OWLS-LO: extending OWL-S to support learning object

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Abstract: The essential challenge in e-learning is finding and identifying a learning object from a big corpus on the one hand, and ensuring the independence and reusability of learning objects in a different context, on the other hand. These problems can be solved by using the principles of Web service paradigm. In this paper, we propose a semantic description of learning services that encompasses the description of the learning intention and the use of context that characterise a learning object. Then, we propose a semantic service descriptor, based on our OWL-S extension, to enrich service registry. The feasibility of our extended semantic OWLS-LO is proved by experimental results obtained.

Keywords: e-learning; learning paths; learning service; ontology; OWL-S; web services.

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1 Introduction

Nowadays, e-learning offers advantages over traditional learning in terms of independence. In fact, learners can study from anywhere at any time and communicate with the e-learning system or other learners by e-mail, electronic forums, chat, video and other forms of communication based on Web (Zhu, 2009). E-learning will not replace traditional teaching methods, but will greatly enhance the effectiveness of education thanks to its many advantages such as flexibility, diversity, and extent of openness.

In most cases, the educational content comes in the form of learning objects, which present problems related to their accessibility and use. At this stage, it is very important to add a semantic layer to learning objects for their common understanding by the systems.

Therefore, many rules and metadata standards have been proposed as a solution to overcome the problem of accessibility and interoperability of learning objects, and many norms and standards were created to achieve this. At this stage, several standardisation efforts have been launched including LOM and SCORM. These standard descriptions of learning resources focus on the characterisation of content rather than on its use.

In fact, the above standards have limitations in the context of heterogeneous learning objects. In addition, the definition of specialised courses according to desired skills requires a composition of learning objects to provide the learner with a personalised learning course. The problems of interoperability, reusability and composition of learning content can be solved by using the principles of Web service paradigm. Web services are defined as open standards that provide a flexible solution for integrating heterogeneous and dynamic applications that enable interoperability between different systems (Ngamnij et al., 2005).

In this paper, we propose a semantic description of learning services that encompasses the description of the learning intention and the use of context that characterises a learning object. Then, we propose a semantic service descriptor, based on our OWL-S extension, to enrich service registry. The rest of the paper is organised as follows: Section 2 presents a brief overview of the semantic Web services. In Section 3, we present some related works. We give an overview of our approach in Section 4. In Section 5, we propose an extension of OWL-S to support learning object. In Section 6, we present the principle of learning semantic web service publication and discovery. In Section 7, the evaluation of the feasibility of our extended semantic OWLS-LO is discussed. In Section 8, we finish with a conclusion and some remarks/hints about future work.

2 Background

Semantic Web services (SWS) represent an extension of the current Web services technology. They expand the Web from a source of distributed information to a source of distributed services, where the software resources can be assembled hurriedly to accomplish the goals of the user (Lara et al., 2003).

In fact, SWS are used to describe Web services with semantic content so that service discovery, composition, and invocation can be done automatically, by using, for example, intelligent agents capable of processing the semantic information provided. Currently, there are several frameworks and languages to, formally, describe Web services, each having its strengths and limitations. OWL-S (Ankolekar et al, 2002) is a standard recommended by W3C.

OWL-S (Ankolekar et al, 2002), formerly known as DARPA Agent Markup Language for Services (DAML-S), was established to develop the capabilities of Web services semantically in an open environment. Specifically, OWL-S offers support to exchange semantically rich messages between Web peers. In the context of AI planning, the messages exchanged between the agents present three types of essential knowledge: the functionality provided by the service to potential customers, the internal architecture (model) of service, and the service deployment requirements, respectively. OWL-S classes associated with each of the three aspects (Figure 1) are ServiceProfile, ServiceModel, and ServiceGrounding, respectively (Wang et al, 2013).

Figure 1 Top level of the service ontology OWL-S (Wang et al, 2013) (see online version for colours)

- Profile: provides a description of high-level service containing meta information such as the name of the service, the inputs and prerequisites, and the results generated. It is only used for service discovery. The profile class can be specialised, providing support to create service profiles hierarchies.
- Model: is also known as the process model and gives a detailed view of the various work processes in a service, i.e., simple and composite atomic.
- Grounding: contains information about accessing a service, i.e., the formats of message protocols, serialisation, transportation, and addressing. The strong point of chief OWL-S is that it is better integrated with the existing standards of the Web Ontology (as formulated by W3C) and has well-defined deployment mechanisms.
WSMO define four principal components inspired by the conceptual work done in the definition of WSMF (De Bruijn et al., 2006) (Figure 2):

- Ontologies: They provide the terminology and semantics description of the elements in WSMO.
- Goals: They provide the means to specify the requester side objectives when consulting a Web Service, describing at a high-level a concrete task to be achieved.
- Web Services. They provide a semantic description of Web Services, containing their functional and non-functional properties, as well as other aspects for interoperating with them.
- Mediators: These elements are connectors that resolve heterogeneity problems in order to enable interoperability between heterogeneous parties.

