A Semantic Web Service Architecture for Learning Object Repositories

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ABSTRACT

The evolution of learning technology standards has resulted in a degree of interoperability across systems that enable the interchange of learning contents and activities. Nonetheless, learning resource metadata does not provide formal computational semantics, which hampers the possibilities to develop technology that automates tasks like learning object selection and negotiation. In this paper, the provision of computational semantics to metadata is addressed from the perspective of the concept of Semantic Web Service. An architecture based on the specifications of the WSMO project is described, including the definition of an ontology for learning object metadata, and issues of mediation, all under the perspective of the Learning Object Repository as the central entity in learning object reuse scenarios. The resulting framework serves as a foundation for advanced implementations that consider formal metadata semantics as a mechanism for the automation of tasks related to the interchange of learning objects.

KEYWORDS
e-learning, Learning Object, Semantic Web, Semantic Web Services, WSMO.

INTRODUCTION

Current standardized *e-learning* systems are centered on the concept of *learning object* (Wiley, 2001), which can be defined as "a self-standing and reusable unit predisposed to be used in learning activities" (Polsani, 2002). Several interrelated standardization efforts – including the IEEE LTSC, ADL SCORM and the IMS Consortium (Anido et al., 2002) – are devoted to produce and refine specifications oriented to fostering consistency in learning contents and related elements. These specifications currently cover learning object packaging and metadata, sequencing and composition of activities, and the definition of specialized types of learning objects like questionnaires, among other aspects. Nonetheless, these specifications do not provide details about the use of well-known knowledge representations for the sake of automating some processes like selection and composition of learning objects, or adaptation to the user or platform. In addition, the information schemas provided in such specifications are not free of controversial interpretations (Farance, 2003), which seriously hamper the possibility of implementing standardized "intelligent" behaviors. Such situation has lead to consider Semantic Web technology as a promising enhancement for learning object-based technology.

Ontologies are shared knowledge representations that form the basis of the current Semantic Web vision (Berners-Lee et al., 2001) and that are becoming widespread due to the availability of common languages like OWL and associated modeling and development tools (Fensel, 2002). Ontologies have been described elsewhere (Lytras et al., 2003; Stojanovic et al., 2001; Qin, & Finneran, 2002) as enablers of more flexible and advanced learning systems, but the mere use of Ontologies does not guarantee that consistent functionality will become available in the future, since it is also required an effort of specification about the *uses* of Ontologies *for each* particular learning technology scenario. Precise and unambiguous usage specifications for Ontologies in *e-learning* would eventually result in a higher level of automation in learning systems. But preciseness requires a clear separation of responsibilities for the participants in each scenario, along with concrete, machine-oriented interpretations for metadata elements, that is not the focus of current specification efforts.

Previous work (Sánchez, Sicilia & López-Cobo, 2004) has addressed how Web Service architectures combined with precise metadata descriptions can be used as a framework to specify learning object selection and composition processes, which are an essential part of any approach to automation in this area, pointing out to the appropriateness of using richer frameworks of Web Service description as the Web Service Modeling Ontology (Roman et al., 2004). Recent work has begun to explore the mapping of existing learning technology standards to the WSMO framework (López-Cobo, Sicilia & Arroyo, 2004) in the area of metadata-based selection.

In this chapter, the architecture of a Semantic Web Service based Learning Object Repository is described, targeting selection and composition processes as basic scenarios for automation in the field of e-Learning. An ontology based on the LOM specification is used to specify both client goals and diverse offerings, and the surrounding issues of mediation are also explored.

The design described in the chapter is based on WSMO technology, and it provides an underlying substrate to machine-understandable semantics for learning object metadata which delivers benefits both to individuals and organizations engaged in e-Learning. In practice, such enhanced support for automation in repositories represents an important step in mass customization and electronic interchange as envisioned by the paradigm of learning objects (Martínez, 2001). The chapter focuses on Ontologies as shared knowledge representations that can be used to obtain enhanced learning object metadata records – according to existing criteria (Duval et al., 2002) -, and also to enable automated or semi-automated consistent processes inside *Learning Management Systems* (LMS).

The rest of this paper is structured as follows. The second section provides background information and states the problem addressed in the rest of the chapter. The third section describes the role of Ontologies in describing learning object metadata. Then, the fourth section introduces how WSMO goals and capabilities can be used to semantically describe learning-object providing Web Services. The fifth section provides the overall architectural framework for selection and composition as based on those semantic descriptions. Finally, the last section is devoted to conclusions.

BACKGROUND

In this section, background information on learning object technology and Semantic Web Services is provided. Concretely, the state of relevant standards and specifications on learning technology is briefly summarized, and the main efforts related to Semantic Web Service technology are sketched. The section also provides a definition of the problems of selection and composition of learning objects that are dealt with in the rest of the chapter, and the rationale for using Semantic Web services as the architecture for these processes.

Standards related to learning objects

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 (IEEE, 2002), 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 (Sicilia et al., 2004). 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.

Another important specification is ADL SCORM, which adopts IEEE LOM as the metadata language for learning resources, and provides specifications oriented towards achieving a degree of interoperability in the functioning of Learning Management Systems (LMS). Concretely, the SCORM content packaging specification determines an interoperable format for the interchange of learning contents structured as hierarchical units, and the SCORM run-time specification specifies a common protocol and language for the Web browser-LMS communication, including the delivery of some kind of learning objects (called Sharable Content Objects in SCORM) and the recording and tracking of the activities of each user. The recent sequencing and navigation specifications go a step beyond and provide a language in which complex navigational patterns can be devised, including learning paths that adapt to the accomplishment of some objectives by the learner. The SCORM specifications together provide
The recent IMS Learning Design (LD) specification addresses the description of activity-based designs of learning activities, in which several different roles are joined together in each activity, and interact with learning objects and services (like chat services) to accomplish some goals. IMS LD implementations like the CopperCore engine provide a coordination support that is able to deliver the activities to the specified learners in the order and under the conditions specified in the learning design.

