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An Approach to Technology Enhanced Learning by Application of Semantic Web Services[1]

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Abstract: *In the current Learning Management Systems the allocation of learning resources is done at design-time, relying on expertises of the institutional designer only, and there are not many capabilities to reuse existing blocks. A possible approach to increase the effectiveness of preparation and use of adaptable learning content is to change this data- and metadata-based paradigm to a dynamic service-oriented approach based on Semantic Web Service technologies. The paper presents an approach that follows this idea – 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 their compliancy. Based on the lessons learnt from several FP6 IST projects, we propose a Semantic Service Oriented Framework for creating eLearning professional eLearning providers, but mainly mass authors of learning materials without specific knowledge and skills concerning information models and basics of ontology engineering and hence aiming to develop more mass-user-centred and user-friendly approach and tools to facilitate learning content creation.*

Keywords: *e-Learning, Semantic Web Services, Service Oriented Architectures.*

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1. Introduction

The rapidly changing world of the Information Society with the continuous change of working conditions and the evolution of information and communication technologies boosts the needs for updating people's knowledge and skills.

Current approaches to Technology Enhanced Learning (TEL) are fundamentally based on providing a learner with appropriate learning content. In the current Learning Management Systems the allocation of learning resources is done at design-time, relying on expertises of the institutional designer only, and there are not much capabilities to reuse existing blocks. So 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, learning style, technological platform etc. - can suit only this specific requirements and cannot be reused across different learning contexts.

Authoring of adaptive content, realised to some extent in the Learning Content Management Systems, is one of the most important and labour-intensive activities in the modern TEL practice. Traditionally it relies on the design of a fine-grained domain model and careful indexing of various learning objects with multiple domain concepts [6, 7]. Such approach requires from the authors expertise in both the learning subject domain and knowledge engineering, as well as a considerable time investment. That's why adaptive learning technologies are so slow to transfer from research labs to the education practice. Lecturers and teachers who are the mass authors of the learning content normally do not have necessary experience in the development of sophisticated domain models and enrichment of learning content with domain knowledge, while the developers of TEL environments are physically unable to create sufficient volumes of intelligent content that can suit the needs of multiple teachers. The complexity of content authoring in modern adaptive education systems primarily originates in the complexity of the domain models used in these systems. The more detailed and precise the modelling is, the more accurately the system can assess student knowledge, and the more effectively it can potentially adapt its content to the individual student. The promising methodology here is to rely on domain models developed by experts and provide teachers with dedicated and friendly authoring tools supporting effective indexing of learning content.

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

- Limited reusability across different learning contexts, and metadata standards.
- Limited dynamic adaptability to actual learning context.
- High labour intensiveness of learning content preparation and hence high development costs.

A possible approach to increase the effectiveness of preparation and use of adaptable learning content is to change this data- and metadata-based paradigm to a

dynamic service-oriented approach based on Semantic Web Service (SWS) technologies [6].

In this article we propose an approach that follows this 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 their compliancy.

The structure of the paper is as follows: the next section is a short introduction to the state-of-the-art in Technology Enhanced Learning and Semantic Web Service Technologies. Section 3 describes the main idea of the approach. The last section presents some conclusions.

2. State-of-the art

2.1. Technology enhanced learning

Learning content has always been keystone for all learning situations in classical education as well as in e-Learning activities. With the huge growth of digital archives and digital libraries the problem to make enormous existing digital resources easily available for learning needs becomes more significant and actual. Digital archives (and especially education-focused digital archives) are expected to support the reuse of resources for the creation of new digital objects. This involves integrating and relating existing resources into a new context. A learning context has many dimensions including social and cultural factors: the learner's educational system, the learner's abilities, preferences and prior knowledge.

The need to specify and separate the information about the context of usage of a learning resource from the resource itself led to creation of various kinds of metadata schemas. This work has focused around the notion of Learning Object (LO), as a conceptual base for technology, 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 tools, 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 [11, 14]. Moreover, the traditional approaches to create a LO typically rely on expertises of the institutional designer only, and have no capability to reuse existing blocks. Currently a number of research teams are exploiting virtualisation mechanisms (by which each resource is virtualised as a service), to obtain some dynamicity during the LO delivery, enabling the automatic search and late binding of resources and services, and to reuse the learning resources and other already developed building blocks (e.g. ontologies, learner models, didactic methods) during the LO building [8].