WSMO (Web Service Modelling Ontology) represents thus a modelling ontology of semantic Web services providing a conceptual model for these services. The concepts of this ontology are formally described by WSML (Web Service Modelling Language) (de Bruijn et al., 2006). The WSMO descriptions, formalised in WSML, are executed by the environment WSMX (Web Service Modelling eXecution environment), which also enables the discovery, mediation, invocation and interoperability of semantic services.

**Figure 2** WSMO core elements (De Bruijn et al., 2006)

Finally, compared to OWL-S, WSMO has only a few editing tools, such as WSML Editor (Kerrigan, 2005) and not particularly powerful reasoning engines. Thus, the development of tools for WSMO prove a more difficult to develop than OWL-S, because OWL-S are based on the RDF and OWL that are used more than WSML.

### 3 Related work

The topics of e-learning and the integration of learning resources have attracted growing interest in recent years. Zniber (ZNIBER, 2010) presented an approach to building personalised pathways called POPS (Process-Oriented Pedagogic Service) by arranging services dynamically. This approach is a conceptual framework that defines a model for describing the pedagogical services. This model provides a set of concepts to portray the services. According to Zniber, a pedagogical service is composed of three parts: “profile,” “structure” and “behaviour”. The first part describes the general appearance of the pedagogical service and corresponds to the service interface. It is used when searching for a match between the available services and the learners intentions. It is composed of the definition of a pedagogical objective and a learning context. The second describes the organisation of the process to reach the pedagogical objective. It is defined by a process, an initial position and a final position. The third part is the “executable” level of service which describes the use of the service by a learner and takes the form of an implementation plan with activities and resources to be mobilised. The latter is composed of resources and links to use these resources. In this approach, the author used ontologies to describe both pedagogical services and the intentions of learners who need personalised pathways. This description of pedagogical services is based on two ontologies: one to describe pedagogy and another to describe the domain taught. These ontologies are used to associate a semantic description of the elements of services.

A functional and semantic approach was proposed by D’Mello (2012) to describe the e-learning web services with various objects and learning resources. It defines a learning service as an extension of the WSDL2.0 document structure integrating functional semantics to e-learning web services and their operations in order to ensure the publication of these services. This extension is composed of a set of new elements. The element “documentation” is chosen to include the information necessary for better service discovery in WSDL. The label entitled “operationDesc” is defined to introduce the functional semantics of all operations present in the learning service. The new elements “operationList”, “operation”, “action”, “call”, “object” and “name” are used within the operationDesc element. These new elements are defined in the XML schema that manages the structure of the extended documentation element. Functional semantics of a transaction are defined inside the element semantics, the element is placed inside the element operation. Elements such as action, qualify, object and not are used in the element semantics that provides a functional description of a learning operation.

### 4 Approach overview

#### 4.1 Motivation

The development of learning systems aims to provide learners with courses adapted to their needs and their profile. The challenge therefore is to make the system more responsive to the request of the student based on learning objects scattered on several platforms.

In this context, we consider a learning system as a set of Learning Semantic Web Services where each service represents a learning object that describes an intention and context of use. This is done by composing dynamically services learning to make it possible to build a custom course adapted to a given profile. The description of these services and the formulation of the request of learner are made by two ontologies (Ben Mahmoud et al., 2014): objectives ontology and ontology of the domain learning.
The domain ontology was a generic and comprehensive context ontology that provided the properties of context-related learning. Indeed, it could describe the concepts and links relating to an individual educational field. The ontology of educational objectives described the types of learning objectives. It represented a classification of educational objectives according to Bloom’s Taxonomy. It played an essential role in the mapping of available services with the need of the learner.

4.2 Overview of our approach

The architecture, shown in Figure 3, represents our e-learning approach to provide learners with learning paths adapted to their requests (Ben Mahmoud et al., 2015; Ben Mahmoud et al., 2014). This approach consisted of three components:

- **Learning data representation component**: This component’s role was to present and provide services in the form of semantic learning data of learning in order to achieve the learner’s learning objectives.