IEEE LTSC, IMS and ADL, among other organizations, are currently active in the evolution and extension of the body of learning technology standards. Other areas currently covered and not discussed here for brevity include educational portfolios, learner descriptions, tests, digital repositories and competency specification. An important specification for the objectives of this chapter is the IMS Digital Repositories Interoperability (DRI) Specification (IMS, 2003). The purpose of this specification is to provide recommendations for the interoperation of the most common repository functions, described in terms of XQuery and SOAP recommendations.

Semantic Web Services

The combination of machine-processable semantics facilitated by the Semantic Web with current Web Service technologies has coined the term Semantic Web Services. Semantic Web Services offer the means to achieve a higher level of value-added services by adding dynamism to the task driven assembly of inter-organization business logics. They count with the potential to make the Internet a global, common platform where agents (organizations, individuals, and software) communicate with each other to carry out various activities.

Semantic Web Services represent an extension to current Web Services technology. They broaden the Web from a distributed source of information to a distributed source of services (Lara et al., 2003), where software resources can be assembled on the fly to accomplish user's goals. They are defined as "*Decoupled, semantically marked-up Web Services (Tidwell, 2000), with concrete execution semantics, that can be published, discovered, selected, composed, mediated and executed across the Web, in a task driven way, carrying its interaction by means of document exchange (Arroyo et al., 2004) following a choreographed or orchestrated approach*".

In order to fully allow the usage and integration of Web Services their capabilities need to be semantically marked up, and their interfaces need to provide the means to understand how to consume their functionality. Further, the exchange of documents requires describing the meaning of the content in a way that can be understood and communicated independently of some particular domain knowledge.

WSMO (Roman et. Al., 2004) tries to alleviate these problems by defining the modeling elements for describing several aspects of Semantic Web Services. WSMO is a formal ontology and language for describing the various aspects related to Semantic Web Services. It represents the backbone for the development of Web Service Modeling Language (WSML) and Web Service Modeling Execution Environment (WSMX). The conceptual grounding of WSMO is based on the Web Service Modeling Framework (WSMF) (Fensel and Bussler, 2002), wherein four main components are defined:

- **Ontologies** provide the formal semantics to the information used by all other components. Ontologies are used to: (1) express goals in a machine processable and understandable language; (2) they permit to enhance Web Services so they can be matched against goals; and (3) interconnect the different elements with each other by means of mediators,. Ontologies are described by means of non-functional properties, used mediators, axioms, concepts, relations and instances.
- **Goals** specify objectives that a client may have when consulting a Web Service. They provide the means to express high level description of a concrete task. The WSMO definition of goal is restricted to post-condition, effects, non-functional properties and used mediators.
- **Web Services** represent the functional part which must be semantically described in order to allow their semi-automated use. Web Services are described, by means of a capability, interface, used mediators and non functional properties.
- **Mediators** used as connectors provide interoperability facilities among the rest of components. Currently the specification defines four different types of mediators, which are classified in two main classes: refiners (ggMediators and ooMediators) and bridges (wgMediators and wwMediators). While refiners are used to define new components as a specialization of an existing one, bridges help to overcome interoperability problems by enabling components to interact with each other. In the general case WSMO defines mediators by means of non-functional properties, source component, target component and mediation service, where source and target component can be a mediator, a Web Service, and ontology or a goal.

WSMO facilitate the means to publish, discover, select, mediate, compose, execute, monitor, replace, compensate and audit services, for the benefit of some agent who seeks to fulfill some user-defined task conceptualized as a goal, minimizing human intervention and realizing the process in a more dynamic way.
The set of all these steps has been termed Semantic Web Service Usage Process (Arroyo et al., 2004). It allows to publish the description of the capability and interface of a service, discover different services suitable for a given goal, selecting the most appropriate services among the available ones, compose services to achieve the goal, mediate (data, protocol, process) mismatches among the combined services, execute services following programmatic conventions, monitor the execution process, replace

services by equivalent ones, compensate and mitigate unwanted effects and audit service execution.

The problems of selection and composition of learning objects

The problems of selection and composition addressed in this chapter are two aspects of the same process. The overall process of learning object seeking can be abstractly characterized as follows. The process starts with the raise of some kind of *learning need*. Such needs may be expressed in simple terms as plain *goals* like "learner L requires learning about topic T", but they could also be expressed in a complex form. Such complex descriptions may include requirements on the profile, learning style and previous knowledge of the learner, constraints of the technical platform in which the learning objects will be delivered, and even limitations on cost, duration or calendar of the resulting on-line learning design. Even the theoretical positions on learning should be accounted for in learning object selection (Sicilia & Lytras, 2005). In addition, learning goals are intrinsically decomposable, in the sense that an overall goal can be broken up into simpler sub-goals that may be subject to independent inquiry.

In that concept, the process of learning selection can be defined as "the process of decision in which one or several learning objects are selected to fulfill a specific learning goal under concrete contextual circumstances". Then, selection must first search for a set of candidate learning objects on which the decision takes place. Candidate learning objects are to be found on local or public systems often called "Learning Object Repositories", which should expose some kind of search services to resource seekers.

Learning object composition can be defined as the "process of combining several learning objects into a higher level instructional unit in order to fulfill some learning goals under concrete contextual circumstances". In consequence, composition actually requires selection as a constituent process. Nonetheless, composition imposes additional constraints on the process, since it may be possible that the selection processes generated by the breakdown of a goal into sub-goals results in selected learning objects that can not be joined together, for example, due to incompatible style designs or even to inconsistency in the pedagogical approach or level of description.

Selection and composition would therefore in many cases be intertwined in a sequence of steps as part of the overall process of assembling an on-line learning design. If no single learning object is available to selection for a particular goal or sub-goal, a process of composition may be started in an attempt to craft a new one from lower-level pieces. In turn, this composition process will trigger other selection activities. It should be noted also that the term learning object as used in this chapter not only includes pieces of static contents, but it may also encompass designs of activities involving multiple roles. For example, a LD method may be considered a composite learning object that has an internal activity-based structure.

