

Specifying Learning Object-Based Goals and Capabilities with WSMO

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Abstract

The Web Service Modelling Ontology (WSMO) allows the definition of Semantic Web Services in terms of capabilities, interfaces using mediators to link them to the goals that a user might have when consulting a service. The concept of pre- and post-conditions embodied in that capabilities have a correlate in the technique of learning object *Design by Contract*, pointing out to the adequacy of using WSMO to model flexible learning object search and discovery processes. This paper describes how WSMO can be used to specify goals and capabilities for learning object selection, using a subset of LOM as a case study.

1 Introduction and Motivation

Web Services are self-contained, self-describing software applications that can be published, discovered, located and invoked across the Web, and using standard Web protocols. Nowadays, the basic support for Web Services is provided through the SOAP, WSDL and UDDI specifications, which address message format, service description and service publishing and lookup, respectively.

Nonetheless, this basic support still provides limited help in automating configuration and combination, which has fostered proposals like DAML-S and WSMF that employ Semantic Web technologies for service description and related aspects. The *Web Service Modeling Framework* (WSMF) [Fensel and Bussler, 2002] provides the conceptual model and related tools required to describe complex Web Services in a context of decoupled and scalable components [Arroyo *et al.*, 2004].

The *Web Service Modeling Ontology* (WSMO)¹ refines the framework of WSMF providing a formal ontology and formal language. WSMO allows the definition of ontologies comprised by four building blocks: concepts, relations, axioms and instances. Then, these ontologies can be used to describe:

- Goals. A goal specifies the objectives that a client may have when he consults a Web Service.
- Web Services, described in terms of mediators, capabilities and interfaces.

Goals include the definition of post-conditions, that describe the state of the information space that is desired in terms of axioms, and Web Services include *capabilities*, which are in turn described by axioms representing preconditions, postconditions, assumptions and effects. Preconditions define requirements on the input, and post-conditions describe the outputs of the system (in case that precondition was met in the invocation). Assumptions are previous conditions not limited to the inputs, but to the state of the world

¹ <http://www.wsmo.org>

in a broad sense, and effects describe such state of the world after the call. All these information items support the description of requirements and outcomes in a logical form. Concretely, WSMO has adopted the *F-Logic* [Kifer *et al.*, 1995] for their representation.

The recent approach of learning object *Design by Contract* (DBC) [Sicilia, 2003] has highlighted that a contractual approach using assertions in the form of pre- and post-conditions leads to clearer semantics oriented to automation of the targeting and delivery of learning objects, taking into account the characteristics of the learner, of his/her interaction means and of the overall learning context.

The similarity of the WSMO and LO-DBC has led us to exploring the possibility of providing richer semantics to learning object contracts by using WSMO facilities. Concretely, the WSMO approach seems adequate for expressing learning object selection services. Such a service could be implemented as a WSMO Web Service, using as ontology some adapted learning technology schemas. The overall architectural issues for Web service-based e-learning systems has been addressed elsewhere [Xu and El Saddik, 2003 and Blackmon and Rehak, 2003], so that here we focus on ontology-based descriptions that provide a higher level of definitional flexibility to existing architectures.

Two scenarios have been identified in the direction described. First, the post-conditions section of the learning object contracts could be used as goals used in requesting appropriate learning objects. Second, "Instructional Services" (IS) could be considered as a specific kind of learning object implemented as a WSMF Web Service (WS), enabling scenarios of constraint-based search with the following pattern:

- A requester or client *R* (e.g. a Learning Management System or an agent) is looking for learning objects (being those simple contents or complex learning activities) for a given need.
- *R* is able of expressing the characteristics of the need in terms of: the characteristics of the user *U*, the characteristics of the interaction devices and software *D*, and the learning outcome desired *O*, e.g. in terms of expected acquired competencies.
- *R* uses a service *P* to find appropriate learning objects by sending the service *U*, *D* and *O*. The context of learning *C* can also be considered.
- *P* may check as preconditions that the devices and overall type of learner matches its current capabilities.
- *P* begins the execution of the service.

It should be noted that the non-synchronous nature of the WSMF as described in [Fensel and Bussler, 2002] allows for diverse implementations of such service, including those in which not all the input data is transferred at the beginning of the execution of the service, but concurrent with it. This enables smart approaches to selection without the need of completely transferring *U*, *D* and *O* at a time. In addition, being able to check some constraints as preconditions has the advantage of preventing execution in case that the ser-

vice is not capable of providing the service due to an *a priori* restriction.