- **Formulation component of the learner query**: presented a formulation space of the learning application.

- **The building component of the learning path**: This component supported the construction of the learning path and enhancements based on the composition of existing learning data. It comprised the search, selection, and composition; it relied on the semantic description of services and ontologies. This construction process generated, at the time of its execution, an individualised path that satisfied a particular objective set by the learner.

Each learning object (LO) was described by a learning Web service (WS) allowing access via the platform. This learning Web service was represented in the directory by a semantic web service (OWLS-LO) to describe a semantic understanding of the object represented. When the learner launches a learning process (learning application), our system offers a personalised learning path of the objects. This route was created by the composition of semantic learning web services according to the learners’ profile.

5 Proposed extension of OWLS

In order to describe learning Web service conveniently, we need to define an appropriate OWL-S extension. This extension allows describing the educational aspect of service learning in a “Service Learning” ontology. It corresponds to the service interface and is used when searching for a match between the semantic learning services available on the one hand, and the requests expressed by the learners, on the other hand.

This level of description defines the purpose for which the service responds and the context in which it can be used. This was to describe the process at an abstract level in which we considered only the result the service achieved.

The consideration of this aspect of learning in the description of services led to changes in the ontology services, to present the learning pedagogy and the profile ontology to appeal to this description during the discovery mechanism and the construction of learning paths.

Figure 3 Components of the learning approach architecture (see online version for colours)
This extension and its code, as shown in Figures 4 and 5 respectively, adds to OWL-S a new property to the service, named “Has_Learning” and perspective class “Service Learning”. Each instance of “Service Learning” is used to represent the learning pedagogy.

Figure 4  OWL-S extension to represent the learning pedagogy (see online version for colours)

The ontology “ServiceLearning” provides the necessary information to describe and discover the learning resources searched by the learner. This ontology is composed of three basic concepts: learning intention, context use and required services (Figure 6).

Figure 6  The ServiceLearning ontology (see online version for colours)

This intentional vision places the concept of service to a higher level of abstraction where the service is designed to lead to the satisfaction of a user’s intention.

According to (Jackson, 1995), the term “intention” refers to a declaration for “optative”, expressing a condition that should be achieved or maintained. In other words, the intention is the objective or goal we want to achieve without saying how to run it. (Kaabi, 2007) define an intention as the goal, by a user, without specifying how to achieve. Santos et al. (Santos et al., 2009) describe an intention as a goal to be achieved by the implementation of a process presented as a sequence of intentions.

In our description of a service, the learning intention allowed to define the finality of service, without going into the details of its use. It expressed an intention the learner sought to achieve.

With the emergence of the concept of intention in the area of engineering requirements, Prat (1997) proposed a model for the concept of intention which is derived from the linguistic approach and inspired by the case grammar of Fillmore (1968) and extensions of Dik (1989). According to this model, an intention is represented by a verb, targets and different parameters that play specific roles in relation to the verb. In this modelling, the verb describes the action of the realisation of the intention, while the target is affected by the object embodiment of the intention. The parameters (way, direction, quantity and quality) are used to clarify and express additional information. In our context, the intention was defined by a learning objective (verb) and a concept of learning domain (Target) (see Figure 7).

Figure 7  The basic concept “Intention” (see online version for colours)

5.1 Intention

An intention is what the user awaits in performing a service. It, therefore, represents the user’s vision of the features he requires from a service (Fensel et al., 2011).

5.1.1 Concept learning objective

The concept learning objective depicted the types of learning objectives in accordance with Bloom’s taxonomy (Bloom, 1975). They are expressed in terms of goals and organised in levels. The definition of the objective falls within the ontology of learning objectives.

5.1.2 Concept learning domain

The learning concept domain indicated the target of the learning intention. The specification of the concept used the terminology defined in the ontology of the educational domain.

For example, for the OWLS-LO(01) Service (“Define Class”) was characterised by the learning objective “Define” defined in the ontology of learning objectives and
the concept of learning “class” defined in the ontology of the educational domain “Java”.

5.2 The context

The context gives a description of the pedagogical aspect of the learning resource as well as the learning situation in which the service can be used. To describe this aspect we based on the descriptions of the IEEE LOM (2007). Then our extension was a selection of properties of the LOM allowing indexing learning objects semantically and describing mainly the container but not its content.

