TOWARDS SEMANTIC WEB ENHANCED LEARNING

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Keywords: Technology Enhanced Learning (TEL), Semantic Web Services (SWS), Service oriented Architecture (SOA).

Abstract: The paper discusses an approach for facilitating the authoring process for Technology Enhanced Learning by providing service oriented access to learning materials based on their content. This service-oriented approach is based on Semantic Web Service technologies. It reflects current work in the frame of an on-going Bulgarian research project SINUS "Semantic Technologies for Web Services and Technology Enhanced Learning".

1 INTRODUCTION

The research and development efforts in the field of Technology Enhanced Learning (TEL) address the exploitation of the huge potential of Information and Communication Technologies to unbound and multiply the opportunities for accessing learning in general. While learning human knowledge must be constructed – not by the teacher (or courseware author) for the student, but by the student himself with the teacher's or peers' assistance. Technology has to provide information and create situations, enabling activities for constructing learner's knowledge. Current TEL systems and tools facilitate the development of various learning situations, reducing substantially the time and space limitations on the learning process, supporting more pro-active and knowledge-pulling types of learning architectures (Aceto et al, 2007).

Learning content has always been regarded as keystone for all learning situations in classical education as well as in e-earning activities. That's why the authoring of learning materials is one of the most important and labour-intensive activities in the modern TEL practice. The present paper discusses a way for facilitating the authoring process by providing service oriented access to learning materials based on their content. The paper reflects the current work accomplished in the frame of an on-going national research project SINUS "Semantic Technologies for Web Services and Technology Enhanced Learning" (http://sinus.iinf.bas.bg).

2 SOME TENDENCIES IN TEL

The continuous growth of multiple digital libraries makes the problem to open enormous existing digital resources to be easily available for learning needs more significant and actual. Education-focused digital archives are expected to support the reuse of resources for the creation of new learning materials. This involves re-purposing - integrating and relating existing resources into a new context. A learning context has many dimensions including various and difficult to coordinate social and cultural factors: the learner's educational system, the learner's cognitive abilities, his/her prior knowledge, learning style, cultural preferences.

The need to specify and separate learning resources from the information about the context of their usage led to creation of various kinds of metadata schemas. This work has focused around the notion of learning object (LO), as a conceptual base, capable to guarantee interoperability to the rapidly growing number of Web-based educational applications. In the TEL tools based on current e-Learning standards (IMS-LD, LAMS etc.), a LO can be considered as a static and monolithic block, since once created, it is rather difficult to change or modify its inner resources and/or to add/remove services and resources at run-time. The traditional approaches to create a LO typically rely on expertises of the institutional designer only, and have practically no capability to reuse existing blocks.

In the last years there is an increasing interest for semantic descriptions of learning materials as a

Dochev D. and Agre G. (2009).
TOWARDS SEMANTIC WEB ENHANCED LEARNING.
In *Proceedings of the International Conference on Knowledge Management and Information Sharing*, pages 212-217
DOI: 10.5220/0002330202120217

mean to make TEL systems more flexible and helpful for end users. By accessing semantically annotated and adequately structured knowledge from digital archives lecturers/authors should participate in ‘open source’ dynamic content development from massive, dynamically growing learning resources. This tendency fits well to the new TEL research tendencies aiming at more learner-centric, interest-oriented, pro-active and knowledge-pulling types of learning architectures.

2.1 The LOGOS Approach

The FP6 IST project LOGOS “Knowledge-on-demand for ubiquitous learning”, developed by 15 partner organizations from 8 countries, concerned innovative developments for all the e-Learning processes components – resources, services, communication spaces (www.logosproject.com). The project focused on learning resources by addressing the transformation of digitised information from existing large-scale repositories into learning content, adequately enhancing and facilitating the learners’ knowledge building. One of the main results of the project was the implementation of a platform for ubiquitous (any place, any time, personalized) learning, combining an authoring studio for creation of learning materials from existing digital repositories with emphasis on semantic annotation and access, and facilities for cross-media courseware delivery through different communication channels (IP-based, digital TV and/or mobile devices)

The architecture of LOGOS authoring studio is based on hierarchy of information objects:

- Media objects - ‘raw’ multimedia (MM) objects, catalogued with some technical characteristics to enable multiple channel delivery;
- Digital objects - media objects, annotated with technical and administrative, as well as with semantic metadata (based on domain ontologies);
- Learning objects (incl. assessment objects) - digital objects, enriched with educational metadata (LOM);
- Courseware objects - graphs of learning activities associated with learning objects.