The rest of this paper is structured as follows. Section 2 describes the basic elements of an ontology for describing simple learning object metadata and goals based on it. Section 3 sketches how Web Services mapping such goals can be described through an example. Finally, Section 4 provides some conclusions and future research directions.

2 Describing Learning needs as WSMO Goals

A basic ontology describing some essential metadata items in LOM could be described through the following definitions in WSML, which correspond to the elements depicted in Figure 1. It basically addresses language (which should be matched to that of the user described by *U*), cost (dependant on the context *C* of the scenario), basic technical requirements (part of *D*) and classifications (a basic form to express intended outcomes *O*). Some instances are defined for illustration purposes.

```
ontology http://www.uah.es/.../lom4flogic.wsml
namespace
  default=http://www.uah.es/...lom4flogic#,
  dc=http://purl.org/dc/elements/1.1#,
  wsml=http://www.wsmo.org/.../v0.2/20040418#
non-functional-properties
  dc:title "Learning Object Model for fLogic
  Ontology"
  ...
concept currency
  non-functional-properties
    dc:description "Represents the currency in
    which is expressed the cost of a Learning
    Object"
    currencyName oftype xsd:string
    currencyCode oftype xsd:string
concept cost
  non-functional-properties
    dc:description "Represents the cost of a
    Learning Object, expressed as an amount
    and the currency in which is referred"
    hasCurrency oftype currency
    amount oftype xsd:float
concept humanLanguage
  non-functional-properties
    dc:description "a humanLanguage is a lan-
    guage in which can be expressed a Learning
    Object"
    name oftype xsd:string
    ISOCode oftype xsd:string
```

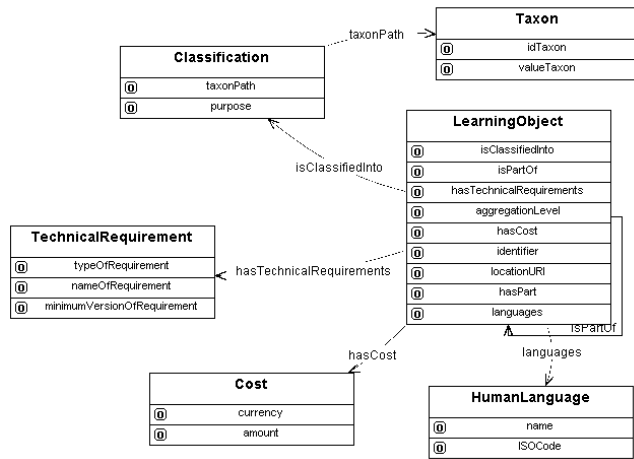


Figure 1. Overall view of a basic LO metadata ontology

concept taxon

non-functional-properties

dc:description "a taxon is a concrete value for a Taxonomy in which a Learning Object can be classified"

idTaxon **oftype** xsd:string

valueTaxon **oftype** xsd:string

concept typesOfRequirement

non-functional-properties

dc:description "Defines a set of values which can be taken for a type of requirement"

idTypeOfRequirement **oftype** xsd:integer

labelTypeOfRequirement **oftype** xsd:string

concept technicalRequirement

non-functional-properties

dc:description "Technical requirements could be any constraint which has to be solved for the correct use of the Learning Object"

typeOfRequirement **oftype** typesOfRequirement

nameOfRequirement **oftype** xsd:string

minimumVersionOfRequirement **oftype** xsd:integer

concept purposes

non-functional-properties

dc:description "Defines a set of values which can be taken for purposes of a LO"

idPurpose **oftype** xsd:integer

labelPurpose **oftype** xsd:string

concept classification

non-functional-properties

dc:description "Means of classify a learning object into one specific taxonomy"

taxonPath **oftype** taxon

purpose **oftype** purposes

concept learningObject

non-functional-properties

dc:description "Any digital entity that may be used for learning, education or training"

identifier **oftype** xsd:string

aggregationLevel **oftype** xsd:integer

locationURI **oftype** xsd:string

isClassifiedInto **oftype** set classification

hasCost **oftype** cost

hasTechnicalRequirements **oftype** set technicalRequirement

languages **oftype** set humanLanguage

isPartOf **oftype** set learningObject

hasPartOf **oftype** set learningObject

variable LOone, LOtwo **memberOf** learningObject

variable X,Y **memberOf** xsd:integer

axiom inverseFunctionBelong

non-functional-properties

dc:description "Integrity Constraint: A learning Object is composed by Learning Objects"

logical-expression

"LOone[hasPartOf hasvalue LOtwo] <- LOtwo[isPartOf hasvalue LOone]."