To annotate a learning object (LO), we presented three types of knowledge: affiliation, accessibility and competence (Figure 8):

- **Affiliation**: describing the level of targeted studies for learning object.
- **Accessibility**: mainly describing the language in which the resource were presented (French, English, …).
- **Competence**: describing the level of difficulty of this Learning Object relative to the target audience: easy, medium, or difficult.

For example, for the OWLS-LO(01) Service (“Define Class”) referred to a learning object whose context was characterised by a “University” affiliation, language was “Fr” and competence “Easy.”

5.3 The required services

The required services are all the knowledge required so that the learner can use the learning object. This notion can describe a navigation strategy among the reused learning objects. Indeed, for a learner to access the contents of an object check that it has a body of knowledge needed to tackle it. Therefore, the requirement for each service must be satisfied. In our extension, we define the services required as the set of coupled Concept learning domain and Concept learning objective needed to use the service learning during any one specifying the weighting of each (see Figure 9).

For example, for the OWLS-LO(01) Service (“Define Class”), we could define two required services: Define, Attribute with a weighting of 0.5 and Define, Method, with a weighting of 0.5.

Figure 9 The basic concept “Required Service” (see online version for colours)

Figure 10 shows a complete implementation example of OWLS-LO(01) Service that describes the main intention “Define Class”.

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Figure 9 The basic concept “Required Service” (see online version for colours)
6 A learning semantic web service publication and discovery

After describing the learning Web service semantically, we now turn to integrate them in order to be discovered and used dynamically, we present the principle of learning semantic web service publication and discovery (see Figure 11).

Figure 11 Principle of learning semantic web service publication and discovery (see online version for colours)

6.1 Implementation of OWLS-LO discovery

Our service publication approach extended our UDDI registries with semantic descriptions in a different manner to that traditionally recommended. It is flexible in the manner that any service must be published syntactically in a UDDI repository, and semantically in an OWLS-LO repository.

Each learning Web service, in our approach, had an appropriate OWLS-LO that served to store the semantic descriptions necessary to service requesters to discover services in order to use them. Therefore, the operations available on UDDI registries, our OWLS-LO repository provide mainly two additional operations in order to semantically publish and discover OWLS-LO services that are implemented with PublishSemanticOWLS-LO and FindSemanticOWLS-LO, respectively. The publication of learning semantic Web service was performed in the following way: WSDL descriptions were advertised in a UDDI registry (by invoking UDDI PublishService) and OWLS-LO descriptions advertised in a OWLS-LO repository (by invoking PublishSemanticOWLS-LO).

In fact, when OWLS-LO services are published, as described above, service requesters can look for them with domain ontology (what to teach) and ontology of educational objectives expressing their requirements. This Request is matched by the OWLS-LO repository to advertised profiles using Jena and OWL reasoner.

6.2 Process of publishing OWLS-LO

In this section, we present the generic scenario of the publication process (Figure 12). The instruction designer presents the learning object to be interoperable. After the learning Web service, appropriate to learning object, was generated, we passed to semantic description of learning web service by using existing ontologies. Finally, the learning Web service and OWLS-LO were published in UDDI registry and OWLS-LO repository, respectively.

Figure 12 Process of publishing (see online version for colours)

6.3 Process of discovering OWLS-LO

After publishing the learning semantic Web services both in an OWLS-LO repository and in UDDI registry, we proceeded to discover them. Thus, we present the generic scenario of the discovery process (Figure 13). The learner used Semantic Description Query to describe their intention (Semantic Request) of learning through browsing ontologies (Domain ontology, Ontology of educational objective). Once the semantic request is validated, we moved on to build the learning path. This step (Construction of Learning Path) used Semantic Discovery to find the various OWLS-LO according to the request learner and Semantic Matching to select the best OWLS-LO. When discovered, the OWLS-LO was mediated in order to resolve the semantic heterogeneity. Finally, we presented a learning path to the learner according to their goal.

Figure 13 Process of discovery (see online version for colours)

This section gives a global description of the discovery process (Figure 14), starting from the query submission to the OWLS-LO replies, by emphasising the main steps related to this matchmaking.
When the learner presented their request based on an intention to be satisfied, the discovery process was started. The discovery mechanism loaded all OWLS-LO semantic description of the services and launched the matching. In a first step, we proceeded to match the learner’s intention with the intention that the OWLS-LO service satisfied. Then we calculated the importance factor of each service required for this selected OWLS-LO. In the end, we matched the educational context services with learners current context. After getting a list of the most appropriate OWLS-LO, we selected the service having the highest score matching.

