.org/basicLOM#",
     comp _"http://www.luisa.org/basicCompetency#",
     wsml _"http://www.wsmo.org/wsml/wsml-syntax#" }

webService GetLOfromCompetencyWS
     importsOntology
          { _"http://www.luisa.org/basicLOM",
            _"http://www.luisa.org/basicCompetency"}

capability cap1
sharedVariables {?competency, ?lo, ?maxcost}

precondition axiom_pre
     definedBy
          ?competency memberOf CompetencySpec
  and ?maxcost memberOf _decimal.

postcondition axiom_post
     definedBy
          ?lo memberOf lom#LearningObject
  and forall ?x
  ( ?x memberOf CompetencyComponent
  and ?competency[hasComponent hasValue ?x] )
implies
exists ?z
  ( ?z memberOf lom#LearningObject
  and ?z[lom#LomRelationPartOf hasValue ?lo]
  and ?z[lom#LomClassCompetency hasValue ?competency] )
  and ?lo[lom#LomCost hasValue ?totalcost]
  and wsml#numericLessThan(?totalcost,?maxcost).
```

Table 3 GetLOFromCompetency Web Service

The *nfp* section describes non-functional properties (in this case, only a description and version). The fragment above defines a simple Web service that searches for a (possibly aggregated) learning object that covers as learning objectives all the competency components [0] required in the invocation, and it is also constrained by a total cost restriction. The definitions are based in the ontology of competency specifications described by [0] and in a basic learning object ontology that includes competency as a way of classifying the learning object, just as it is prescribed in the LOM standard. It should be noted that the implementation of this web service could follow different paths and could consider different levels of detail or structure of the resulting learning object (`?lo`). Further, the Web service may carry out an aggregation of existing learning objects by itself (or by invoking other services). Another interesting possibility is that an additional Web service can use the service provided by this one to impose an additional restriction on the results required by the user, for example, by requiring that the "typical learning time" of the resulting `?lo` is below a given value.

The inclusion of the user profile in the matching of the user's desire with this service will also allow us to redefine the set of restrictions given by this service (or the aggregation of others) in terms of skills needed *to learn* this Learning Object.

5. Conclusions and Future Work

SWS are able to provide the required technology for automated selection, discovery and aggregation of learning objects, bringing the required machinery for the fulfilment of the economic statements regarding reuse of learning objects.

This paper has presented the description of a reference SOA that uses the communication facilities of an ESB for the development of e-Learning applications and their deployment on different settings regardless of the application domain. Key characteristics of the architecture are the tooling support required to produce semantic metadata that describes LOs, the provision of suitable repositories to store LOs and LOs metadata, and the mediation support for the agile and flexible reuse of LOs regardless of the conceptualization used to describe them.

The paper tries to adopt the point of view of the instructor as far as it takes under consideration the discovery and composition of micro contents with the aim of building complete materials, but also of the learner who will consume the contents in a ubiquitous environment.

As future steps, the ideas presented in this work will be implemented and tested as part of the EU-funded project LUISA, which tries to combine and apply Semantic Web and Semantic Web Services technologies to e-Learning in general.

Acknowledgments

This work is funded by the European Commission under the IST project LUISA (FP6-027149).

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