The research area of Technology Enhanced Learning is among the priority areas of the EC Sixth and Seventh Framework RTD programmes: 32 projects were developed under 6 FP and 6 new projects under Call 1 of 7 FP. Among the projects,

influenced the current proposal, are LUISA[2], KALEIDOSCOPE[3], PROLEARN[4], ELeGI[5], TENCompetence[6], etc. The area "Intelligent Content and Semantics" is among the priorities of 7 FP and 15 new projects are developed under its Call 1.

In Bulgaria most universities introduce e-Learning practices in their work. Sofia University, Plovdiv University, University of Rousse, Technical University – Sofia etc. and some BAS institutes (Institute of Information Technologies, Institute of Mathematics and Informatics, Institute of Parallel Information Processing) have their own contributions also in research and development activities in the field. Teams from Bulgarian academic institutions are partners in international projects under the EC Framework programmes and Life Long Learning Programme, aiming development of modern solutions for TEL, some of them concerning also semantic technologies: TENCompetence "Building the European network for lifelong competence", KALEIDOSCOPE "Concepts and methods for exploring the future of learning with digital technologies", UNITE "Unified eLearning environment for the school" (Sofia University); ERASMUS-TN „Doctoral Education in Computing"(University of Rousse with many other academic partners); LOGOS "Ubiquitous Learning-on-demand", JASON "On the Job e-Training Skills to Deal with Digital Cultural Heritage Content", KNOSOS "New Media Knowledge Village for Innovative e-Learning Solutions" (IIT-BAS, IMI – BAS), etc.

2.2. Semantic Web services

The emerging generation of information technologies starts by abstracting from software and sees all resources as services in a service-oriented architecture (SOA). In a world of services, it is the service that counts for a customer and not the software or hardware components which implement the service. Service-oriented architectures are rapidly becoming the dominant computing paradigm. However, current SOA solutions are still restricted in their application context to being in-house solutions of companies. A service Web will have billions of services. While service orientation is widely acknowledged for its potential to revolutionize the world of computing by abstracting from the underlying hardware and software layers, its success depends on resolving a number of fundamental challenges that SOA does not address today.

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 [8]. Realization of the full potential of the Web services requires further technological advances in the areas of service interoperation, discovery, choreography and orchestration. A possible solution to all these problems is likely to be provided by converting Web services to Semantic Web

[2] www.luisa-project.eu
[3] http://www.noe-kaleidoscope.org/
[4] http://www.prolearn-project.org/
[5] http://www.elegi.org/
[6] http://www.tencompetence.org/

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 [5]. SWS can constitute a solution to the integration problem, as they enable dynamic, scalable and reusable cooperation between different systems and organizations.

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[7], 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) [17], a European initiative intending to create an ontology for describing various aspects related to Semantic Web Services 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[8], SEKT[9], Knowledge Web[10], ASG[11], INFRAWEBS[12] and LUISA[13] by consortia including in total more than 70 academic and industrial partners.

In Research Framework Programme 7 the European Commission also provides substantial funding for research into "Service and Software Architectures, Infrastructures and Engineering". This Objective integrates research activities in the areas of services, software, grid and virtualisation technologies. Under its First Call EU is now funding 28 new research projects in this area among which Soa4All[14], ADMIRE[15], ROMULUS[16], SHARE[17] and SLA@SOI[18] address the issue of developing new Service-oriented Architectures.

The research on Semantic Web Services in Bulgaria is mainly conducted in the frame of EC research programmes. Except in the Institute of Information Technologies – BAS, the research and development in this direction is manly done by software development companies. For example, semantic technologies are the main R&D direction of Ontotext Lab. – a Bulgarian SME, which is the leading software company in such area not only in Bulgaria, but in Europe as well. Ontotext Lab.[19] takes part in European research projects with total budget of more that 100 million EURO. SWS technology is the subject of such projects as SWWS, DIP and

[7] http://www.daml.org/services/owl-s/
[8] http://dip.semanticweb.org/
[9] http://sekt.semanticweb.org/
[10] http://knowledgeweb.semanticweb.org/
[11] http://asg-platform.org/
[12] http://www.infrawebs.eu
[13] http://www.luisa-project.eu
[14] http://www.soa4all.org/
[15] http://admire1.epcc.ed.ac.uk/
[16] http://www.ict-romulus.eu/home
[17] http://www.shape-project.eu/
[18] http://www.sla-at-soi.eu/
[19] http://www.sirma.bg/

INFRAWEBS. The main roles of the Ontotext Lab. in these projects are developing Semantic Repositories and SWS Development Tools.

Another Bulgarian SME iSoft is responsible for testing and validation of Semantic Services that will be developed in the frame of ongoing IST FP-6 Research Project STASIS: The Road to Semantic Interoperability[20]. The project aims at research, development and validation of open, distributed Semantic Web Services for SME empowerment within the automotive, furniture and other sectors. The STASIS project will be completed on 2009.