The role of Ontologies in learning object descriptions

The benefits of using ontology description languages to express learning object metadata are of two fundamental kinds (Sicilia & García, 2005). On the one hand, those languages provide richer knowledge representation formalisms (Davis & Szolovits, 1993) for metadata descriptions than using plain text, XML bindings or even RDF. Here the benefits are the result of using description logics, instead of simply using structured data in XML format or using RDF, which is a less expressive language than DAML+OIL or OWL. On the other hand, the use of Ontologies may eventually produce synergies with the technological advances that are taking place under the overall label of "Semantic Web". The most prominent of such synergies may come from the availability of shared, consensual Ontologies on many domains along with tools to develop systems that exploit them for diverse "intelligent" behaviors.

In addition, Ontologies can be used to provide an explicit integration with broader organizational models. For example, a recent integration of learning activity-specific concepts provided elsewhere (Sicilia, Lytras, Rodríguez & García, 2005) has integrated learning object concepts with the ontology of Knowledge Management (KM) described by Holsapple and Joshi (Holsapple & Joshi, 2004).

Describing goals and capabilities in terms of learning objects

A basic ontology describing some essential metadata items in LOM could be described through the following definitions in WSML, which correspond to the main elements depicted in Figure 1. It basically addresses the central concept of the Learning Object and some related concepts as languages, life cycle, technical requirements, educational purposes, classification in different taxonomies, right management of the LO and complex treatment of the LO identifier. Some instances are defined for illustration purposes.

