Addressing Context-Awareness and Standards Interoperability in E-Learning: A Service-oriented Framework based on IRS III

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ABSTRACT

Current technologies aimed at supporting learning goals primarily follow a data and metadata-centric paradigm. They provide the learner with appropriate learning content packages containing the learning process description as well as the learning resources. Whereas process metadata is usually based on a certain standard specification – such as ADL SCORM or the IMS Learning Design – the used learning resources – data or services - are specific to pre-defined learning contexts, and they are allocated manually at design-time. Therefore, a content package cannot consider the actual learning context, since this is only known at runtime of a learning process. These facts limit the reusability of a content package across different standards and contexts. To overcome these issues, this paper proposes an innovative Semantic Web Service-based approach that changes this data- and metadata-based paradigm to a context-adaptive service-oriented approach. In this approach, the learning process is semantically described as a standard-independent process model decomposed into several learning goals. These goals are accomplished at runtime, based on the automatic allocation of the most appropriate service. As a result, we address the dynamic adaptation to specific context and - providing the appropriate mappings to established metadata standards - we enable the reuse of the defined semantic learning process model across different standards. To illustrate the application of our approach and to prove its feasibility, a prototypical application based on an initial use case scenario is proposed.

Keywords

E-Learning, Semantic Web Services, Ontologies, Learning Process, Context Adaptibility, Standards Interoperability.

1. INTRODUCTION

E-Learning is aimed at supporting individuals in fulfilling a specific learning need within a specific situation through the use of information and communications technology. The current state of the art is mainly represented by approaches based on software systems – e. g. learning content management systems (LCMS) – which provide a learner with composite learning contents – the so called Learning Objects (LO). Several metadata standards are available for supporting the interoperability between different learning software platforms; they aim to provide a common specification for describing complex learning objects as well as the sequencing which has to be followed by the learner to fulfil his current learning need. Widely established E-Learning standards are IEEE LOM [6], ADL SCORM [1] – based on IMS Simple Sequencing - or IMS Learning Design (IMS LD) [7]. Complex learning objects are composite content packages containing the learning resources as well as its metadata. Thus, learning support usually follows the following practices:

- Use of specific metadata and learning resources – whether data or services - to support a specific learning objective
- Resources are manually associated with specific learning objectives based on the subjective appraisals of an individual learning designer
- Learning resources are allocated at design-time, i. e. when the actual learning context is not known

Due to these facts, the following limitations have been identified (cf. [2], [8], [4]):

L1. Limited appropriateness and dynamic adaptability to actual learning contexts. It is assumed that every learning objective occurs in a specific context which, for instance, is defined by the preferences of the actual learner – e. g. his native language or his technical platform. Learning data is allocated at design-time of a learning process – i.e. when the composite content package is developed. This limits the appropriateness of the data to the actual learning context, since the actual learning context can only be considered at runtime of a learning process. Moreover, the use of data excludes the dynamic adaptability a priori. In parallel to data-centric approaches, analogous issues can also be observed with service-oriented approaches. However, in that case, these issues are related to the allocation of services only.

L2. Limited reusability across different learning contexts and metadata standards. Due to L1, for every different learning context or specific learner requirement a new learning content package has to be developed. For example, a learning package suiting the needs of a learner with specific preferences – e. g. his native language – cannot be used for other contexts or learners having distinct requirements. Since metadata is described based on standard-specific specifications, an individual content package cannot be reused across different standards.

L3. High development costs. Due to L1 and L2, high development costs have to be taken into account when developing standard-compliant E-Learning packages.

To overcome these issues, the approach described in this paper changes the current data- and metadata-based paradigm to a dynamic service-oriented approach based on Semantic Web Services (SWS) technology.

SWS enable the automatic discovery, composition and invocation of available Web services. Based on the semantic descriptions of functional capabilities of available Web services, a SWS broker automatically selects and invokes Web services appropriate to achieve a given user 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) [12] 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 Web services, in order to enable the automation of their discovery, composition, mediation and invocation. The meta-model of WSMO defines four top level elements: *Ontologies*, *Goals*, *Web Services* and *Mediators*. Whereas *Ontologies* describe the terminology and its semantics used by the other WSMO elements, *Web Service* describes the capabilities and interfaces of a particular service; *Goal* describes a task from the user perspective; and *Mediator* solves data and process interoperability issues that arise when handling heterogeneous systems.

