Interoperability of Adaptive Learning Components

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Contents

1 Introduction

Personalized adaptive learning requires (IST, 2004) development of semantic-based and context-aware systems to acquire, organise, personalise, share and use the knowledge embedded in web and multimedia content, and achievement of semantic interoperability between heterogeneous information resources and services. This includes the possibility of systems to connect to other systems in a flexible and easy way as well as to bridge the semantical differences. To minimize the costs and effort we are not so much interested in the possibility of interfacing that requires human effort. Semantic interoperability can be achieved when models are more or less meant for each other and there are just some semantic differences to detect and solve. We define model as a formal and explicit representation that can be used to precisely describe a part of the design, e.g. the content or the user's knowledge state. Sometimes these models also have a graphical representation which could facilitate easy communication between designers and stakeholders, but that is not necessary.

Our task “Design and development of solutions for professional personalized adaptive learning” includes description of interoperability for various adaptive learning components. The semantic differences can be bridged either by standards or using approaches based on Semantic Web. This document deals with the issue how to provide semantic interoperability of educational contents on the web, considering the integration of Semantic Web and adaptive technologies to meet the requirements of corporate learners. The semantic interoperability always boils down to make arrangements to transfer data and then deal with "differences": one basic way to do this is what we describe in the first more general part, but it is good to point out that for specific models there exist standards as we explain in the second part. In a way one can choose to invest time beforehand by developing and choosing standards, or afterwards – that is part of the design. The third part is considering the ways two types of metadata can be accessed. So the structure of this deliverable is as follows: In the Introduction we have clarified the motivation of this document. Section 2 deals with semantic interoperability for user-adaptive systems. Section 3 presents formal models and standards. Section 4 shows how metadata of adaptive learning systems can be accessed.

2 Semantic Interoperability of User-Adaptive Systems

The increasing demand for personalization in (e-learning) applications leads to a process of user profiling which is inherently distributed. For applications to effectively share and exchange user information for adaptation, they need to know the semantics of this user information, and therefore resolve the issues related to semantic interoperability. In this part we consider the state of the art in semantic interoperability in relation to distributed user profile in terms of methods, techniques, tools, and issues related to semantic interoperability.

2.1 Applications, personalization, and user profiles

In the past decade we have witnessed a growing interest in applying adaptation and personalization in numerous application domains. The process of engineering of information systems has shown a considerable change and adaptation is a significant driver for this change. Concept-based systems represent *content* using *concept structures*, in the sense that a model of the content (often referred to as domain model or content model) is a characteristic element of the design. This model includes, as relevant aspects, the *user's knowledge* (user model) or the *adaptation knowledge* (adaptation model). These systems are distinguished from systems in which the adaptation is defined without an explicit model of the content (e.g. because the content and structure are rather straightforward or small). Adaptive concept-based systems are becoming especially accepted in application areas where the main goal is to tailor large amounts of information to the individual preferences and knowledge state of the different users. In the case of educational applications, it has become more or less standard that the system expresses a behavior that matches the specific user (as, by the way, was long the case for the real classroom where the teacher would approach each student differently). The construction of concept-based systems is not a straightforward issue, certainly when the challenge is combined with the desire to add adaptation, e.g. adaptive hypermedia systems, adaptive Web information systems, and adaptive task-based systems. When we talk about adaptation and personalization, the user plays a fundamental role in the system and therefore in its design. The system might want to record the user's preferences, but also its assumption on the user's (knowledge) state. The systems typically maintain a model of the individual user as an overlay of the domain model in order to record the current state of the user with respect to his/her knowledge of domain concepts. The application dependent user models with the preferences and the state of the user are integrated in the user profile that in general comprises the available information about a user, and is used as a basis for adaptation of the content presentation to the user.

2.2 Distributed user profiles and semantic interoperability

The nature of cooperation between systems and applications implies that there is a distributed process of sharing and exchanging user profiles. In order to be able to effectively manage the distributed user profiles, and control this process of on the one hand providing profile information for personalization and on the other hand consuming user models for personalization or adaptation, architecture for distributed profile exchange and management is necessary. The issue of semantic interoperability in the context of user profiling is a direct consequence of the distribution in user profile information. The decentralized process of distributed user profile information management demands a control that is essential for a successful application of user profiles.

2.3 User profile data context

For long it has been very difficult or even impossible to share and exchange user profile data. More recently, suppliers and consumers of user profiles have become more aware of the need for standards for the representation and exchange of user profile data, and especially the e-learning domain is making enormous progress. At the same time we observe that the amount and diversity of profile-based applications makes it practically impossible to easily create a unified "user profile infrastructure". One important aspect that should not be underestimated is that the metadata for user profile data implies a lot of manual labor before the metadata can effectively be exploited in the exchange of profile data between applications. The technological advances of the last few years, especially around the Web and the Semantic Web, can come to the rescue with a demand for tools and methods

- to combine the available data,
- to annotate profile information automatically or semi-automatically,
- to supply applications with the necessary profile metadata.