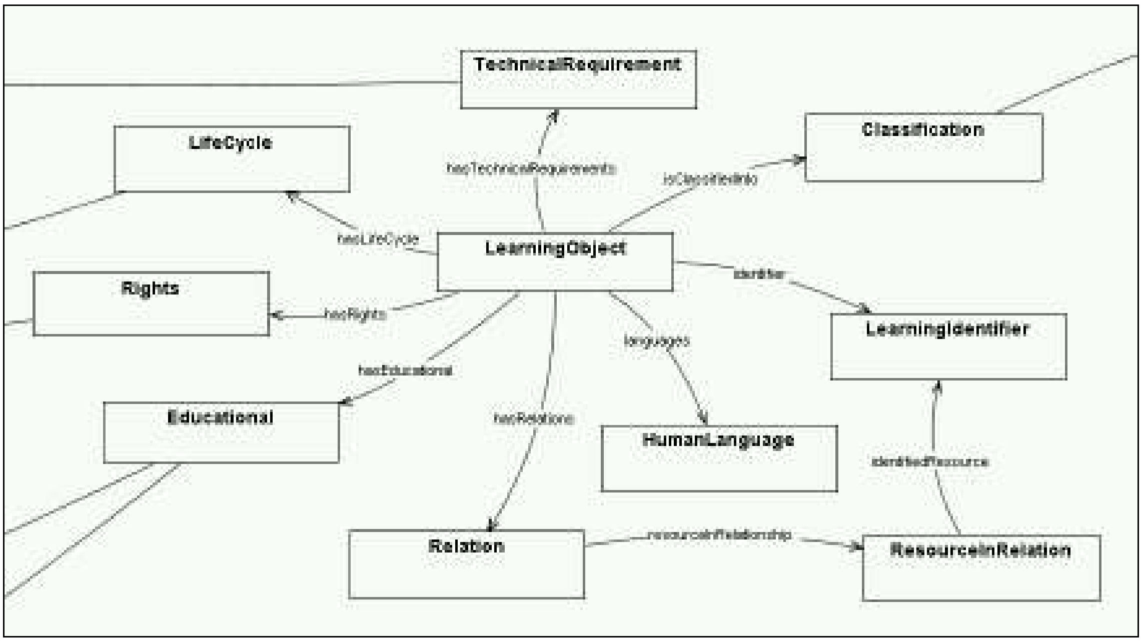

Figure 1 Excerpt form the Ontology Diagram for Learning Object Description

One of the most important concepts of the ontology is the “Relation” concept. With it, we can connect one Learning Object with other in terms of versioning, belonging, requirements and other useful relationships. These relationships could allow a reasoner to find and retrieve related Learning Objects with the selected by the customer.

```
namespace
_http://www.uah.es/ontologies/lom4WSMO#
dc: _http://purl.org/dc/elements/1.1#
vcard: _http://www.w3.org/2001/vcard-rdf/3.0#
xsd: _http://www.w3.org/2001/XMLSchema#

ontology
_http://www.uah.es/ontologies/lom4WSMO

nonFunctionalProperties
  dc:title hasValue "LOM Specification for
WSMO"
  dc:creator hasValues {vcard:UaH}
  dc:subject hasValues {"Learning Object",
"LOM", "Metadata"}
  dc:description hasValue {"LOM Specification
written in WSML for WSMO"}
  dc:publisher hasValue {vcard:UaH}
  dc:contributor hasValues {vCard:Ozelin,
vcard:Sicilia, vcard:Sinuhe}
  dc:date hasValue "2005-02-28"
  dc:type hasValue
_http://www.wsmo.org/2004/d2#ontologies
  dc:format hasValue "text/html"
  dc:identifier hasValue
_http://www.uah.es/ontologies/lom4WSMO
  dc:language hasValue "en-UK"
  dc:relation hasValues
{_http://www.w3.org/2001/vcard-rdf/3.0}
  dc:rights hasValue
_http://www.uah.es/privacy.html
  version hasValue "$Revision: 0.2 $"
endNonFunctionalProperties

/**
Highlighted Concepts of the Ontology
**/

concept cost
nonFunctionalProperties
  dc:description hasValue "Cost of the Learning
Object, if it exists"
endNonFunctionalProperties
 amount ofType amount
 currency ofType currency

concept rights
nonFunctionalProperties
  dc:description hasValue "Right Properties of
the Learning Object"
endNonFunctionalProperties
 descriptionOfRights ofType xsd:string
 hasCopyright ofType xsd:boolean
 hasCost ofType xsd:boolean
 price ofType cost

concept humanLanguage
nonFunctionalProperties
  dc:description hasValue "a humanLanguage is
a language in which can be expressed a
Learning Object"
endNonFunctionalProperties
name ofType xsd:string
ISOCode ofType xsd:string

concept taxon
nonFunctionalProperties
  dc:description hasValue  "A pair {id, value}
which represents some node in a taxonomy. A
Taxon may have a father and may have multiple
sons"
endNonFunctionalProperties
 idTaxon ofType xsd:string
 valueTaxon ofType xsd:string
 sonOfTaxon ofType taxon
 fatherOfTaxons ofType set taxon

concept taxonPath
nonFunctionalProperties
  dc:description hasValue "one possible path in
a taxonomy classification for a Learning
Object"
endNonFunctionalProperties
 hasSourceTaxonPath ofType sourceTaxon
 hasTaxon ofType set taxon

concept classification
nonFunctionalProperties
  dc:description hasValue "Each LO can be
classified into many ways. A classification will
gather this information"
endNonFunctionalProperties
 purpose ofType purpose
 taxonPath ofType set taxonPath

concept educational
nonFunctionalProperties
  dc:description hasValue "The Educational
aspects of the Learning Object"
endNonFunctionalProperties
 descriptionOfEducational ofType xsd:string
 interactivityType ofType interactivityType
 learningResourceType ofType
learningResourceType
 hasInteractivityLevel ofType interactivityLevel
 hasDifficulty ofType difficulty
 contextEducational ofType contextEducational
```

```
 intendedEndUserRole ofType
intendedEndUserRole

concept orCompositeTechnicalRequirement
nonFunctionalProperties
  dc:description hasValue "Define the
possibilities of a choice for a Technical
Requirement of a LO"
endNonFunctionalProperties
 minimumVersionOfTR ofType xsd:string
 maximumVersionOfTR ofType xsd:string
 typeOfRequirement ofType xsd:string
 nameOfRequirement ofType xsd:string

concept technicalRequirement
nonFunctionalProperties
  dc:description hasValue "A Technical
Requirement that a LO has to comply"
endNonFunctionalProperties
 installationRemarksOfTR ofType xsd:string
 formatOfTR ofType set xsd:string
 sizeOfTR ofType xsd:string
 locationOfTR ofType xsd:anyURI
 durationOfTR ofType xsd:duration
 hasOrCompositeRequirements ofType set
orCompositeTechnicalRequirement

concept learningIdentifier
nonFunctionalProperties
  dc:description hasValue "An unique and
unambiguous identifier for a LO"
endNonFunctionalProperties
 entryCatalog ofType xsd:string
 catalogIdentifier ofType xsd:string

concept resourceInRelation
nonFunctionalProperties
  dc:description hasValue "Describes the
Resource (LO) which is related with other LO"
endNonFunctionalProperties
 descriptionOfResource ofType xsd:string
 identifiedResource ofType learningIdentifier

concept relationship
nonFunctionalProperties
  dc:description hasValue "Describes one
relationship between the LO owner and other
LO"
endNonFunctionalProperties
 kindOfRelationship ofType kindOfRelation
 resourceInRelationship ofType
resourceInRelation

concept learningObject
nonFunctionalProperties
  dc:description hasValue "Any digital entity
that may be used for learning, education or
training"
endNonFunctionalProperties
 aggregationLevel ofType aggregationLevel
 languages ofType set humanLanguage
 isClassifiedInto ofType set classification
 hasRights ofType set rights
 hasTechnicalRequirements ofType set
technicalRequirement
 locationURI ofType xsd:anyURI
 hasEducational ofType educational
 identifier ofType learningIdentifier
 title ofType xsd:string
 structure ofType structure
 hasRelations ofType relationship

/**
Definition of the Relations of the Ontology
**/

relation hasAncestor
nonFunctionalProperties
  dc:description hasValue "(X,Y) is a tuple of
the binary relation iff X is ancestor of Y"
endNonFunctionalProperties
 ancestor ofType taxon
 descendant ofType taxon

/**
Description of the axioms of the Ontology
**/

axiom fatherIsAnAncestor
nonFunctionalProperties
  dc:description hasValue "A Father is an
ancestor"
endNonFunctionalProperties
definedBy
hasAncestor(?T1,?T2)
        impliedBy
                ?T1 memberOf taxon and
                ?T2 memberOf taxon and
                ?T2[sonOfTaxon ?T1].

axiom transitivityOfAncestor
nonFunctionalProperties
  dc:description hasValue "The Ancestor
relation is transitive"
endNonFunctionalProperties
definedBy
hasAncestor(?T1, ?T3)
        impliedBy
          hasAncestor(?T1, ?T2) and
          hasAncestor(?T2, ?T3) and
          ?T1 memberOf taxon and
          ?T2 memberOf taxon and
          ?T3 memberOf taxon.

axiom taxonLackOfCycles
nonFunctionalProperties
  dc:description hasValue "One taxon can not
be ancestor of itself"
endNonFunctionalProperties
definedBy
```

```
false
        impliedBy
          hasAncestor(?T1, ?T2) and ?T1 = ?T2
        and
          ?T1 memberOf taxon and
          ?T2 memberOf taxon.

axiom relationOfBelonging
nonFunctionalProperties
  dc:description hasValue "One LO belongs to
other iff participates in a isPartOf relationship
and its aggregationLevel is greater than its
father"
endNonFunctionalProperties
definedBy
constraint
        ?A1 = ?A2 + 1
          equivalent
        ?A1 memberOf aggregationLevel and
        ?A2 memberOf aggregationLevel and
        ?LO1[aggregationLevel hasValue ?A1,
                hasRelations hasValue ?R1,
                identifier hasValue ?I1]
        memberOf learningObject and
        ?R1[ kindOfRelationship hasValue
        hasPart,
        resourceInRelationship hasValue ?RiR1]
        memberOf relationship and
        ?RiR1[identifiedResource hasValue ?I2]
        memberOf resourceInRelation and
        ?LO2[  aggregationLevel hasValue ?A2,
                hasRelations hasValue ?R2,
                identifier hasValue ?I2]
        memberOf learningObject and
        ?R2[kindOfRelationship hasValue
        isPartOf,
        resourceInRelationship hasValue RiR2]
        memberOf relationship and
        ?RiR2[identifiedResource hasValue ?I1]
        memberOf resourceInRelation.

axiom uniqueLearningIdentifier
nonFunctionalProperties
  dc:description hasValue "There can't be two
different Learning Objects with the same par
{catalog, entry}"
endNonFunctionalProperties
definedBy
constraint
        ?X = ?Y
          equivalent
        ?X memberOf learningIdentifier and
        ?Y memberOf learningIdentifier and
        ?X.entryCatalog = ?Y.entryCatalog and
        ?X.catalogIdentifier =
        ?Y.catalogIdentifier.

axiom minimumLevelOfAggregation
nonFunctionalProperties
  dc:description "A Learning Object that is not
composed by other learning objects has an
aggregation level of 1"
endNonFunctionalProperties
definedBy
?LO1 [aggregationLevel hasValue 1,
hasRelations hasValue ?R] memberOf
learningObject
  impliedBy
not ?R[kindOfRelationship hasValue hasPart]
memberOf relationship.

axiom taxonLukeImYourFather
nonFunctionalProperties
  dc:description hasValue "If one taxon T1 has
a son T2, then the father of T2 is T1."
endNonFunctionalProperties
definedBy
constraint
?T2[sonOfTaxon hasValue ?T1]
memberOf taxon
  impliedBy
?T1[fatherOfTaxons hasValue ?T2]
memberOf taxon.

axiom taxonHolyGhost
nonFunctionalProperties
  dc:description hasValue "A taxon can not be
son of itself"
endNonFunctionalProperties
definedBy
constraint
  false
    impliedBy
  ?T1 memberOf taxon and ?T2 memberOf
taxon
  and ?T1 = ?T2 and ?T2[sonOfTaxon
hasValue ?T1].

axiom relationshipSelf
nonFunctionalProperties
  dc:description hasValue "A Learning Object
can not be related with itself"
endNonFunctionalProperties
definedBy
false
  impliedBy
?LO1[ hasRelations hasValue ?R, identifier
hasValue ?I] memberOf learningObject and
?R[ resourceInRelationship hasValue ?RiR]
memberOf relationship and
?RiR[ identifiedResource hasValue ?I]
memberOf resourceInRelation.

/**
Definition of the Knowledge Base of the
Ontology
**/

instance spanish memberOf humanLanguages
```

```
name hasValue "spanish"^^xsd:string
ISOCode hasvalue "ES"^^xsd:string

instance englishUK memberOf
humanLanguages
name hasvalue "englishUK"^^xsd:string
ISOCode hasvalue "en-UK"^^xsd:string

instance euro memberOf currency
currencyName hasvalue "Euro"^^xsd:string
currencyCode hasvalue "EUR"^^xsd:string

instance usDollar memberOf currency
currencyName hasValue "US
Dollar"^^xsd:string
currencyCode hasValue "USD"^^xsd:string

instance ARIADNE memberOf sourceTaxon
instance MESH memberOf sourceTaxon

instance restrictions memberOf purpose
instance idea memberOf purpose
instance discipline memberOf purpose
instance active memberOf interactivityType
instance expositive memberOf
interactivityType
instance mixed memberOf interactivityType

instance graph memberOf
learningResourceType
instance exam memberOf
learningResourceType
instance selfAssesment memberOf
learningResourceType
instance lecture memberOf
learningResourceType
instance school memberOf contextEducational
instance higherEducation memberOf
contextEducational
instance learner memberOf
intendedEndUserRole
instance teacher memberOf
intendedEndUserRole
instance author memberOf
intendedEndUserRole
instance isVersionOf memberOf
kindOfRelation
instance requires memberOf kindOfRelation
instance hasPart memberOf kindOfRelation
instance references memberOf kindOfRelation
instance hasFormat memberOf kindOfRelation
instance linear memberOf structure
instance atomic memberOf structure
```