In our approach, we abstract from learning data as well as existing learning process models. We semantically describe a learning process as a composition of learning goals. Learning goals are mapped to WSMO goals; in this fashion, we exploit the benefits of SWS in our framework. Moreover, our semantic model of learning processes is independent from any metadata standard; to achieve compliancy with them, we can be link to multiple metadata standards by providing the appropriate mappings.

2. SEMANTIC WEB SERVICE BASED E-LEARNING APPLICATIONS: VISION AND APPROACH

This section describes our vision as well as the approach to support context-adaptive learning designs. Moreover, we use the formalization introduced in the previous section to highlights the benefits of our approach.

2.1 Vision: Context-Adaptation through Automatic Service Selection and Invocation

To overcome the limitations L1 – L3 described in Section 1, we consider the automatic allocation and invocation of functionalities at runtime. A typical learning related service functionality provides the learner with, for instance, appropriate learning content or topic-specific discussion facilities. Learning processes are described semantically in terms of composition of user objectives (goals) and abstract from specific data and metadata standards. The most adequate functionality is selected and invoked dynamically regarding the demands and requirements of the actual specific context. This enables a highly dynamic adaptation to different learning contexts and learner needs.

This vision is radically distinctive to the current state of the art in this area, 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.

Addressing limitations L1 and L2, we consequently reduce the efforts of creating learning process models (L3): one unique learning process model can adapt dynamically to different process contexts and can be translated into different process metadata standards.

2.2 Approach: Semantic Abstraction from Process Metadata, Functionalities and Data

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

P1. Abstraction from learning data and learning functionalities.

P2. 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 (Figure 1):

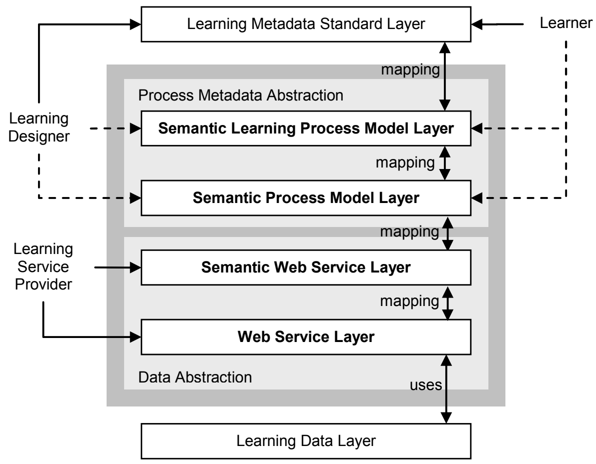

Figure 1. Semantic layer architecture for supporting context-adaptive learning designs.

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 the functionalities appropriate to fulfill specific learning objectives. This first step enables a dynamic supply of appropriate learning data to suit a specific context and objective. Services exposed at this layer may make use of semantic descriptions of available learning data to accomplish their functionalities.

In order to abstract from these functionalities (Web services), we introduce an additional layer – 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; i.e. declarative descriptions of available services that enable the dynamic matching of service capabilities 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 – Semantic Process Model Layer. This layer introduces for instance the mapping between learning objectives and business objectives to support all kind of organizational processes.

Mappings. 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. It is important to note that we explicitly consider mappings not only between multiple semantic layers but also within a specific semantic layer.

3. A SWS-ORIENTED PROTOTYPE APPLICATION BASED ON IMS LD, ADL SCORM AND WSMO

In order to validate the technical feasibility of the described approach, a first prototype was implemented. In this section, we describe an application based on IMS LD, ADL SCORM as well as the WSMO framework. The application implements the initial scenario described in Section 2 by utilizing the semantic layers and fundamental concepts introduced in Section 3.