6.4 Process of path building

The path building starts when the learner sends a request defining its learning intentions and profile. Once the request received, the path building process extracts the intention and learner profile and then proceeds to discover and select the appropriate services through the discovery process. Each found service defines its own learning requirements, which become intents that need to be satisfied. The same process is repeated until no requirements are needed. This recursive discovery process will enrich the learning path. The diagram below shows the path building process.

To illustrate the path building process we consider the following request formulated by a learner. Specifically, this request is related to a teaching course titled Introduction to Object-Oriented Programming:

Request (Intention [Recall, Method], Profile [Academic, Fr, Basic])

This request presents an intention where the desired teaching concept is “Method” and the objective concept is “Recall”. The current profile of the learner is (Academic, Fr, Basic). The path building process receives this request and triggers the discovery of the best services in order to satisfy this request. This process is iterative. The resulting learning path is shown in Figure 16.
7 Evaluation

Here, we generated a learning semantic OWLS-LO repository containing a set of extended semantic description service based on the extended OWLS-LO. Among the provided learning domains, we opted to evaluate our proposed semantic OWLS-LO service in the OOP Java domain. It represents about 700 OWLS-LO semantic services enriched with learning intention, context use and required services. The evaluation was performed under two machine: an Intel I5 2.5 GHz CPU with 4Gb of main memory and Intel Xeon E3-1241V3 3.5 GHz with 8Gb of main memory.

The purpose of our experiments was to evaluate the feasibility of our extended semantic OWLS-LO service descriptor.

Two main observations appear from this experiment: (i) Scalability: if the course time is reasonable; (ii) Result Quality: if the algorithm can, in fact, select the most appropriate OWLS-LO services.

7.1 Scalability

We measured the scalability of our OWLS-LO service discovery algorithm with respect to the number of OWLS-LO services and the capabilities from different machines, by measuring the processing time. Figure 17 illustrates the experimental results of the processing time consumed when running our algorithm of OWLS-LO service discovery.

The results demonstrate that the response time of the OWLS-LO service discovery algorithm, in both machines increased, confirming that the implemented mechanism has a good scalability.

Thus, we notice the greater impact of the processor family. However, we believe that this performance can be improved by parallelising programming on multicore architectures.

Figure 17 OWLS-LO discovery performance

7.2 Quality

In order to determine the quality of the result, we covered the two most useful quality metrics: precision and recall. These two measures are defined in terms of a set of retrieved OWLS-LO services and a set of relevant OWLS-LO services. The precision represents how well a system retrieves only the relevant OWLS-LO services, while the recall measures the ability of a system to retrieve all the relevant OWLS-LO service (Chan et al., 2012).

The definition of recall and precision measures are defined as follows:

\[
\text{Precision} = \frac{|\text{relevant services} \cap \text{retrieved services}|}{|\text{retrieved services}|} \quad (1)
\]

\[
\text{Recall} = \frac{|\text{relevant services} \cap \text{retrieved services}|}{|\text{relevant services}|} \quad (2)
\]

At the beginning and in order to evaluate these two measures, we formulated a learning request relative to the POO Java domain. The request is represented by a learning intention. In this case, learner looked for a learning Class. Thus, he searched a Define (Learning concept) of a Class (Learning objective) in French language destined to university for easy learning. Through the experiments, we notice that the precision and recall are interesting measures when considering the learning intention, learning context and the required service in the OWLS-LO service discovery. The result shows that with the method named ICRS (Intention, Context and Required Service) we obtained the highest precision percentage compared to other methods. Precision with the ICRS method reached about 60% compared to about 37% with the IRS method (Intention and Required Service) and about 6% with the Intention method (Figure 18).

Figure 18 Precision results
8 Conclusion and future works

In this paper, we proposed an approach to provide learners with learning paths adapted to their requests. The courses were generated by the composition of the learning semantic Web services. Our approach defined a learning Web service for each learning object to overcome the problems of interoperability and accessibility of learning objects. This web service is represented by an extension of OWLS composed of three basic concepts: learning intention, use of context and required services.

The evaluation of our implementation demonstrates that our extension of the service description (by adding the learning intention, context use and required services) makes the description more meaningful and the service discovery more precise and appropriate to the learners’ needs. To this end, our next step is to improve the implementation and analysis the results of our proposed semantic descriptor and service discovery mechanism.

Then, we expect to evaluate our service discovery mechanism in a more interesting scenario. Besides, this approach will be tested on a more important number of OWLS-LO in future work.

References