Listing 1. LOM4WSMO Ontology and some instances

Goals in these conceptual models are defined by the postconditions and the effects required on the learning objects selected. We have to consider here that the discovery and select of a Learning Object can be considered as the purchase of an item in a “Purchase Order” paradigm. Acting this way we can reuse the Purchase Order Ontology developed by the WSMO team. The cost of the Learning Object, if free, is irrelevant for the model of the goal and the ontology.

The overall goal *find learning objects in English that tell something about Internet Algorithms"* can be expressed as follows:

```
goal
_http://www.uah.es/ontologies/goals/goalLO.ws
ml
nonFunctionalProperties
  dc:title hasValue "Searching for a Learning
Object about Internet Algorithms"
  dc:creator hasValue vcard:UaH
  dc:description hasValue "Express the goal of
buying a Learning Object for learn Internet
Algorithms"
  dc:publisher hasValue vcard:UaH
  dc:contributor hasValues {vCard:Ozelin,
vcard:Sicilia, vcard:Sinuhe}
  dc:date hasValue "2005-02-07"
  dc:type hasValue
_http://www.wsmo.org/2004/d2#goals
  dc:format hasValue "text/html"
  dc:language hasValue "en-uk"
  dc:rights hasValue
_http://www.uah.es/privacy.html
  version hasValue "$Version: 0.1 $"
endNonFunctionalProperties

importedOntologies
{_http://www.uah.es/ontologies/lom4WSMO,
_http://www.wsmo.org/ontologies/purchase}

postcondition
axiom
purchasingLearningObject4InternetAlgorithms
nonFunctionalProperties
  dc:description hasValue "This goal expresses
the general desire of purchasing a Learning
Object in order to learn Internet Algorithms"
endNonFunctionalProperties
definedBy
```

```
exists ?Purchase, ?Purchaseorder, ?Buyer,
?Product, ?PaymentMethod, ?LearningObject,
?Classification, ?Paths
(?Purchase memberOf po:purchase[
  po:purchaseorder hasValue ?Purchaseorder,
  po:buyer hasValue ?Buyer ] and
?Buyer memberOf po:buyer and
?Purchaseorder memberOf po:purchaseOrder[
  po:product hasValues {?Product},
  po:payment hasValue ?PaymentMethod ] and
?PaymentMethod memberOf
po:paymentMethod and
?Product memberOf po:product[
  po:item hasValues {?LearningObject} ] and
?LearningObject memberOf
lom4WSMO:learningObject[
  lom4WSMO:isClasssifiedInto hasValue
Classification? ] and
?Classifications memberOf
lom4WSMO:classification[
  taxonPath hasValues {?Paths} ] and
?Paths memberOf lom4WSMO:taxonPath[
  hasSourceTaxonPath hasValue
lom4WSMO:ARIADNE,
  hasTaxon? hasValues {valueTaxon hasValue
"Internet Algorithms"^^xsd:string} ] ).

effect
axiom havingTradeForLO
nonFunctionalProperties
  dc:description hasValue "The goal effect is to
get the purchased Learning Object delivered to
the buyer."
endNonFunctionalProperties
definedBy
exists ?Delivery, ?Product, ?Buyer,
?LearningObject
(?Delivery memberOf po:delivery[
   po:deliveryItem hasValues {?Product},
   po:receiver hasValue ?Buyer ] and
 ?Product memberOf po:product[
   po:item hasValues {?LearningObject} ] and
 ?Buyer memberOf po:buyer and
 ?LearningObject memberOf
lom4WSMO:learningObject ).
```