3.1 Scenario

To report a simple - but concrete - scenario, we consider several learners that request to learn different languages: English, German and Italian. It is assumed, that all learners have different preferences – e.g. their spoken native language – which have to be considered. For example a German native speaker requiring to learn the language “English” should be provided with German learning resources to teach the English language. Furthermore, we are going to support two different metadata standards – ADL SCORM and IMS LD. Following the current approach of creating a standard-compliant learning content package, for every individual learner a specific package would have to be created in order to achieve a high level of appropriateness. In addition, for every metadata standard which has to be supported, a new standard-compliant process model has to be created. Applying our SWS-based approach, we enable all learners to utilize the same standard-compliant learning package – respectively learning process model – which dynamically adapts to the actual learning context and learning need.

3.2 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 [11] 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 3.

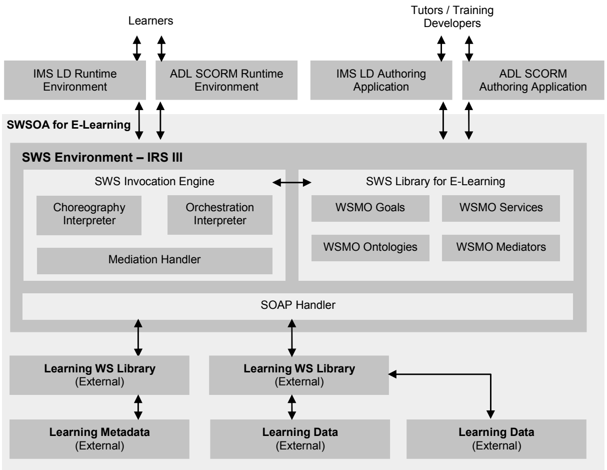

Figure 2. SWS-based software architecture as utilized in the prototype application.

To support the scenario described in Section 3.1, the following elements had to be provided within the 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 [9].
2. *WSMO Ontologies.* To implement the Semantic Learning Process Model Layer (Section 2.2), initial semantic representations of ADL SCORM, IMS LD, a Learning Process Model Ontology (LPMO) and the content objects provided by the Open Learn Project [10] have been created. LPMO has to be perceived as the central ontology within our architecture, since it describes the semantics of a learning process from a general point of view and independent from any supported platform or learning technology standard. To support individual learner preferences, we particularly consider semantic learner profiles which describe 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 used within 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 Semantic Process Model Layer (Section 3.2) is not currently fully implemented, 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. These functionalities are exposed as Web services, which are part of an external learning Web services Library.
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, we link to the respective WSMO goal descriptions. 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 (figure 2).

3.3 Dynamic Adaptation at Runtime

At runtime, an end-user (learner) accesses a standard-compliant player. He/she loads the content packages compliant with IMS LD and ADL SCORM that were developed as described in bullet 5 of the previous section. The learning application then sequentially presents all of the learning activities that would have to be performed. The WSMO goal associated with such an activity – as described in bullet 5 of section 3.2 - is invoked, and the SWS broker dynamically selects and invokes the Web service exposing the appropriate capabilities to achieve the specified goal.

First, an initial activity authenticates the learner and retrieves the semantic learner profile description. At this point, the learner preferences are set within the player environment. In the same way, when the learner selects an