axiom minimumLevelOfAggregation

non-functional-properties

dc:description "A Learning Object that is not composed by other learning objects has an aggregation level of 1"

logical-expression

"LOone[aggregationLevel hasvalue 1] <- not LOone[hasPartOf hasvalue LOtwo]."

axiom levelOfAggregation

non-functional-properties

dc:description "A Learning Object that is composed by other learning objects has an aggregation level greater than the aggregation level of the learning objects which composed it"

logical-expression

"LOone[aggregationLevel hasvalue X] <- LOone[hasPartOf hasvalue LOtwo] and LOtwo[aggregationLevel has value Y] and X = Y + 1 ."

comment: instanceDefinitions

instance browser **memberOf** typesOfRequirement

idTypeOfRequirement **hasvalue** 1

labelTypeOfRequirement **hasvalue** "Browser"

instance operatingSystem **memberOf** typesOfRequirement

idTypeOfRequirement **hasvalue** 2

labelTypeOfRequirement **hasvalue** "Operating System"

```

instance device memberOf typesOfRequirement
  idTypeOfRequirement hasvalue 3
  labelTypeOfRequirement hasvalue "Device"
instance educationalObjective memberOf purposes
  idPurpose hasvalue 1
  purpose hasvalue "Educational Objective"
instance competency memberOf purposes
  idPurpose hasvalue 2
  purpose hasvalue "Competency"
instance spanish memberOf humanLanguages
  name hasvalue "spanish"
  ISOCode hasvalue "ES"
instance englishUK memberOf humanLanguages
  name hasvalue "englishUK"
  ISOCode hasvalue "en-UK"
instance englishUSA memberOf humanLanguages
  name hasvalue "englishUSA"
  ISOCode hasvalue "en-US"
instance portuguese memberOf humanLanguages
  name hasvalue "portuguese"
  ISOCode hasvalue "PT"
instance euro memberOf currency
  currencyName hasvalue "Euro"
  currencyCode hasvalue "EUR"

```

Goals in these conceptual models are defined by the post-conditions required on the learning objects selected.

The overall goal *find free learning objects in spanish for WAP devices that tell how to reach Guadalajara* can be expressed as follows:

```

goal http://www.uah.es/.../goalLO.wsml
namespace
  default=http://www.uah.es/.../goalLO#,
  lom=http://www.uah.es/.../lom4flogic#,
  dc=http://purl.org/dc/elements/1.1#,
  wsml=http://www.wsmo.org/.../20040418#
non-functional-properties
  dc:title "Obtaining a Learning Object"
  ...
used-mediators
  comment: At this moment of the work any mediator is needed.
postcondition
  axiom findALearningObject
non-functional-properties
  dc:description "The goal postcondition is represented as a fact. It represents that we want to find a free Learning Object in spanish for WAP devices for learn how to get to Guadalajara"

```

```

logical-expression
"someLearningObject memberOf
lom:learningObject
[
  lom:isClassifiedInto hasvalues _# memberOf
  lom:classification
  [
    lom:taxonPath hasvalue _# memberOf
    lom:taxon
    [
      valueTaxon hasvalue "ddc:/History & Geography/Geography & travel/Geography and travel in Europe/Guide to Guadalajara",
      lom:purpose hasvalue lom:competency ],
    lom:hasTechnicalRequirements hasvalues _#
    memberOf lom:technicalRequirements
    [
      lom:typeOfRequirement hasvalue
lom:device,
      lom:nameOfRequirement hasvalue "WAP"],
    lom:languages hasvalue lom:spanish,
    lom:hasCost hasvalue _# memberOf lom:cost
    [
      lom:amount hasvalue 0]]."

```

The outcomes of the goal (once linked to a service execution) are instances of learningObject with a number of constraints. Zero cost and language are represented as direct constraints, while the technical requirement is expressed by matching the collection implicit in Figure 1. The classification is used to match only elements linked to a given element in a taxonomy. It should be noted that using classifications this way results in "hardcoded" requirements and it should be replaced by a more flexible approach that uses concepts instead of strings, enabling eventual inference about subtypes.