Listing 2 Requester Goal

The outcomes of the goal (once linked to a service execution) are instances of learningObject with a number of constraints. This goal has only constrained that the desired Learning Objects have to be complaint to the ARIADNE taxonomy and versed in “Internet Algorithms”. The rest of the constraints for a Learning Object are free to be matched against the repository of Learning Objects.

Capabilities offered by Web Services can be described within the same ontological framework. The following simple definition specifies a capability that could eventually fulfill the need expressed in the previous goal. It has to be noticed that the capability of a Web Service is more detailed than a goal, because it serves not only for matching purposes but for advertising in a repository where other goals from other requesters can be matched.

```
webservice
_http://www.uah.es/ontologies/ws.wsml
nonFunctionalProperties
  dc:title hasValue "Algorithm for Internet
Applications Learning Object Web Service"
  dc:creator hasValue vcard:UaH
  dc:description hasValue "Web service for
access the content of a Learning Object on
Algorithms and purchase it"
  dc:publisher hasValue vcard:UaH
  dc:contributor hasValues {vCard:Ozelin,
vcard:Sicilia, vcard:Sinuhe}
  dc:date hasValue "2005-02-07"
  dc:type hasValue
_http://www.wsmo.org/2004/d2/#webservice
  dc:format hasValue "text/html"
  dc:language hasValue "en-uk"
  dc:rights hasValue
_http://www.uah.es/privacy.html
  version hasValue "$Version: 0.1 $"
endNonFunctionalProperties

importedOntologies
_http://www.wsmo.org/ontologies/purchase
capability _#

precondition
axiom _#
nonFunctionalProperties
  dc:description hasValue "The input to the
Web Service has to be a user with an intention
to select a Learning Object for learn Algorithms
for Internet applications"
endNonFunctionalProperties
definedBy
```

```
?Buyer memberOf po:buyer and
?LO memberOf lom4WSMO:learningObject[
  isClassifiedInto hasValues {?Classifications},
  hasRights hasValue ?Rights,
  hasTechnicalRequirements hasValues
{?TRs},
  hasEducational hasValue ?Educational,
  languages hasValues
{lom4WSMO:englishUK},
  aggregationLevel hasValue "3"^^xsd:integer
  identifier hasValue ?Identifier,
  title hasValue "Algorithms for Internet
Applications (WS2001/02, lecture
14)"^^xsd:string ] and
?Identifier memberOf learningIdentifier[
  entryCatalog hasValue
lom4WSMO:ARIDANE,
  catalogIdentifier hasValue
"V3VIROR_v_3.1_nr_22"^^xsd:string ] and
?Classifications memberOf
lom4WSMO:classification[
  purpose hasValue lom4WSMO:discipline,
  taxonPath hasValues {?Paths} ] and
?Paths memberOf lom4WSMO:taxonPath[
  hasSourceTaxonPath hasValue
lom4WSMO:ARIADNE,
  hasTaxon? hasValues {
    idTaxon hasValue
"000000001"^^xsd:string,
    valueTaxon hasValue "Exact, Natural and
Engineering Sciences"^^xsd:string,
    fatherOfTaxons hasValues {
      idTaxon hasValue
"000000002"^^xsd:string,
      valueTaxon hasValue "Informatics &
Information Processing"^^xsd:string,
      fatherOfTaxons hasValues {
        idTaxon hasValue
"000000003"^^xsd:string,
        valueTaxon hasValue
"General"^^xsd:string}
    },
    idTaxon hasValue
"000000004"^^xsd:string,
    valueTaxon hasValue "Internet
Algorithms"^^xsd:string }] and
?Rights memberOf lom4WSMO:rights[
  descriptionOfRights hasValue "The cost of
this LO is 5 Euros",
  hasCopyright hasValue "true"^^xsd:boolean,
  hasCost hasValue "true"^^xsd:boolean,
  price memberOf lom4WSMO:cost[
    amount hasValue "5.0"^^xsd:float,
    currency hasValue lom4WSMO:euro]] and
?TR memberOf
lom4WSMO:technicalRequirements[
  installationRemarksOfTR hasValue "unzip
archive and read further instructions in
README"^^xsd:string,
  formatOfTR hasValues {"application/x-aof",
"audio/x-aiff", "image/gif", "text/html"},
  sizeOfTR hasValue
"162099200"^^xsd:string,
  hasOrCompositeRequirements hasValues {
    typeOfRequirement hasValue "operating
system"^^xsd:string,
    nameOfRequirement hasValue "Multi-
OS"}] and
?Educational memberOf
lom4WSMO:educational[
  interactivityType hasValue
lom4WSMO:expositive,
  learningResourceType hasValue
lom4WSMO:video,
  hasInteractivitLevel hasValue
lom4WSMO:mediumInteractive,
  hasDifficulty hasValue
lom4WSMO:mediumDifficulty,
  intendedEndUserRol hasValue
lom4WSMO:learner ].

postcondition
axiom _#
nonFunctionalProperties
  dc:description hasValue "the output of the
service is a Learning Object about Internet
Algorithms."
endNonFunctionalProperties
definedBy
?LO memberOf lom4WSMO:learningObject[
  identifier hasValue ?Identifier] and
?Identifier memberOf learningIdentifier[
  entryCatalog hasValue
lom4WSMO:ARIDANE,
  catalogIdentifier hasValue
"V3VIROR_v_3.1_nr_22"^^xsd:string ].

effect
axiom _#
nonFunctionalProperties
  dc:description hasValue "there shall be a trade
for the Learning Object of the postcondition"
endNonFunctionalProperties
definedBy
?someTrade memberOf po:trade[
  po:items hasValues {?LO},
  po:payment hasValue ?acceptedPayment ]
and ?acceptedPayment memberOf
po:creditCard.
```