The LOGOS authoring process is sketched on Figure 1. Some lessons learnt from LOGOS practice of authoring learning materials are:

- Investigations to unify the mechanisms and tools for access to information objects and processing of semantic information would increase the effectiveness of TEL platforms development and maintenance by creating “lightweight” versions of authoring tools, based on well defined and well understood use cases.
- It seems desirable to use and combine limited-world domain ontologies, reflecting viewpoints on the domain for specific well defined user groups in order to increase the effectiveness of the preparation of semantic resources.
- The manual high labour-intensive work to annotate resources should be facilitated by providing templates and finding similarities with existing annotations.
- There is definite need to increase the usability of the authoring tools making them more dedicated and end-user-friendly in order to support effectively the indexing and re-purposing of learning content.
- The authoring tools have to be validated and experimented with different user groups to fit well enough with the significant use cases for the different user roles of the TEL platform.

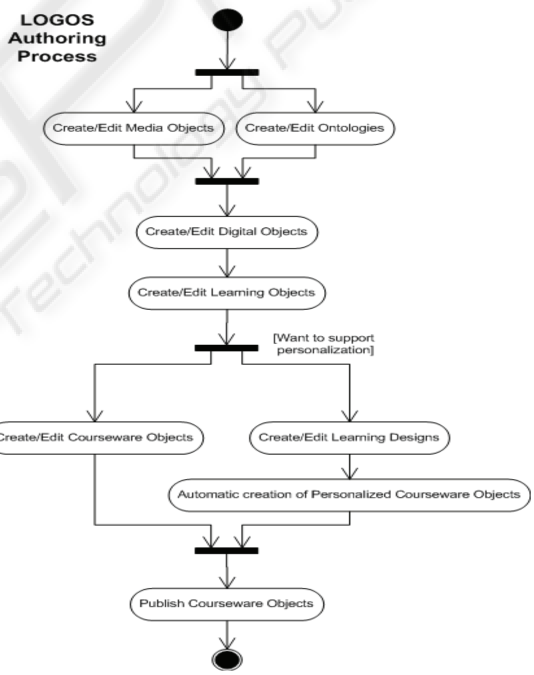

Figure 1: LOGOS authoring process.

The limitations of current approaches for authoring learning content can be summarized as follows:

- High knowledge and labour intensiveness of learning content preparation.
- Rigid schemes of metadata standards, considering only objective (factual) and static (created only once) metadata

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

These limitations result in high development costs and lack of enough high quality adaptable e-Learning materials available for mass usage.

Currently a number of research teams are exploring virtualisation mechanisms by which each resource is virtualised as a service. Such attempts to use SWS technology aims to exploit common mechanisms and tools to reuse the learning materials and other already developed building resources by enabling automatic search and late binding of resources and services.

3 SWS TECHNOLOGY

Web services define a new paradigm for the Web, in which a network of computer programs becomes the consumer of information. However, Web service technologies only describe the syntactical aspects of a Web service and, therefore, only provide a set of rigid services that cannot adapt to a changing environment without human intervention. Realization of the full potential of the Web services requires further technological advances in service interoperation, discovery, choreography and orchestration. A possible solution to these problems is likely to be provided by combining the Semantic Web technology (ontologies) with Web services. The result is Semantic Web Services (SWS), which are self-contained, self-describing, semantically marked-up software resources that can be published, discovered, composed and executed across the Web in a task driven semi-automatic way. SWS can constitute a solution to the integration problem, as they enable dynamic, scalable and reusable cooperation between different systems and organizations.

