Towards adaptive e-learning applications based on Semantic Web Services

Book Section

Towards adaptive E-Learning Applications based on Semantic Web Services

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Abstract: The current state of the art in supporting E-Learning objectives is primarily based on providing a learner with learning content by using metadata standards like ADL SCORM 2004 or IMS Learning Design. By following this approach, several issues can be observed – e. g. high development costs due to a limited reusability across different standards and learning contexts. To overcome these issues, our approach changes this data-centric paradigm to a highly dynamic service-oriented approach. By following this approach, learning objectives are supported based on a automatic allocation of services instead of a manual composition of learning data. Our approach is fundamentally based on current Semantic Web Service (SWS) technology and considers mappings between different learning metadata standards as well as ontological concepts for E-Learning. Since our approach is based on a dynamic selection and invocation of SWS appropriate to achieve a given learning objective within a specific learning context, it enables the dynamic adaptation to specific learning needs as well as a high level of reusability across different learning contexts.

Keywords: Semantic Web Services, Learning Applications, Learning Processes, WSMO, Learning Standards, ADL SCORM, IMS Learning Design

1 Introduction

Current approaches to support a learning objective are fundamentally based on providing a learner with appropriate learning content – the so called learning objects. Composite learning objects contain the learning resources - the physical data assets – as well as a description of the learning process to be followed by the learner. The latter usually is based on existing metadata standards - IEEE LOM [8], IMS Learning Design (IMS LD) [6] and ADL SCORM [1] which utilizes the IMS Simple Sequencing standard [7].

Due to this approach of allocating learning resources at design-time of a content package, the actual learning context – known at runtime only – cannot be considered. This means, a new learning content package has to be developed for every different learning scenario or individual needs of specific learners. For instance, a package suiting the needs of a learner with specific preferences – e. g. his native language or technological platform - can suit only this specific requirements and cannot be reused across different learning contexts. These limitations can be summarized as follows (cf. [2], [9], [4]):

- Limited reusability across different learning contexts, and metadata standards.
- Limited dynamic adaptability to actual learning context
- High development costs

To overcome these issues, the approach described in this paper changes this data- and metadata-based paradigm to a dynamic service-oriented approach based on Semantic Web Service (SWS) technologies. We follow the idea of providing the learner with a dynamic supply of appropriate functionalities in order to enable a dynamic adaptation to the learning context at runtime of a learning process. By describing a learning process semantically as a composition of learning goals independent from any metadata standard, a learning process model can be mapped to different standards to achieve standards-compliancy.

The following section provides brief background information about the SWS whereas section three explains our vision of a SWS-oriented architecture for E-Learning. Section four then introduces a prototype application which is fundamentally based on our approach. The last section finally draws a conclusion and provides an outlook to future work related to our approach.

2 Background: Semantic Web Services

SWS are aimed at enabling a automatic discovery, composition and invocation of available Web services. Based on semantic descriptions of functional capabilities of available Web services, a SWS broker automatically selects and invokes Web services appropriate to achieve a given goal.

IRS-III [3], the Internet Reasoning Service, is an implementation of a SWS broker environment. It provides the representational and reasoning mechanisms, which enable the dynamic interoperability and orchestration between services as well as the mediation between their semantic concepts. IRS-III utilizes a SWS library based on the reference ontology Web Service Modelling Ontology (WSMO) [15] and the OCML representation language [5] to store semantic descriptions of Web services and knowledge domains. WSMO is a formal ontology for describing the various aspects of services in order to enable the automation of Web service discovery, composition, mediation and invocation. The meta-model of WSMO defines four top level elements:

- *Ontologies* provide the foundation for describing domains semantically. They are used by the three other WSMO elements.
- *Goals* define the tasks that a service requester expects a Web service to fulfil. In this sense they express the requester's intent.
- *Web Service* descriptions represent the functional behavior of an existing deployed Web service. The description also outlines how Web services communicate (*choreography*) and how they are composed (*orchestration*).
- *Mediators* handle data and process interoperability issues that arise when handling heterogeneous systems.

3 SWS based E-Learning Applications: Vision and Approach

This section describes our vision as well as the approach to support E-Learning based on SWS.