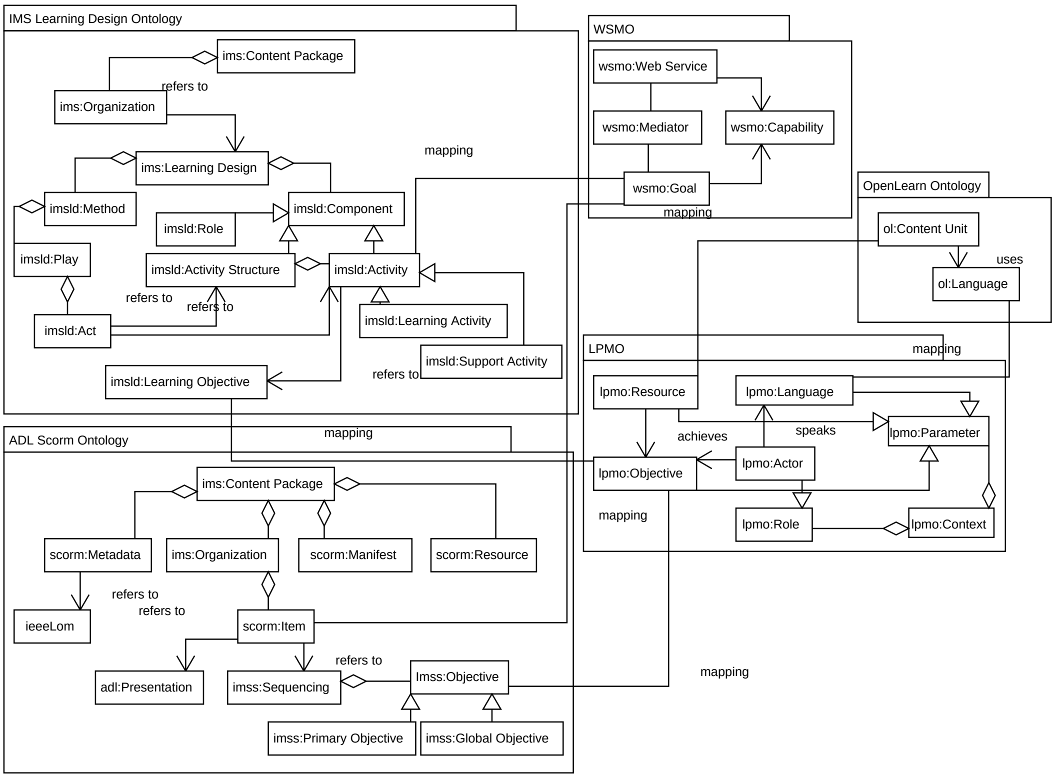

Figure 3. Ontological mappings implemented and utilized in the prototype

individual objective within the standard 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 ADL SCORM-based package to learn the language German, a scorm:Item with the imss:Objective=Learn German is mapped to a WSMO Learn-German-Goal. The accomplishment of such a goal involves the selection, orchestration and invocation of different Web services, which perform the described mappings and retrieve appropriate learning content. The following OCML code listing shows a portion of the capability description of a Web service, which is able to provide learning content to teach German. Specifically, the capability assumes that the objective provided by the ADL SCORM package has to be "Learn German".

```
(DEF-CLASS ACHIEVE-OBJECTIVE-GERMAN-WS-CAPABILITY
   (CAPABILITY)
   ?CAPABILITY
     ((USED-MEDIATOR :VALUE ACHIEVE OBJECTIVE-GERMAN-MED)

       (HAS-ASSUMPTION
            :VALUE
            (KAPPA
              (?WEB-SERVICE) (= (WSMO-ROLE-VALUE ?WEB-
              SERVICE 'HAS-IMSS-OBJECTIVE)"Learn German")))
```

Listing 1. Partial source code of a Web service capability description

Such a Web service orchestrates the following WSMO Web services: (i) the imss: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. Each of these goals is accomplished by a distinct Web service dynamically selected at runtime. The retrieved learning object is finally presented in the ADL SCORM runtime environment.

Figure 4 depicts a screenshot of the Reload ADL SCORM 2004 Package Viewer while presenting a standard-compliant ADL SCORM 2004 content package and dynamically invoking SWS appropriate to fulfil the given learning objective "Learn German". Besides several limitations, our current prototype implements the basic approach of a standard-compliant SWSOA for E-Learning, as described in this paper.

Figure 4. Reload ADL SCORM 2004 Viewer while dynamically invoking SWS to retrieve appropriate learning content.

4. 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. By using SWS technology, we overcome the limitations described in section 1 and support a high level of standard-compliancy and reusability within existing runtime environments, since it is fundamentally based on compliancy with current E-Learning metadata standards. In particular, the following contributions should be taken into account:

- Dynamic adaptation to specific learning contexts at runtime
- Automatic allocation of learning resources based on comprehensive semantics
- High reusability across learning contexts
- Platform- and standard-independence
- Reuse and integration of available learning resources
- Decrease of development costs

Since our framework is currently developed to some extent only, 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. For example, currently the Semantic Process Model Layer is not fully implemented and semantic mappings between the Learning Process Model Ontology and available process metadata standards are only developed in extracts. 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 more valid quantifications of the expected benefits, further case studies are needed to illustrate the formalized measurements introduced in the sections above. 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.

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