Another Bulgarian SME – Davidov Ltd, is currently participating as a content provider and end-user in the ongoing IST FP-6 Project OPUCE (Open Platform for User-centric service Creation and Execution)21, which main goal is to design, implement and deliver a global software infrastructure for business enabled collaborative and dynamic loosely coupled services. The project has been completed in the August 2008.

The strengthening the capacity in research on Service Oriented Computing in Bulgaria and especially in Sofia University is one of the main objectives of just started FP-7 European project "SISTER: Strengthening the IST Research Capacity of Sofia University".

3. The approach

3.1. The background

As it has been noted [18], at the moment the practical application of SWS technologies is still rather restricted due to several reasons, some of which are:

- The high complexity of both OWL-S and WSMO.
- The lack of standard domain ontologies and unavailability of mature tools supporting WSMO or OWL-S, and
- The absence of pilot applications focusing on every-day needs of consumers, citizens, industry, etc., which can demonstrate the benefits of using semantics.

The IST FP-6 research project INFRAWEBS that was successfully completed in the beginning of 2007 and in which Institute of Information Technologies – BAS, was a leading R&D partner, proposed a technology-oriented step for overcoming some of the above-mentioned problems. 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;

[20] http://stasis-project.net
[21] http://www.opuce.tid.es

- Clarifying different phases of the Semantic Service Engineering process, and
- Developing a specialised software toolset oriented to the identified user types and intended for usage in all phases of the SWS Engineering process.

The INFRAWEBS has been recognized 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 [1].

As a SOA-oriented framework the contribution of the INFRAWEBS Project is mainly positioned in the Service Integration Layer of the NESSI Framework [15], however it can be also positioned in its Semantic Layer since the project results improve the state of the art on semantic tools. From the point of view of Service-Oriented Computing Roadmap [16], the INFRAWEBS contribution lies both in the Foundation and Composition planes as it provides innovative solutions for description, publishing, discovery and dynamic composition of semantic WSMO-based Web services.

The ongoing IST FP-6 project LOGOS[22] aims at design and implementation of a platform for e-Learning on demand in different domains and diverse delivery channels (Internet, digital TV, mobile devices). Main subsystem of this platform is the Authoring studio for creation of learning materials from existing digital repositories [4]. Its multilevel architecture is based on hierarchical data models, international metadata standards (METS, MPEG7, LOM) and domain ontologies. It permits the use of multimedia materials as building blocks of e-Learning courseware, considering their content and context characteristics and backed up by modern pedagogical theories. The delivery subsystem of the platform is aimed at coordinated delivery of learning materials through different communication channels. After successful evaluation of the LOGOS results from the first two years now the project is in its last phase of extensive experimentation and valorization in several countries, using the feedback for improving and enhancing its solutions.

Based on the lessons learnt from the both projects we propose an approach for development of a Semantic SOA Framework for creating e-Learning applications addressing not a broad audience of potential users, including professional e-Learning providers, but mainly mass authors of learning materials without specific knowledge and skills concerning information models and basics of ontology engineering and hence aiming to develop more mass-user-centred and user-friendly approach and tools to facilitate learning content creation. Such a Framework will contain innovative user-friendly ontologically-based tools for creating, indexing and storing learning ontologies, e-Learning Semantic Web Services and learning goals as well as specialised middleware for dynamic composition of such services. The Framework will significantly facilitate integration of SWS infrastructure with end-user applications and digital object repositories.

[22] http://www.logosproject.com

3.2. The Framework architecture

The conceptual architecture of the envisaged Framework consists of two main elements – Design-time Environment and Run-time Environment (Fig. 1).

The Design-time Environment proposes:

- ***Information structures*** for storing and retrieving semantic and non-semantic data:
  - *Semantic Web Service Repository* enables efficient storage and retrieval of all elements of the Semantic Web (WSMO objects): goals, ontologies and Semantic Web Services.
  - *Learning Metadata Repository* – contains annotated metadata about Learning Objects, used for grounding of Semantic Web services.
  - *Information Indexer and Retriever* - contains a special representation of both Semantic (WSMO) objects and Learning objects stored in the corresponding information structures that will allow effective similarity-based retrieval of such objects based on their content.
- ***Tools*** for creation and maintenance of resources, metadata and supporting ontologies*:*
  - *Semantic Web Service Creator* aims at designing WSMO-based Semantic Web Services by reusing already existing semantic and non-semantic descriptions stored in the Semantic and Learning Metadata Repositories.
  - *Ontology Creator* aims at creating ontologies in a user-friendly manner.
  - *Semantic Goal Creator* provides means for creation of WSMO-based reusable goals used for designing of SWS-based eLearning applications and end-user goals.
  - *Learning Content Description Tool* aims at creating metadata annotation of multimedia and learning objects according to certain eLearning standards and some formal ontologies.
- ***Methods*** used for creating and maintaining Semantic and Learning objects:
  - Combination of eLearning-specific and logic-based methods for object discovery
  - e-Learning-specific decision-support methods for dynamic service composition
  - Several methods for calculating similarity and object retrieval – structural, linguistic, statistical, fuzzy, etc.