The (semi-)automatic generation of metadata is an essential prerequisite for the semantic interoperability of profile-based applications such as e-learning applications. The creation of such metadata usually requires a considerable intellectual input of humans. Current Web technology may offer opportunities for semantic interoperability between applications and their metadata on a large scale, which could not be achieved by human input alone. When we investigate how the automatic creation of semantic metadata can be achieved, we observe that ontologies (see below) provide an option for semantic coherence between profile data items. Tools could then minimize the amount of user effort required for creating and maintaining semantic annotations and could thus help to increase the overall quality level of annotations.

2.4 Architecture and design

To manage distributed user profiles, an architecture for distributed profile exchange and interpretation is needed. Different types of systems use different kinds of architectural solutions. There are differences in the way in which user profiles are used, and this has consequences for the personalization. As basic architecture types, here we mention:

- adaptive Web-based systems
- adaptive hypermedia systems
- adaptive task-based systems

All these architectures share the facility to maintain a representation of assumptions about one or more types of user characteristics in models of individual users. In other words the system should maintain a model about the user that for instance contains assumptions about their knowledge, misconceptions, goals, plans, preferences, tasks, or abilities. We list a number of issues related to this user representation that need to be considered in a complex approach:

- user environment (e.g. class, school, family, background)
- roles and stereotypes
- historic and sensor information
- trust and acceptance
- generality and domain independence
- expressiveness
- inferential capabilities
- import and export
- privacy

- mobility

Obviously there are also different ways to communicate user profile data, e.g. via a centralized server, via peer-to-peer communication, using agent-based techniques, or using a constraint-based approach.

2.5 Representation formats and languages

For such a distributed user profile architecture, data models and languages for profile metadata are needed, especially to describe the semantics and semantic differences. The languages and technologies designed for the development of the Semantic Web provide useful instruments for the representation of semantics of profile data. We mention the concept of *ontology* as “an explicit specification of a conceptualization”. This basically means that an ontology is a formal way of describing (some aspects of) the real world. With this key concept, the Semantic Web research has given us languages that are useful for the basic interoperability of user profile data. The Semantic Web provides a framework for expressing and using ontologies through the use of RDF, RDF Schema and OWL. These languages come also with relevant tool support, such as APIs, e.g. Jena and Sesame, browsers and editors, e.g. Protege and KAON, and reasoners.

2.6 Interoperability issues

Representing the semantics of the user profile data is one step in the process, but with the distribution come several interoperability problems and issues related to the semantics metadata. As examples, we have incompatibility (both between profiles and between profiles and applications), incompleteness in the sense of information missing from profiles, and contradiction in (unified) profiles.

The need to consider these issues arises from the fact that a learner may attempt to use an application that requires more information than the user’s profile can provide, or that responds with information that cannot be accommodated in the user’s profile. The complementary case arises when an application cannot handle parameters such as preferences, specified by the learner or provides a response that contains too little information to enable the user to choose between alternate follow-up actions. Another class of problems arises when the learner’s profile contains sufficient information but the application possesses information of its own that disagrees with the information present in the learner’s profile, because of conflicting values or semantics.

When two e-learning applications are directly interacting to provide a learner with a certain service, but without the direct involvement of the user, they may face the situation that they may have a partly overlapping but not complete view of the user profile. The question now becomes how to resolve the overlap and fill in the gap. When applications are allowed to fill in missing data themselves, it could occur that two applications fill in contradictory data. Can and should something like this be prevented from happening? And if not, how can the contradictory data be corrected afterwards, or how can possibly conflicting data that co-exists simultaneously be dealt with?

Other sources of contradictory information are different versions of the same information (freshness). The issue here is whether to trust the most recent version (newer is better in the age of cut and paste?) or to establish a procedure to validate information. When information statements inside one source (document) are contradictory one speaks of an inconsistency. When information statements from different sources are contradictory, one speaks of disagreement. A disagreement may turn up when two sources are merged (in reality in a warehouse project or virtually as above). These two situations require different handling. In the context of interoperability, one may assume as a starting point that the sources are consistent. The proper treatment of disagreement is the more relevant problem to tackle.

These examples illustrate the situations that have to be prepared for and dealt with. The information related issue can be discussed from several angles: at the level of schemas or ontologies, or at the level of instances, within an information source, or between information sources. The issue is how to identify and deal with missing or incomplete information.