Listing 3 Web Service from a Learning Object Provider

Learning object types could be integrated in goal and capability definitions directly, simply putting restrictions on type where necessary for filtering out some kinds of objects, since subsumption guarantees that specialized learning objects are directly considered.

Mediators and the overall architecture

The overall architecture for Learning Object Repositories based on Semantic Web Services is depicted in Figure 2 as an extension to the functional architecture of the IMS DRI 1.0 specification (IMS, 2003) in what concerns to resource search. Concretely, only the core function EXPOSE is depicted, since it is the base function required by selection and composition. In these processes, the results of the search process would eventually result in REQUESTS and subsequent DELIVER of the assets required, but this is out of the scope of the problems addressed in this chapter. The STORE core function is also omitted, since it does not have direct impact in the process o Semantic Web Service-based selection and composition processes.

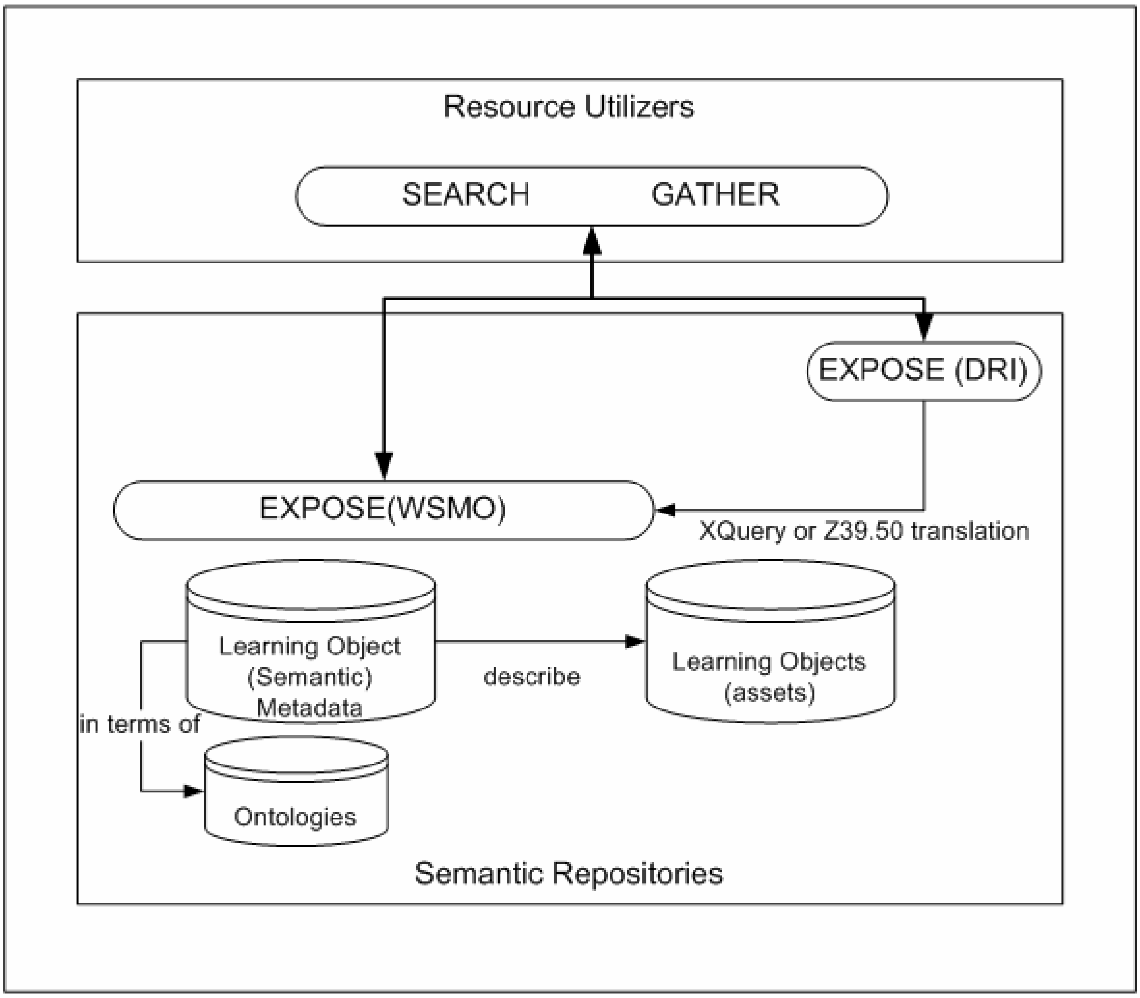

Figure 2. Functional architecture of the Semantic Learning Object Repository

The DRI specification addresses the selection and composition problems as complex problems in which different and heterogeneous repositories may play a role. In order to address such heterogeneity, the model introduces an optional intermediary component that may accomplish one or several of the following functions:

1. A *Translator* function translates formats of descriptions.
2. An *Aggregator* function gathers data from multiple repositories and makes these metadata available for search.
3. A *Federator* function passes a search query to multiple repositories and manages the responses.