The Framework *Run-time Environment* is responsible for discovery, dynamic composition, execution and monitoring of SWS. The *Run-time Environment* consists of the SWS Discoverer, SWS Composer and SWS Executor components.

The proposed Conceptual Architecture is an adaptation of the INFRAWEBS Semantic SOA-based architecture [1] towards e-Learning applications and presents a novel approach for creating and maintaining Semantic Web services and SWS applications. It is based on tight integration of similarity-based and logic-based reasoning. Similarity-based reasoning is used for fast finding of approximate solutions, which are further concretized by the logic-based reasoning.

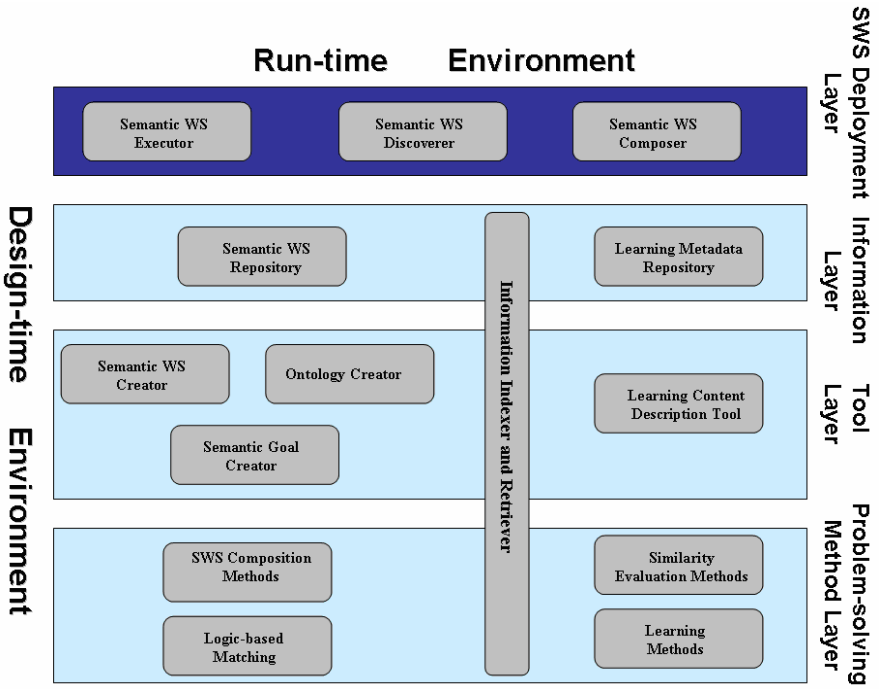

Fig. 1. Conceptual architecture of the Project Framework

The Framework implements a layered approach for creation e-Learning applications (Fig. 2).

It is assumed that operation on different layers may be accomplished by different types of *users* of the Framework (Learning content and data Providers, Semantic SWS Providers and SWS Learning application Providers):