When it comes to the techniques and architectures to be considered for solutions to interoperability, we can benefit from results from classical databases, data warehouses, mobile information systems, and the Semantic Web. Several issues are relevant in this context and will need solutions – here is just a brief outline:

- imprecise information
- imprecise manipulation
- uncertain information
- schema and ontology mapping
- data cleaning
- inconsistency
- mediation

- data dissemination
- data replication
- conflict detection and reconciliation

3 Formal Models and Standards

The knowledge driving the adaptation process can be represented in adaptive hypermedia systems as five complementary models (Figure 1) – the domain model specifies *what* is to be adapted, the user and context models tell *according to what* parameters it should be adapted, and the activity (instruction) and adaptation models express *how* the adaptation should be performed. We use this model to identify the different design aspects in which the separation between applications asks for interoperability. Note that individual models may be distributed in reality. In the following paragraphs we discuss formal models and standards that apply to each of the particular models. As we can see the existing standards do not really support interoperability as a common abstract model is missing. They can be used in isolation, but this is not desirable.

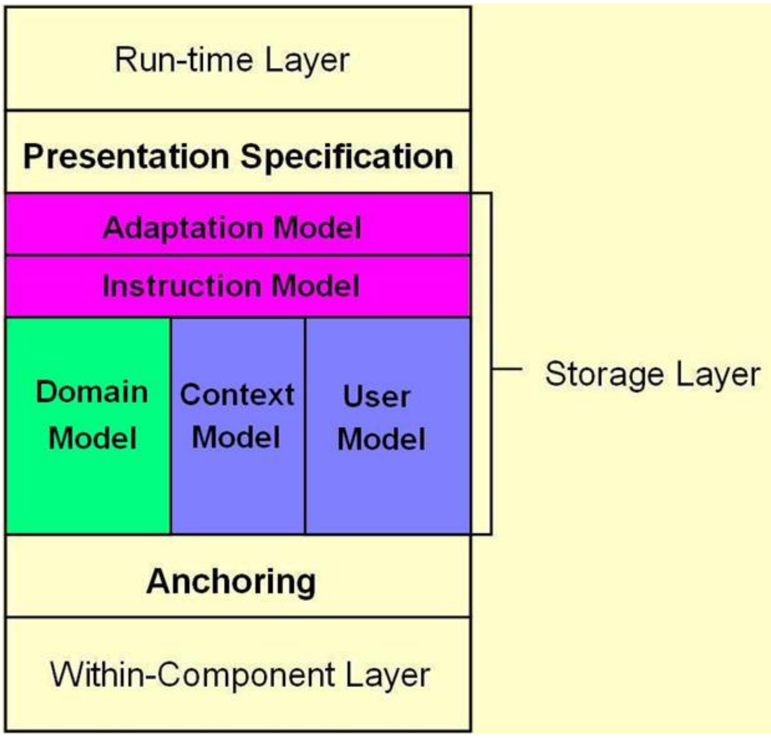

Figure 1: Enhanced Adaptive Hypermedia Application Model

3.1 Domain model

The domain model specifies the *conceptual design* of an adaptive hypermedia application, i.e. *what* will be adapted. The information structure of a domain model in a typical adaptive hypermedia system can be considered as two interconnected networks of objects (Brusilovsky, 2003):

- Knowledge Space – a network of concepts
- Hyperspace – a network of hyperdocuments

Accordingly, the design of an adaptive hypermedia system involves three key sub-steps:

- Structuring the knowledge
- Structuring the hyperspace
- Connecting the knowledge space and the hyperspace

3.1.1 Knowledge Space

Modern AHSs model the domain as a semantic network (Brusilovsky, 2003). They use *network models* with several kinds of links that represent different kinds of relationships between concepts. The most popular kind of links in educational AHS is prerequisite links between concepts which represent the fact that one of the related concepts has to be learned before another. Other kinds of links that are popular in many systems are classic semantic links “is-a” and “part-of”. These domain ontologies represent the expert's knowledge about the domain. The domain model offers a natural framework for goal modeling. An individual educational goal can be modelled as a structure (e.g. sequence, tree, stack) of subsets of domain concepts.