3.1 Core Initiatives and Projects

There are two major initiatives working on developing a world-wide standard for the semantic description of Web services. The first one is OWL-S (www.daml.org/services/owl-s/) a collaborative effort by BBN Technologies, Carnegie Mellon University, Nokia, Stanford University, SRI International and Yale University. OWL-S is intended to enable automation of Web service discovery, invocation, composition, interoperation and execution monitoring by providing appropriate semantic descriptions of services. The second one is the Web Service Modeling Ontology (WSMO) - a European initiative intending to create an ontology for describing various aspects related to SWS and to solve the integration problem. WSMO has been under development over the past four years and has been adopted in several IST FP-6 Integrated Projects such as DIP (dip.semanticweb.org/), SEKT (sekt.semanticweb.org/), Knowledge Web (knowledgeweb.semanticweb.org/), ASG (asg-platform.org/), INFRAWEBS (www.infrawebs.eu) and LUISA (www.luisa-project.eu) by consortia including in total more than 70 academic and industrial partners.

WSMO (www.wsmo.org) is conceptually grounded on Modelling Framework (WSMF) (Fensel and Bussler 2002) using Web Service Modeling Language (WSML) for describing its four main components - ontologies providing the formal semantics to the information used by all other components, goals specifying objectives that a client may have when consulting a Web service, Web services representing the functional part which must be semantically described in order to allow their semi-automated use and mediators used as connectors providing interoperability facilities among the rest of components.

At the moment practical application of SWS technologies is still rather restricted due to several reasons, some of which are high complexity of both OWL-S and WSMO, the lack of standard domain ontologies and unavailability of mature tools supporting WSMO or OWL-S.

3.2 INFRAWEBS Project

A technology-oriented step for overcoming some of the above-mentioned problems was proposed by IST FP-6 project INFRAWEBS (Agre et al. 2009). It focused on developing a Semantic Service Engineering Framework enabling creation, maintenance and execution of WSMO-based SWS, and supporting SWS applications within their life-cycle. Being strongly conformant to the current specification of various elements of WSMO (ontologies, goals, semantic services and mediators), the INFRAWEBS Framework *managed with* the complexity of creation of such elements by:

- Identifying different types of actors (users) of Semantic Web Service Technologies;
- Clarifying different phases of the Semantic Service Engineering process, and
- Developing a specialized software toolset oriented to the identified user types and

intended for usage in all phases of the SWS Engineering process.

The INFRAWEBS Framework has been implemented on the top of an extensible Enterprise Service Bus (ESB) middleware (Mule) that exposes the public methods of the INFRAWEBS components and can be extended by any future components or services. Such Integrated INFRAWEBS Framework (IIF) can be seen as the underlying P2P infrastructure for communication and integration of all the INFRAWEBS components, and at the same time the unique selling point for exposing the functionality of such components to the external world in form of services. All these features have allowed recognizing INFRAWEBS as one of the first frameworks for semantic service engineering that covers the whole SWS life-cycle and allows creation of complex semantically-enabled applications.

4 AN APPROACH TO SEMANTIC WEB ENHANCED LEARNING

As it has been already mentioned SWS technology promises to provide a possible solution to increase the effectiveness of preparation and use of adaptable learning content by changing the current data- and metadata-based paradigm to TEL to a dynamic service-oriented approach (Dietze et al., 2007).

The current national research project SINUS - Semantic Technologies for Web Services and Technology Enhanced Learning (sinus.iinf.bas.bg) aims at providing a framework for development TEL-oriented applications based on SWS technology. It stands on methods and tools developed as well as on lessons learnt in LOGOS and INFRAWEBS projects.

4.1 SINUS Conceptual Architecture

The Conceptual Architecture of SINUS is an adaptation of the INFRAWEBS Semantic SOA-based architecture (Agre 2009) towards TEL applications. The architecture defines two main elements: SINUS Design-time and Run-time Environments (Figure 2).