3.1 Vision: Automatic Service Allocation at Runtime

To overcome these limitations, we consider the automatic allocation and invocation of functionalities at runtime. A typical learning related service functionality provides the learner for instance with appropriate learning content or with subject-specific discussion facilities. Since services are selected and invoked dynamically at runtime, a dynamic adaptation to different learning contexts is supported. Learning processes are described semantically in terms of a composition of user objectives (goals) to abstract from specific data and metadata standards. This vision is radically distinctive to the current state of the art in this area (Section 1), since it shifts from a data- and metadata-centric paradigm to a context-adaptive service-oriented approach. Moreover, using adequate mappings, our standard-independent process models can be translated into existing metadata standards in order to enable a reuse within existing standard-compliant runtime environments.

3.2 Approach: Abstraction from Process, Data and Functionalities

Our approach is fundamentally based on utilizing SWS technologies to realize the following principles:

1. Abstraction from learning data and learning functionalities
2. Abstraction from learning process metadata standards

To support these principles, we introduce several layers as well as a mapping between them in order to achieve a gradual abstraction:

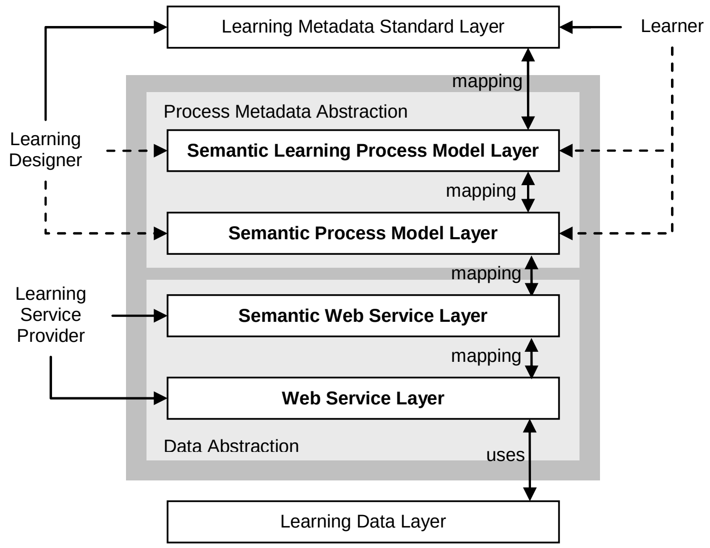

Fig. 1. Semantic layer architecture for supporting learning processes through a standard-compliant SWSOA

Abstraction from Learning Data and Functionalities

To abstract from existing learning data and content we consider a Web Service Layer. It operates on top of the data and exposes functionalities appropriate to fulfil specific learning objectives. This first step enables a dynamic supply of appropriate learning data to suit a specific context and objective. This will be supported furthermore by the use of semantic descriptions of available learning data. In order to abstract from these functionalities (Web services), our approach introduces the Semantic Web Service Layer. This layer enables the dynamic selection, composition and invocation of appropriate Web services for a specific learning context. This is achieved on the basis of formal semantic, declarative descriptions of the capabilities of available services to enable a dynamic matching of services to specific user goals.

Abstraction from Learning Process Metadata

A first layer concerned with the abstraction from current learning process metadata standards is the Semantic Learning Process Model Layer. It allows the description of processes within the domain of E-Learning in terms of higher level domain concepts - e. g. learning goals, learners or learning contexts. This layer is mapped to semantic representations of current learning metadata standards in order to enable the interoperability between different standards. To achieve a further abstraction from domain specific process models – whether it is e. g. a learning process, a business process or a communication process – we consider an upper level process model layer – the Semantic Process Model Layer. For instance, this layer supports the mapping between learning objectives and business objectives to support all kind of organizational processes.

Based on mappings between the described layers, upper level layers can utilize information at lower level layers. In particular, we consider mappings between a learning objective and a WSMO goal to enable the automatic discovery and invocation of a Web service (Web Service Layer) from, for instance, a standard-compliant learning application (Learning Application Standard Layer). As a result, a dynamic adaptation to individual demands of a learner within a specific learning context is achieved by using existing standard-compliant learning applications. In addition, mappings are also considered within a specific layer to enable a wide applicability of our approach. For instance, concepts of the Learning Process Model Layer could be mapped to existing concepts representing similar learning-related entities – e. g. learning process modules as defined in [12], [10].