3.1.2 Hyperspace

The *Learning Object Metadata* (LOM) standard defines a learning object as any entity, digital or non-digital, that may be used for learning, education or training (LOM, 2002). Content models identify different kinds of learning objects and their components. A comparative analysis of six known content models (Verbert & Duval, 2004) led to the creation of a general model that includes the existing standards and distinguishes between:

- *Content fragments* – learning content elements in their most basic form (text, audio, video), representing individual resources uncombined with any other; instances
- *Content objects* – sets of content fragments; abstract types
- *Learning objects* – they aggregate instantiated content objects and add a learning objective

The standards that can be used at this level include

- *IMS Content Packaging* – description and packaging of learning material
- *IMS Question and Test Interoperability* – XML language for describing questions and tests
- *IEEE Learning Object Matadata* – description of learning resources

3.1.3 Connecting Knowledge Space with Hyperspace

According to (Brusilovsky, 2003) the process of connecting domain knowledge with educational material is also known as indexing because specifying a set of underlying concepts foe every page of educational material is very similar to indexing a page of content with a set of keywords. There are four important aspects to distinguish indexing approaches:

- Cardinality – single concept indexing (each fragment is related to one concept) and multi-concept indexing (each fragment can be related to many concepts)
- Expressive power – the amount of information that can be associated with a link between a concept and a page
- Granularity – concerns the precision of indexing (e.g. the whole page, fragments)
- Navigation – whether the link between a concept and a page exists only on a conceptual level or also defines a navigational path

3.2 User model

The majority of educational AHS use *overlay model* of user knowledge (Brusilovsky, 2003). The key principle of the overlay model is that for each domain model concept, individual user knowledge model stores some data that is an estimation of the user knowledge level on this concept. A weighted overlay model of user knowledge can be represented as a set of pairs "concept-value", one pair for each domain concept. Some systems store multiple evidences about user level of knowledge separately. Another alternative to model the user knowledge is provided by *historic model* that keeps some information about user visits to individual pages. Some AHS use this model as a secondary source of adaptation.

The learner's goals can be modelled as a set of concepts (competencies) that can be represented similarly to the overlay model. Additionally to these dynamic dimensions the leaner model includes also a more static one – *user preferences.* The most relevant ones are preferred cognitive and learning styles, as well as the language. The main challenges and requirements in this field include generic user modeling, enabling reusability and sharing of the model by various applications, as well as group modeling.

The following standards relate to user modeling:

- IEEE Public And Private Information – specifies both the syntax and semantics of a 'Learner Model,' which will characterize a learner and his or her knowledge/abilities
- IMS Learner Information Package – learner information data exchange between systems that support the Internet learning environment

3.3 Context model

The user (learner) and context model specify *to what parameters* the application should adapt. One of the primary objectives is to generate as much metadata as possible automatically, based on the current context and possibly by sensors (additionally to the time parameter also other suitable attributes, e.g. GPS coordinates, temperature, etc). This will enable more precise retrieval of the data when learning objects are processed or elaborated by students and teachers.

Context management has to deal with such issues as automatic acquisition of context metadata, contextualized delivery of content, contextualized delivery of activities (interaction of users), and contextualized delivery of services. The current standards and exchange formats for contextualisation of resources have to be extended. Designing context-based activities involving groups of users interacting within a set of collaborative environments should be enabled. There are no standards related to the context model yet.

3.4 Instruction model

The instruction (pedagogical) and adaptation models specify the navigational design for an adaptive hypermedia application. Together with the presentation specification they tell *how* the adaptation should be preformed, so they describe the dynamics of the system.

Learning design is a way of modeling learning activities and scenarios, as different types of learners prefer different learning approaches – learning styles. A key axiom that is common to all major educational approaches says that *Learners perform Activities in an Environment with Resources* (Koper, 2001). The IMS Learning Design uses the metaphor of a theatrical play to describe the workflow involved in learning and teaching scenarios. Main challenges include encoding dynamic interactions between users and system, representing scenarios (objectives, tasks/activities) and describing interactions between participating roles and system services, as well as separation of scenarios from resources (reusability).

Related standards:

- IMS Simple Sequencing – representing the intended behaviour of an authored learning experience
- IMS Learning Design – defining diverse learning approaches (scenarios)

3.5 Adaptation model

This model specifies the adaptation semantics – which objects are seen, mastered, recommended, etc. Adaptation specifications define the status of individual objects (e.g. content objects or fragments) based on their attributes and the current parameters of the user model, or more generally of the context model. The adaptation effect is usually achieved by adapting contents and links using suitable adaptation techniques that can be chosen on this level. The taxonomy of adaptive hypermedia technologies (Brusilovsky, 2001) includes:

- Adaptive presentation (content level adaptation) to ensure for different classes of users that the (most) relevant information is shown and the user can understand it:
    - Adaptive text presentation
    - Adaptive multimedia presentation
    - Adaptation of modality
- Adaptive navigation support (link level adaptation) to guide the user towards the relevant, interesting information:
    - Direct guidance
    - Adaptive link sorting
    - Adaptive link hiding
    - Adaptive link annotation
    - Adaptive link generation
    - Map adaptation

4 Accessing Metadata of Adaptive Learning Systems

Besides the semantic interoperability, the systems must understand access mechanisms to learning content objects, learners and associated metadata. They must know programming interfaces to connect to, retrieve and manipulate needed metadata. The *Application Program Interfaces* (API) are either *domain specific*, i.e. they are based on specific metadata models or are *generic*, usually suitable to query metadata based on multiple schemas by making use of general purpose query languages like SQL.