The concept of mediator in WSMO is aimed at addressing interoperability problems of a diverse kind, and is thus candidate components for the semantic implementation of the just described DRI functions.

In the case of the *Translator* function the application of ooMediators is straight forward. ooMediators allow to link two Ontologies, resolving the possible mismatches that might occur among them. Thus, a translator function is assimilated with an ooMediator in which the translation logic is defined. Listing 4 shows an example of the WSMO specification of the ooMediator required in to translate Ontologies A and B into C.

```
namespace{
  dc     _"http://purl.org/dc/elements/1.1",
  wsml _"http://www.LOM.com"
}
ooMediator <"Learning Object Ontology Mediator">
nonFunctionalProperties
    dc#title hasValue "OO Mediator import and translate ontology A and B into C"
    dc#creator hasValue <"Sicilia, Lopez y Arroyo">
    dc#description hasValue "Mediator to import and translate ontology A and B into C"
    dc#publisher hasValue _"http://www.SiLoArorg/"
    dc#contributor hasValue _"http://www.uah.es/#Pepe"
    dc#date hasValue "2005-02-03"
    dc#type hasValue _"http://www.wsmo.org/2004/d2/#ooMediator"
    dc#identifier hasValue _"http://example.org/AandBtoC-Mediator.wsml"
    dc#language hasValue "en-us"
    dc#relation hasValue {_"http://daml.umbc.edu/ontologies/ittalks/person/",
                          _"http://example.org/tripReservationOntology"}
    dc#rights hasValue _"http://www.deri.org/privacy.html"
    version hasValue "$Revision: 0.1 $"
  endNonFunctionalProperties
   source {_"http://www.deri.org/ontologyA/", _"http://www.deri.org/ontologyB/"}
   target _"http://www.uah.es/OntologyC"
  useService  _"http://www.uah.es:8080/TranslatorService/AandB2C"
```

Listing 4. OOmediator that imports and translates ontology A and B into C

For the *Aggregator* function, ooMediators can also solve the problem, as far as the data gathered from the different sources has some ontological meaning. In the event of requiring translation to the translator functions would help to present a consistent view of all the data gathered.

And finally for the *Federator* function the pattern follows is quite similar to the one used in the previous functions. Eventually, each one of these repositories will use its one vocabulary thus requiring data and meaning conversion, as provided by translators by means of ooMediators. Once the responses are submitted, the process will be inverse, requiring that the Federator functions convert the different vocabularies to an unified one. Also in this case ooMediators will help to solve the problem.

In order to be completely compliant with the WSMO specification, more mediators are required. Each one of the three functions will be initially specified as goal. In case no existing goal fully achieves the individual functions, ggMediators will be used to link and refine existing ones, until the exact behavior is achieved. Of course, new goals can be defined. By means of wgMediators goals are linked to Web Services who will, in the latest state, be responsible for carrying the execution of the individual functionalities. Figure 3, shows an example of how all the different WSMO elements are used in the case of the translator function.

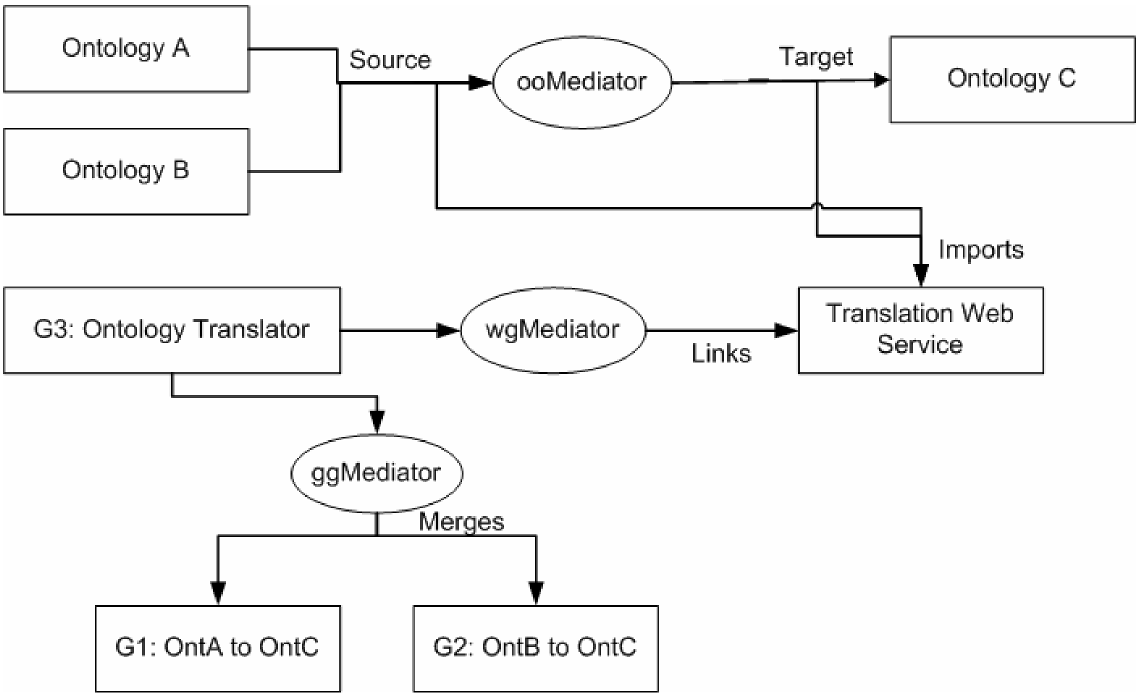

Figure 3. WSMO elements required in the Translation function

CONCLUSIONS

Semantic Web Service architectures provide a framework for the implementation of distributed learning object repositories that enable semantic matching. This chapter has described the motivation for such approach, and the main elements of the solution architecture, based on the WSMO framework. These elements include the ontology of learning object description, the overall architecture and the consideration of mediation as a technique for solving semantic integration and distribution issues.

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