4 A Prototype Application based on IMS Learning Design and WSMO

In order to validate the technical feasibility of the described approach, a first prototype was implemented based on IMS LD as well as the WSMO framework. This application implements an initial use case by utilizing the semantic layers and fundamental concepts as introduced in 3.2.

4.1 Use Case: A context- adaptive Learning Application to support Language Learning

We consider a scenario where several learners request to learn three different languages: English, German and Italian. This introduces three possible learning objectives. Moreover, it is assumed that each learner has one unique preference associated with his/her native language. For instance, if a learner is authenticated as a person with the native language “English” and wants to learn the language “German”, the learner expects to be provided with an English-based online learning unit aimed at teaching the German language. Furthermore, two different metadata standards – ADL SCORM and IMS LD – have to be supported.

Following the current approaches, for every individual learner as well as metadata standard, a specific package would have to be created in order to achieve a high level of appropriateness to the individual learner needs. Conversely, our approach will enable all learners to use only two different learning content packages (ADL SCORM, IMS LD) - which dynamically meet the multiple learner-specific requirements. Furthermore, content will not be pre-defined at design-time, but retrieved at runtime selecting among several available repositories. Since the general approach stated in Section 3 is realised, this simple scenario could be easily extended in the future to achieve a dynamic adaptation to more complex learning contexts.

4.2 SWS-oriented Architecture

Our current implementation makes use of standard runtime environments: IRS III [3] is used as SWS broker as well as development environment for WSMO descriptions; the Reload software suite [14] is used for editing and runtime processing of IMS LD and ADL SCORM content. Figure 2 outlines the Semantic Web Service Oriented Architecture (SWSOA) used in the current prototype. The defined architecture realizes all of the principles described in Section 5.

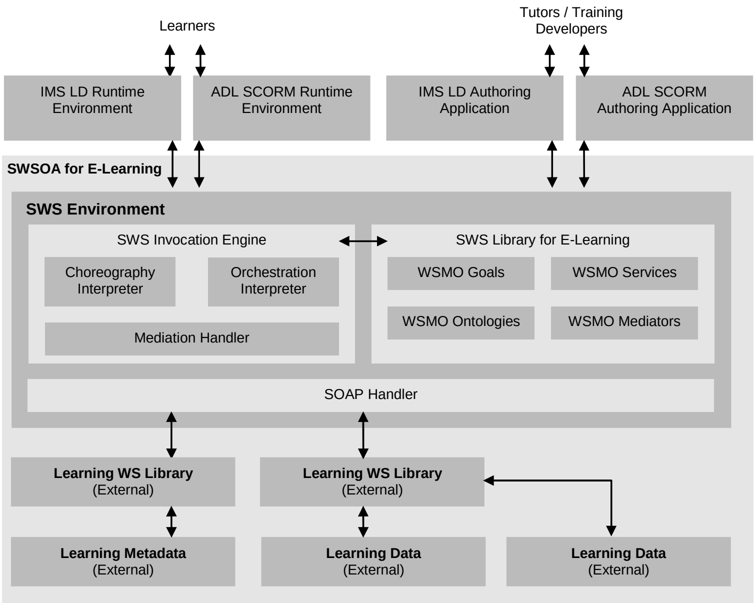

Fig. 2. SWS-based software architecture as utilized in the prototype application

To support the scenario described in Section 4.1, the following elements had to be provided within the general architecture presented above:

1. *Learning Web services libraries*. Web services were provided to support the authentication of the learner, the retrieval of semantic learner profiles, learning metadata and learning contents. Web services utilized in this demonstrator were partly developed within the LUISA project [11].
2. *WSMO Ontologies*. To implement the Semantic Learning Process Model Layer, initial semantic representations of ADL SCORM, IMS LD and content objects provided by the Open Learn Project [13] have been created. To fully provide the Semantic Learning Process Model Layer a Learning Process Model Ontology (LPMO) was described in addition. To support individual learner preferences, we particularly considered semantic learner profiles, describing the native language of every learner. All ontologies have been developed by using OCML [5] as ontology language.
3. *Mappings between semantic layers as well as metadata standards*. We created mappings between the initial implementations of semantic representations of metadata standards (IMS LD, ADL SCORM) and the LPMO as well as WSMO. For instance, we defined a mapping between the *lpmo:Objective* and the objective description as part of the IMS LD