4.1 Querying Learning Repositories

Interoperability among learning repositories requires a common communication framework for querying. In the next sections we present an overview of different query APIs in the learning domain (Simon et al., 2005) and Simple Query Interface (SQI, 2005) – an API for querying learning objects repositories. The overall objective of these activities is to build up a global network of learning object repositories.

4.1.1 Query APIs in Learning Domain

OpenURL (OpenURL, 2004) as well as the Content Object Repository Discovery and Resolution Architecture – *CORDRA* (CORDRA, 2004) are initiatives that investigate the "Identifying" problem. The work on SQI is "orthogonal" to this, in that queries and results can refer to identifiers of arbitrary nature.

Z39.50-International: Next Generation (*ZING*) covers a number of initiatives by Z39.50 implementers to make Z39.50 (ZING, 2001) more broadly available and to make Z39.50 more attractive to information providers, developers, vendors, and users. *SRW* is the Search/Retrieve Web Service protocol, which is developed within ZING and aims to integrate access to various networked resources, and to promote interoperability between distributed databases, by providing a common utilization framework. SRW is a web-service-based protocol (SRW, 2004). SRW takes advantage of CQL ("Common Query Language"), a powerful query language, which is a human-readable query.

SRW has many similarities with SQI, but also some differences. SRW is purely synchronous (source-initiated), i.e. query results are returned with the response. Additional query results can be retrieved later from the results set stored at the target for a pre-defined amount of time. SRU, the Search and Retrieve URL Service, is a companion service to SRW, the Search and Retrieve Web Service. Its primary difference is its access mechanism: SRU is a simple HTTP GET form of the service (SRU, 2005). SRW encourages the use of Dublin Core, but is in general schema neutral (like SQI). SRW packs all the functionalities in a few methods and does not adhere to the "Command-Query separation principle". SRW does not provide hooks for authentication and access control nor is it based on a session management concept. It defines an Explain operation, allowing a client to easily discover the capabilities and facilities available at a particular server. SRW uses a rich set of XML-encoded application level diagnostics for reporting errors. SQI uses faults.

The purpose of the IMS Digital Repository Interoperability (*DRI*) Specification (IMS, 2003) is to provide recommendations for the interoperation of the most common repository functions. The DRI specification presents five core commands, i.e. search/expose, gather/expose, alert/expose, submit/store, and request/deliver, on a highly abstract level. The specification leaves many design choices for implementers. For example, while recommending Z39.50 (with its own query language) it also recommends XQuery as a query language. The query service does distinguish between asynchronous and synchronous query mode.

The *EduSource* project (Hatala et al., 2004) aims to implement a holistic approach to building a network for learning repositories. As part of its communication protocol – referred to as the EduSource Communication Language (ECL) – the IMS Digital Repository Specification was bound and implemented. A gateway for connecting between EduSource and the NSDL initiative, as well as a federated search connecting EduSource, EdNA and Smete serve as a first showcase.

OKI (Open Knowledge Initiative) is a development project for a flexible and open system to support on-line training on Internet (OKI, 2004). OKI has issued specifications for a system architecture adapted to learning management functions. One of the main characteristics of the project is its commitment to the open source approach for software component development. OKI supplies specifications for a model of functional architecture and an API called Open Service Interface Definition (*OSID*). OKI OSID main aspects are:

- To supply specifications for a flexible and open source model of functional architecture
- Service Interface Definitions (SIDs) organize a hierarchy of packages, classes and agents and propose Java versions of these SIDs for use in Java-based systems and also as models for other object-oriented and service-based implementations.
- Components developed by OKI are compliant with specifications issued by IMS and ADL SCORM.

The Resource Description Framework (*RDF*) is one of the key pillars of the Semantic Web (RDF, 2005). RDF is an extensible way to represent information about (learning) resources. One of RDF's design assumptions is that resources are identified by a Unique Resource Identifier (URI) allowing various users and agents to make assertions about uniquely identified things. RDF is designed for representing metadata about all kinds of digital and non-digital artifacts making it a powerful means of integration over disparate sources of information. The graph-based structures of RDF can be serialized in XML. XHTML 2.0 is currently under development, which will support a seamless integration of RDF-based meta-tagging in HTML.