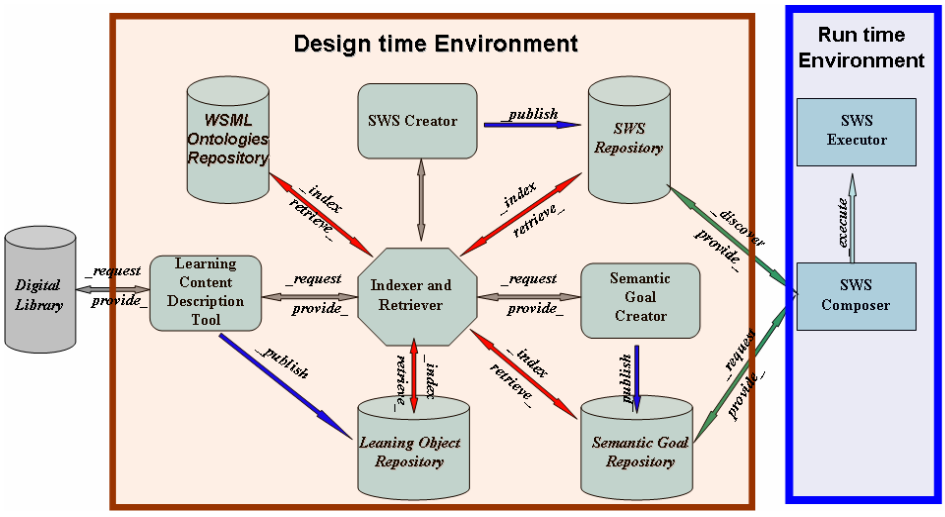

Fig. 2. The framework process model

1. The first layer is devoted to creation of learning objects:

- At the beginning multimedia objects (eventually with some basic content annotations) are retrieved from a Digital Object Repository (Digital Library) implemented as a Web service.
- The Learning Content Description Tool then creates Learning Objects by supplying missing administrative and technical meta-data, adding semantic descriptions of multimedia content according WSMO-based domain ontologies as well as some metadata for possible learning usages of the already annotated multimedia objects according IEEE LOM standard [10].
- The object publishing process is passed through the process of indexing object description done by the Information Indexer and Retriever component of the Framework implemented as Web service.
- The process of creating Learning Objects is facilitated by ability to reuse the existing metadata descriptions of similar objects stored in the Learning Object 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.

2. The second layer is devoted to converting the Learning Objects into Semantic Web Services:

- Some metadata description of Learning Objects stored in the LO Repository are further used for creating SWS described according to WSMO Methodological Framework. Such services are designed by the SWS Creator tools actively exploring already prepared service ontologies (by means of Ontology Creator tool).
- As in the case of creating the Learning Objects, the process of creating SWS description is significantly facilitated by cooperation with the Information Indexer and Retriever component of the Framework, which allows affective reuse of already created Semantic Services stored in the SWS Repository.
- The newly created Semantic Web Services are published in the SWS Repository, which makes them available for discovery and composition by means of Run-time Environment of the Framework.

3. The third layer is devoted for dynamic composition and delivery of Semantic Services:

- At design-time some learning goals (represented as WSMO goals) describing possible goals of the end-user of a SWS Leaning application are created by Semantic Goal Creator tool, which intensively uses some formally represented 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 will be discovered. The resulted dynamically composed complex process may be stored again in the SWS Repository as a new complex Semantic Service or be executed by the Framework Run-time Environment.

4. Conclusions

In this paper we have proposed an approach for developing a new Semantic SOA-based Framework oriented to e-Learning applications facilitating reusability and repurposing of learning objects. The approach is based on analyzing and exploiting the advantages of SWS technology, which proposes new possibilities 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 ongoing FP-6 European project LUISA. The approach is based on reusing and adapting the SWS Framework previously developed in the frame of another IST FP-6 European research integrated 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 *new domain-specific Semantic SOA-based architectures,* 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 [1].

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

1. *Developing new application-oriented methods and end-user oriented tools for description of Semantic Web Services 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. We consider to conduct our research on these topics in the direction of refining and advancing the original graphical and ontology-based approach developed in the frame of INFRAWEBS project [2].

2. *Developing new methods for dynamic composition of Semantic Web Services suited for eLearning.*

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 Semantic Web Services* will be oriented to further development of an original data-driven SWS composition approach [3], which was recognized as "the only fully automated Functional Level-based Composition planner for WSMO yet [12, p. 20].

3. *Developing new methods and tools for creation and semantic annotation of learning objects compatible with SWS methodology.*

The investigation will be aimed at design of activity scheme and information models for dynamic creation and adaptation of learning objects (multimedia objects, annotated with content- and context-oriented metadata), facilitating their reusability and addressing active authoring as learning activity (supporting advanced learners

in their work to find, collect, integrate and create digital objects with learning purposes). The research will address the limitations of standard LO metadata through the usage of ontologies to represent the knowledge encoded in the metadata in machine readable forms.

We are also going to investigate also schemes for metadata organization allowing pre- and post-usage annotation of digital materials for gathering of accumulated experience for re-use of the objects in repositories. The information models and methods for learning content organization will be based on pragmatic restrictions and modifications of the project LOGOS information models [13] to be oriented to mass authors of learning materials without need of specific knowledge and skills concerning information models and basics of ontology engineering. This will permit implementation of user-centred learning content description tool for creating and editing descriptive, content- and context-oriented metadata and the corresponding LO repository. The learning content description tool will consider end-user profiles to be adaptable to different user groups' characteristics. When appropriate the implementations will be built on top of modifications and extensions of some solutions in the LOGOS Authoring studio.

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