3 Describing WSMO Capabilities for Learning Object Repositories

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 goal of the previous section.

```

webservice http://www.uah.es/.../ws.wsml
namespace
  default=http://www.uah.es/.../ws#,
  dc=http://purl.org/dc/elements/1.1#,
  wsml=http://www.wsmo.org/2004/d2/#,
  lom=http://www.uah.es/.../lom4flogic#,
  targetnamespace=http://www.uah.es/.../ws#
non-functional-properties

```

```

    dc:title "Online Guide to Guadalajara for
WAP devices"
    ...
used-mediator
    comment: At this moment of the work any me-
diator is needed.
variable
    ?LObject memberOf lom:learningObject
    ?Language memberOf lom:humanLanguage
    ?Device memberOf lom:technicalRequirement
    ?Taxon memberOf lom:taxon
    ?Classification memberOf lom:classification
capability
postcondition
    non-functional-properties
    dc:description "the output of the service
is a learn ing Object created for WAP de-
vices, in spanish and about travel in
Europe"
logical-expression
    ?LObject memberOf lom:learningObject
    [
        lom:languages hasvalue ?Language,
        lom:technicalRequirement hasvalue ?Device,
        lom:classification hasvalue ?Classifica-
tion
        [
            lom:taxonPath hasvalue ?Taxon]] and
        (?Language.ISOCode = "ES") and
        (?Device.typeOfRequirement = lom.device
and
            ?Device.nameOfRequirement = "WAP")
and
        (?Taxon.valueTaxon = "ddc:/History & Geogra-
phy/Geography & travel/Geography and travel in
Europe/").

```

Learning object types [Sicilia, 2004b] 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.

4 Conclusions and Future Research Directions

The use of WSMO to describe contract-based learning object selection services has been sketched. A simple ontology and examples have been provided. Our current work is on the description of LOM in its entirety, and designing prototype selectors using the ongoing work on WSMX².

Future work should also cover other e-learning specifications (e.g. SCORM, IMS) and also more precise semantics on scenarios involving automation of learning object selection [Sicilia, 2004a].

Ontology mediators could be used as a convenient approach to map different ontologies related to learning outcomes O , different kinds of user models U , or ontologies of devices for technical requirements C , e.g. the FIPA³ one.

References

- [Arroyo *et al.*, 2004] Arroyo, S., Lara, R., Gmez, J. M., Berka, D., Ding, Y., Fensel, D.: Semantic aspects of Web Services, in Practical Handbook of Internet Computing. Munindar P. Singh, editor. Chapman Hall and CRC Press, Baton Rouge, 2004.
- [Blackmon and Rehak, 2003] William H. Blackmon, Daniel R. Rehak. Customized Learning: A Web Services Approach in Proceedings Ed-Media 2003, June 2003.
- [Fensel and Bussler, 2002] Fensel, D. and Bussler, C. The Web Service Modeling Framework (WSMF). *Electronic Commerce: Research and Applications*, 1 (2002) 113{137.
- [Kifer *et al.*, 1995] M. Kifer, G. Lausen, and James Wu: Logical foundations of object oriented and frame-based languages. *Journal of the ACM*, 42(4):741-843, 1995.
- [Sicilia, 2003] Sicilia, M.A., S[anchez, S. 2003. On the concept of learning object "Design by Contract". *WSEAS Transactions on Systems*, Vol. 2, Issue 3, pp. 612-617.
- [Sicilia, 2004a] Sicilia, M. A., Pagés, C., García, E. and Sánchez, S. 2004. Specifying semantic conformance profiles in reusable learning object metadata. In Proceedings of ITHET 2004 - 5th International Conference on Information Technology Based Higher Education and Training. Estambul.
- [Sicilia, 2004b] Sicilia, M.A., García, E., Sánchez, S. and Rodríguez, E. 2004. Describing learning object types in ontological structures: towards specialized pedagogical selection. In Proceedings of ED-MEDIA 2004 - World conference on educational multimedia, hypermedia and telecommunications, pp. 2093-2097.
- [Xu and El Saddik, 2003] Zhengfang Xu and Abdulmotaleb El Saddik. "A Web Services Oriented Framework for Wired and Wireless E-Learning Systems". In Proceedings of the Canadian Conference on Electrical and Computer Engineering (CCECE 2003) Montreal, Quebec, Canada, May 4-7, 2003.

² <http://www.wsmo.org/wsmx>

³ <http://www.fipa.org/specs/fipa00091/PC00091A.html>