The W3C has designed *SPARQL* (SPARQL, 2005) as a query language for RDF. SPARQL is designed to meet the following requirements:

- Conjunction
- Disjunction
- Optional Match
- Extensible Value Testing
- Limited Datatype Support

The development was aligned towards the following design goals:

- Human-friendly Syntax

- Data Integration and Aggregation
- Non-existent Triples
- Addressable Query Results
- Sorting Results

Edutella is an RDF-based Peer-to-Peer infrastructure for querying distributed learning object repositories, that comes with its own query language *QEL* (QEL, 2004), which is similar in functionality to SPARQL.

4.1.3 Simple Query Interface (SQI)

SQI (Aguirre et al., 2005) is an API (developed as part of PROLEARN, see Deliverable 4.1 focusing on SQI for details) that provides method support for asynchronous and synchronous queries. The underlying common schema is specifically designed to the needs of an educational network of training measures while reusing standardized concepts from IEEE LOM and Dublin Core at the same time. One of its major design objectives was to keep the specification simple and easy to implement. The collaborative effort of combining highly heterogeneous repositories has led to the following requirements:

- SQI is neutral in terms of results format and query languages: The repositories connecting via SQI can be of highly heterogeneous nature: therefore, SQI makes no assumptions about the query language or results format.
- SQI supports Synchronous and Asynchronous Queries in order to allow application of the SQI specification in heterogeneous use cases.
- SQI supports, both, a stateful and a stateless implementation.
- SQI is based on a session management concept in order to separate authentication issues from query management.

The design of the API itself is based on following design principles:

- Command-Query Separation Principle,
- Simple Command Set and Extensibility.

The SQI is part of a Learning Object Repository Interoperability (LORI) Framework. LORI is a layered integration architecture, which defines services to achieve interoperability among learning repositories. These services include core services, for example authentication service, session management service and application services like query management or provision services. There are already some applications of SQI in adaptive learning as we mention in the following.

Human Capital Development (HCD) Suite (http://www.hcm-online.com/ubp) is an application especially designed to support goal-driven human capital development processes. It provides a service for identifying and satisfying knowledge gaps and matches them with offers from different service providers according to the needs of the company and the individual learner. It uses a ranking component to rank search results from elena smart spaces for learning. The component assumes that the resources in the smart space are annotated and classified by a skill ontology to be used by a user. An annotator has been developed, facilitating extension of learning resource metadata with specific skill ontology concepts. Annotator is based on metadata analysis and document analysis techniques to get these additional extensions. Ontology concepts are used to index and classify metadata and content (based on term frequency analysis). In both cases, a similarity between concepts on the one hand and metadata or content on the other hand is computed. Highest similarities then determine which resources should be annotated by particular concepts. The extended annotations are used for ranking purposes.

Alocom (http://memling.cs.kuleuven.ac.be/alocom/) is a framework which allows to "split" Open Office presentation files (and Powerpoint files as well) into their building blocks to allow for retrieval of sub-presentation objects and (semi-)automatic generation of presentations. Its specification for the indexing interface closely relates to SQI.

4.2 Querying Learner Profiles

The Lerner API (Dolog & Schäfer, 2005) was developed in the context of FP5 EU/IST project Elena – Creating Smart Spaces for Learning (http://www.elena-project.org). The API is based on learner ontology. Figure 2 depicts an excerpt of a learner profile ontology configured from fragments based on three specifications (the Elena project web site and its personalization section provide complete ontology in RDFS). The abbreviated syntax for namespaces is used in concept and relation labels (e.g. qti stands for Question and Test Interoperability namespace at http://www.elena-project.org/images/other/qtilite.rdfs). The default namespace is http://www.elena-project.org/images/other/learner.rdfs.

The conceptual model describes a situation where a learning performance (IEEE PAPI is used to model performance and portfolio, http://ltsc.ieee.org/archive/harvested-2003-10/working_groups/wg2.zip) of a student is exchanged as his achieved competency records (IMS RDCEO – Reusable Definition of Competency and Educational Objectives, http://www.imsglobal.org). The competencies have been evaluated by learner assessment (e.g. tests) and were derived from learning objectives of tests (IMS QTI). Furthermore, all other educational activities, further materials, and projects created within the activities are reported within the portfolio of the performance. Additional information which is reported under preferences (IMS LIP) comprises language, device, resource and learning style preferences. The standards and open specifications guarantee wider acceptance between e-learning systems and as such can be seen as good candidates for the learner exchange models.

Currently, none of the referenced standards present their metadata in a way that makes it possible to use them in combination as depicted above. Therefore, an RDF translation of these standards had to be developed, which made it possible to use them in combination. This RDF translation is unofficial, and we therefore view it as an important direction for future standardization work that the standards use a common framework such as RDF and the Semantic Web, to enable the added value of using the standards together.