The Design-time Environment consists of a decentralized network of nodes or peers connecting with the rest of peers through the integrated infrastructure. Each peer consists of a centralized bundle of components within a single server and offers a native Java support for integration, and a Web Service interface, which allows the easy incorporation of the components.

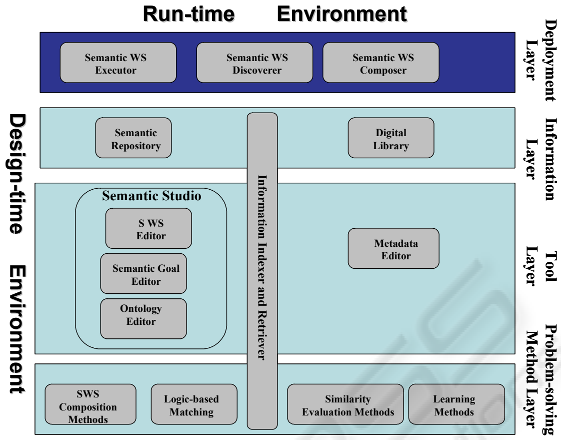

Figure 2: SINUS Conceptual Architecture.

The components of a peer are organized in two directions: (i) problem solving based on semantic information (or Logic-based problem solving) versus problem solving based on non-semantic information (similarity-based problem solving); and (ii) different types of information needed for both kinds of problem solving.

The SINUS Design-time Environment proposes:

- ***Information structures*** for storing and retrieving semantic (ontology-based) and non-semantic (metadata-based) information:
    - *Semantic Repository* enables efficient storage and retrieval of all elements of the Semantic Web (WSMO objects): goals, ontologies and SWS. From TEL point of view the Repository stores all resources *annotated by ontologies* used in TEL process – digital objects, learning objects, learning designs and ontologies themselves.
    - *Digital Library* – contains digital resources with some initial metadata descriptions that can be further used for creating ontology annotated resources.
    - *Information Indexer and Retriever* – contains a special representation of both Semantic (WSMO) and non-semantic resources of the platform. Such a representation allows effective similarity-based search and retrieval of all resources based on their content.
- ***Tools*** for creation and maintenance of semantic and non-semantic resources:
    - *Semantic Studio* – an integrated tool set aiming at designing all elements of WSMO-based Semantic Web objects by

effective reuse of already existing semantic and non-semantic descriptions stored in the Semantic Repository and Digital Library. The Semantic Studio contains *Ontology Editor* aiming at creating ontologies in a user-friendly manner; *SWS Editor* providing graphical ontology-based way for creating and composition of WSMO-based SWS and *Semantic Goal Editor* providing means for creation of WSMO-based reusable learning goals and goals templates (designs) used for developing SWS-based TEL applications.
- *Metadata Editor* aims at creating initial metadata annotations.
- ***Methods*** used for creating and maintaining Semantic and non-semantic objects:
- Combination of TEL-specific and logic-based methods for object discovery.
- TEL-specific decision-support methods for dynamic service composition.
- Several methods for calculating object similarity – structural, linguistic, statistical, fuzzy, etc.

The SINUS Design-time Environment will adapt and enhance such tools as INFRAWEBS Designer (Agre and Dilov 2008) and INFRAWEBS Organization Memory (Andonova et al. 2007), which have been evaluated as an achievement of the INFRAWEBS project that has a potential impact on the adoption of SWS on a larger scale.

The *SINUS Run-time Environment* is responsible for communication with different users and peers of the framework. It will provide a middleware for discovery, dynamic composition, execution and monitoring of SWS.

4.2 Matching Authoring Process to SINUS Architecture

The SINUS Architecture allows natural implementation on a layered approach for creation TEL applications. First layer is devoted to creation of "basic" semantic and non-semantic multimedia resources. It is assumed that operation on this layer will be accomplished by two types of *users* – annotators and knowledge managers. The annotators will use the Metadata Editor for initial annotation of raw multimedia objects (created by them or found somewhere in WWW). The annotated objects will be published in SINUS Digital Library and become available for further semantic annotations for all users of the framework.