metadata (*imsld:Objective*). Moreover, semantic learning object descriptions based on the LPMO were mapped to OpenLearn content units (*ol:Content Unit*), whereas the language of a content unit (*ol:Language*) was mapped to the native language of a learner (*lpmo:Language*). Since the UPO is not currently supported by any run-time environment, the LPMO objective is directly mapped to a WSMO goal. Figure 3 depicts the main ontological mappings as defined in our prototype. The defined mappings are performed at runtime as specific functionalities which exposed as Web services within external Web services libraries.

4. *WSMO Goal, Web Service, and Mediator descriptions* of the available Web services, based on the concepts defined in the WSMO ontologies.

5. *Standard-compliant content packages describing the learning activities.* IMS LD and ADL SCORM compliant learning processes were provided and included into IMS content packages. Instead of grounding the learning activities to static learning data, no static resources were associated with these learning processes. In contrast, only references to the described WSMO goals were associated with every learning activity. This mapping is achieved by associating a learning activity within the learning metadata with HTTP references to a web applet enabling to request the achievement of a specific WSMO goal from the SWS broker.

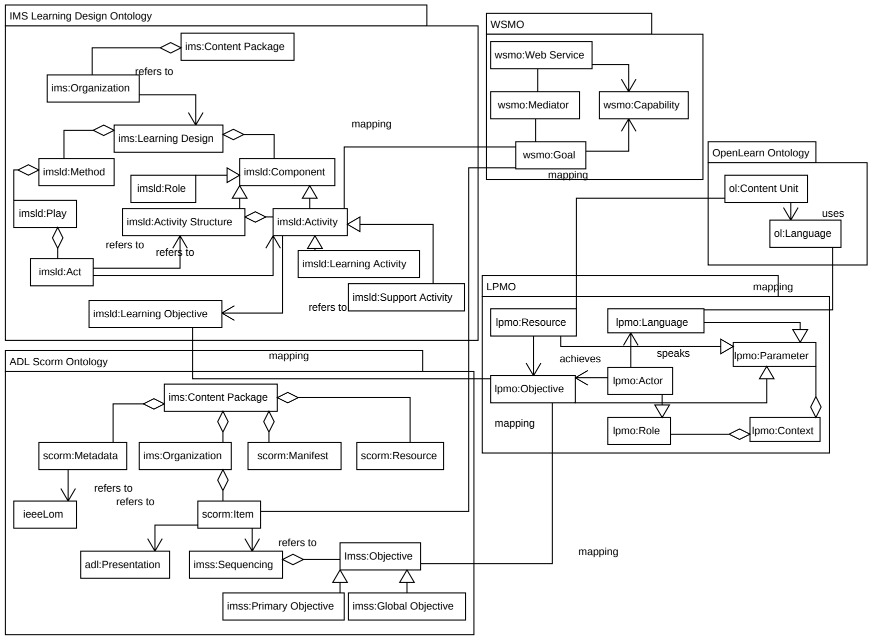

Fig. 3. Ontological mappings implemented and utilized in the prototype application

4.3 Dynamic Adaptation at Runtime

At runtime, an end-user (learner) accesses an standard-compliant player and loads the content packages compliant with IMS LD and ADL SCORM as defined in bullet 5 of the previous section. An initial activity within the standard compliant learning process first authenticates the learner and retrieves the semantic learner profile description. The WSMO goal associated with this activity is invoked, and the SWS broker dynamically selects and invokes the WSMO Web service showing the appropriate capabilities to achieve the specified goal.

In the same way, when the learner selects an individual objective within the content package, our infrastructure dynamically selects and invokes semantic Web services according to his/her preferences and stated objectives. For instance, if a learner is authenticated as an English-speaking person (lpmo:Language=English) and uses an IMS LD-based package to learn the language German, an imsld:Activity with the imsld:Objective=Learn German is mapped to a WSMO Learn-German-Goal. The accomplishment of this goal involves the selection and orchestration of different Web services at runtime: (i) the imsld:Objective is mapped to the lpmo:Objective concept; (ii) the lpmo:Objective is used to retrieve the semantic metadata of an appropriate learning object; (iii) the retrieved learning object identifier is used to obtain an Open Learn learning unit appropriate to the individual language of the learner and its current objective. The retrieved learning object is finally presented in the IMS LD runtime environment.