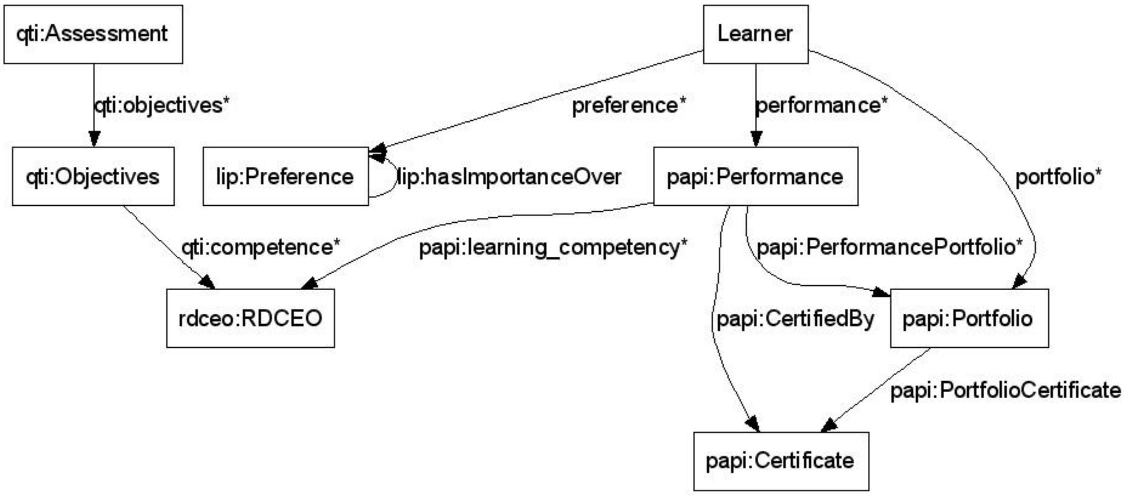

Figure 2: An excerpt of a conceptual model for learner profile based on standards

Figure 3 depicts several possible scenarios of how to access and exchange learner profile fragments. The fragments can be accessed programmatically by the use of a Java API, the web service which exports the learner model through the API and acts as a learner model server, and through a query infrastructure for RDF repositories like Edutella (Nejdl et al. 2002).

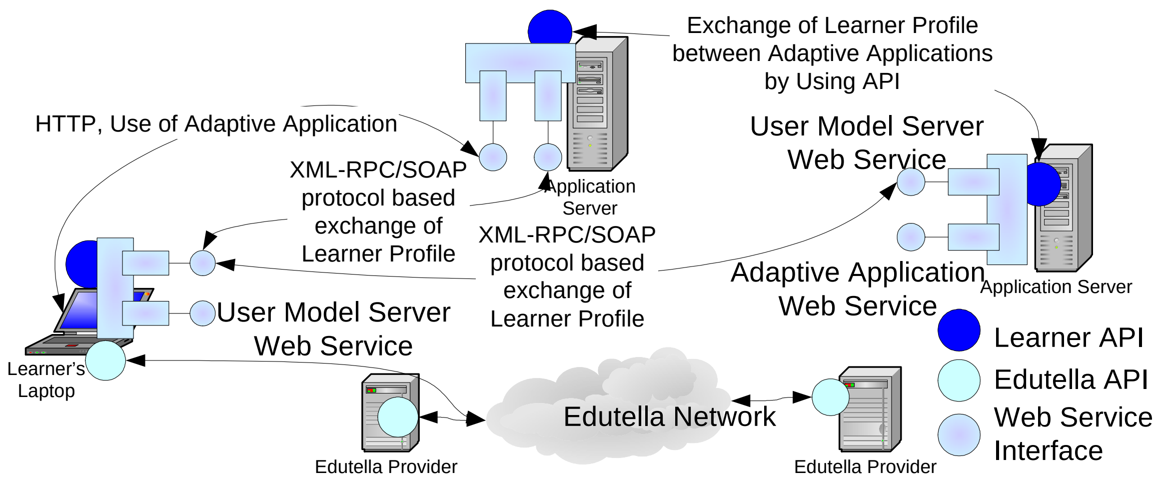

Figure 3: The use of the API in several scenarios

4.2.1 Implementation in Java

A Java API has been developed. It is structured according to the learner ontology fragments mentioned above. The API is meant to be used to retrieve, insert, and update the learner profiles stored in the structures described above. The API defines a class and properties for each class from the RDFS for the learner model. The interface provides access functions for getting, deleting and updating a model of the fragment. It provides further functions to derive additional information or to process more complex manipulations over referenced information types as well. The API is implemented for the RDF representation (instances of the RDFS described above). The API is easily extensible by providing further specializations if additional extensions and interface implementations for local repositories and data models are needed.