The knowledge managers will use the Ontology Editor of the Semantic Studio for creating WSML ontologies to be further used in the process of semantic annotation. The created ontologies will be published in a local (belonging to a concrete SINUS peer) Semantic Repository, which, in its turn, makes them available for all other peers of the framework.

The second layer deals with the creation of semantically annotated digital objects and learning objects – combination of such digital objects additionally annotated by educational metadata (LOM). From technology point of view both types of objects will be represented in a uniform way – as SWS. For this the users of the framework (playing the role of Educationalists) will use the SWS Editor of the Semantic Studio, the domain ontologies stored in the Semantic Repository and a WSML version of LOM (s-lom) ontology, developed under LUISA project.

As usual, all developed objects will be made available for all SINUS peers by publishing them in a local Semantic Repository.

The third layer is intended for creating learning goals and learning designs describing possible goals of the end-user of a SWS Leaning application. At design-time these objects (represented as WSMO goals) are created by the Goal Editor of the Semantic Studio, which intensively uses some formally represented domain and learning strategy ontologies. These goals are the basic blocks for formulating end-user queries to a SWS Learning application in run-time.

In Run-time each end-user goal is dynamically decomposed on sub-goals, for which the corresponding sets of matching Semantic Services (learning or semantic digital objects) will be discovered. The resulted dynamically composed complex process may be stored again in the Semantic Repository as a new complex SWS or be executed by the Framework Run-time Environment.

It should be mentioned that the process of publishing of each newly created object (semantic or non-semantic) is passed through the indexing the object description done by the Information Indexer and Retriever component of the Framework implemented as Web service. The process of creating semantic objects is facilitated by ability to reuse the existing descriptions of similar objects stored in the Semantic Repository. The search of such similar objects is realized by the Information Indexer and Retriever based on object indexes created during the process of publishing the objects.

5 DISCUSSION AND FUTURE WORK

In this paper we have proposed an approach for developing a new Semantic SOA-based framework oriented to TEL applications facilitating reusability and repurposing of learning objects. The approach is based on analyzing and exploiting the advantages of SWS technology in the automation of learning object discovery, selection and composition within a distributed service architecture seamlessly integrated through ontologies.

One of the most promising approaches for creating Learning Management Systems using SWS architecture has been proposed in the frame of the LUISA project. The approach has reused and adapted the SWS Framework previously developed in the frame of another IST project – DIP, which was implemented in parallel with INFRAWEBS Project. Being based on the same SWS methodological framework (WSMO), the projects have created different SOA-based architectures caused by the different objectives to be solved.

Our approach aims at developing a *new domain-specific Semantic SOA-based architecture,* which will be focused on further development and refining the INFRAWEBS Framework for semantic service engineering that covers the whole semantic Web service life-cycle and allows creation of complex semantically-enabled applications (Agre et al. 2009).

The implementation of the proposed approach needs intensive research in several directions:

- Developing new application-oriented methods and end-user oriented tools for description of SWS and Goals. Problems for representation of Semantic Web Services and Goals are among the hottest research aspects of SWS technology for which no general solutions have been found yet. The efforts will be oriented to refining and advancing the original graphical and ontology-based approach developed in the frame of INFRAWEBS project (Agre and Dilov 2007).
- Developing new methods for dynamic composition of Semantic Web Services suited for TEL. The problem of dynamic composition of Web services is the core of the Service-oriented computing paradigm. There are a very few really implemented and rather restricted approaches for this still open problem. Most of them are based on OWL-S Framework. Our research on dynamic composition of SWS will be oriented to further development of an original data-driven SWS composition approach, which was recognized as "the only fully automated Functional Level-based Composition planner for WSMO yet".

ACKNOWLEDGEMENTS

This work is partially funded by Bulgarian NSF under the project D-002-189 SINUS "Semantic Technologies for Web Services and Technology Enhanced Learning".

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