Fig. 4. Reload IMS LD Player while dynamically invoking SWS to retrieve appropriate learning content

Although this prototype implements a simple scenario only, it realizes a standard-compliant SWSOA for adaptive E-Learning applications and proves the feasibility of our approach.

5 Conclusion

Our approach - the support of learning objectives based on a dynamic invocation of SWS at runtime of a learning process model - follows an innovative approach and is distinctive to the current state of the art in this area. Our approach overcomes the limitations described in Section 1 and supports a high level of standard-compliancy and reusability within existing runtime environments, since it is fundamentally based on compliancy with current metadata standards. Since we enable a dynamic adaptation to a specific learning context at runtime, reusability across different contexts and metadata standards is supported. Due to a dynamic allocation of most appropriate resources – data and services – a wide variety of distributed learning resource repositories can be integrated.

Since our framework is developed only in parts currently, next steps have to be concerned with the implementation of complete ontological representations of the introduced semantic layers as well as of current E-Learning metadata standards and their mappings. Nevertheless, the availability of appropriate Web services aimed at supporting specific process objectives has to be perceived as an important prerequisite for developing SWS-based applications. To provide valid quantifications of the expected benefits, further case studies are foreseen. Besides that, future work could also be concerned with the mapping of semantic process models across different process dimensions – e. g. business processes or learning processes to enable a complete integration of a SWSOA in an organizational process environment.

REFERENCES

[1] Advanced Distributed Learning (ADL) SCORM 2004 Specification (http://www.adlnet.org).

[2] Amorim, R. R., Lama, M., Sánchez, E., Riera, A., & Vila, X. A. (2006). A Learning Design Ontology based on the IMS Specification. Journal of Educational Technology & Society, 9 (1), 38-57.

[3] Cabral, L., Domingue, J., Galizia, S., Gugliotta, A., Norton, B., Tanasescu, V., Pedrinaci, C.: IRS-III: A Broker for Semantic Web Services based Applications. In proceedings of the 5th International Semantic Web Conference (ISWC 2006), Athens, USA (2006).

[4] Collis, B. and Strijker, A. (2004). Technology and Human Issues in Reusing Learning Objects. Journal of Interactive Media in Education, 2004 (4). Special Issue on the Educational Semantic Web [www- jime.open.ac.uk/2004/4].

[5] J. Domingue, E. Motta and O. Corcho Garcia (1999). Knowledge Modelling in WebOnto and OCML: A User Guide, available from: http://kmi.open.ac.uk/projects/webonto/user_guide.2.4.pdf.

[6] IMS Learning Design Specification (http://www.imsglobal.org).

[7] IMS Simple Sequencing Specification (http://www.imsglobal.org).

[8] Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC) (http://ieeeltsc.org/).

[9] Knight, C., Gašević, D., & Richards, G. (2006). An Ontology-Based Framework for Bridging Learning Design and Learning Content. Journal of Educational Technology & Society, 9 (1), 23-37.

[10] Koper, R. (2004). Use of the Semantic Web to Solve Some Basic Problems in Education: Increase Flexible, Distributed Lifelong Learning, Decrease Teacher's

Workload. Journal of Interactive Media in Education, 2004 (6). Special Issue on the Educational Semantic Web. ISSN:1365-893X [www-jime.open.ac.uk/2004/6].

[11] LUISA Project - Learning Content Management System Using Innovative Semantic Web Services Architecture (http://www.luisa-project.eu/www/).

[12] Naeve, A., Sicilia, M. A. (2006), Learning Processes and processing learning: from organizational needs to learning designs, ADALE workshop at the Adaptive Hypermedia conference, Dublin, June 20-23, 2006.

[13] Open Learn Project: Online Educational Resources (http://openlearn.open.ac.uk/).

[14] Reload Project (http://www.reload.ac.uk/).

[15] WSMO Working Group, D2v1.0: Web Service Modeling Ontology (WSMO). WSMO Working Draft, (2004). (http://www.wsmo.org/2004/d2/v1.0/).