4.2.2 Implementation as Web Services

The second implementation is provided through web services where several clients can access one model which is persistent on one server. The server holds the main model, i.e. the data of a learner profile gathered from several sources, and handles all requests from the clients. Each client is uniquely identified at the server and can be used by a browsing or assessment system. Furthermore, a client can be used by other learning systems which want to make use of the learner profiles or which want to contribute to them. The model can be accessed directly by invoking functions of a web service or in a synchronized replicated way; i.e. each client has its own repository which is synchronized with the main server every time a change occurs. The web services framework can be used in a distributed way as well (several servers exchanging learner models between each other).

4.2.3 Retrieval through RDF querying infrastructure

The learner profiles are created in RDF. Therefore, a query infrastructure for RDF data is another access option. Edutella provides a datalog-based language to query RDF data provided in a distributed P2P environment. This option enables to collect various fragments by utilizing for example the algorithm from (Dolog, 2004). Another advantage of the P2P sharing infrastructure used with the learner profiles is that it can facilitate an expert finding based on the provided profile which can be queried by people who need a help in learning.

5 Interoperability of Adaptive Learning

Learning objects distributed in various repositories with associated metadata provide the opportunity of using federated search. Early adopters have started using these services. These users can be either learners using learning objects in a similar way like textbooks, or teachers that need suitable materials to support their classes and possibly applying blended learning approaches.

Reuse, interoperability, and personalization belong to the main aims of IMS LD. To allow personalization a method can contain conditions (Koper & Olivier, 2004), i.e. If-Then-Else rules that further refine the assignment of activities and environment entities for persons and roles. Conditions can be used to personalize LDs for specific users. The ‘If’ part of the condition uses Boolean expressions on the properties that are defined for persons and roles in the LD. Notwithstanding IMS LD can be used to model and annotate adaptive learning design, designing more complex adaptivity behaviour might be not too easy. For instance, it is not possible to annotate learning content or define student roles considering their characteristics. Moreover, it is premature to determine the reusability level of learning designs (Koper, 2005). We agree with the finding – from the area of learning objects – that the more context is assigned to the objects the lower is their reusability (Hodgins, 2005); such finding is valid also for learning activities, i.e. learning design and adaptivity. Therefore it would be beneficial to distinguish well-defined learning layers so that each object of a given layer can be substituted with other objects of the same layer and combined with other objects at a different layer so as to build a complete solution. These solutions can be possibly created by different authors.

In the WINDS project (Kravcik et al., 2004; Kravcik & Specht, 2004) we have experienced that authors without programming skills can produce adaptive courses by specifying declarative knowledge for adaptation by means of metadata like pedagogical roles of learning objects and content fragments. This together with procedural knowledge encoded in the course player can generate adaptive delivery of courses. We have also attempted (Kravcik, 2004) to generalize the WINDS experience with the aim to simplify authoring as well as to achieve more flexibility, reusability and interoperability of partial learning resources. At least on the authoring level we need separation of learning design, adaptation and presentation specifications. Our approach is based on a recognition how personalized learning experience is usually delivered:

1. The learning objective is specified
2. The teacher chooses a learning scenario structuring suitable learning activities
3. The teacher assigns learning objects (with the concrete learning objectives and pedagogical roles) to specific learning activities
4. The delivery of a learning object depends on the characteristics of the particular learner, e.g. the learning style

5. The presentation of the leaning object depends on the current context, e.g. the delivery device

This approach is typical when the teacher works with a fixed group of learners. Of course, providing fully individualized learning the learner's characteristics should be considered already in the step 2 and 3 and the group itself can be formed according to the individual traits of learners. From the technological point of view a major issue is what should be specified at which level to achieve reusability and interoperability of resources. We have already specified the layers in the formal model, so let us discuss now how it influences the authoring process.

1. *Domain layer:* This level includes learning objects, ontologies and metadata. Especially important are the pedagogical metadata, like pedagogical roles. It is also important to consider redundancy of learning object and content fragments if personalized adaptive learning is to be provided. This means for instance that a content fragment with a certain pedagogical role (e.g. definition, example, fact) should be created in alternative media – it can be called *learning fragment*.
2. *Instructional (pedagogical) layer:* Learning design includes definition of learning scenarios that can depend on the individual learner, especially her learning style. This means the author creates a structure of learning activities that will provide the learning experience. Examples of such learning activities are question formulation, self learning, explanation, field trip, investigation, creation of an artefact (e.g. essay, design), artefact annotation, performance (e.g. report, review), artefact evaluation. The teacher can provide references to learning objects for certain learning activities, e.g. for those related to expository or exploratory learning (that can be supported by various searching, navigation and visualization facilities in the user interface).
3. *Adaptation layer:* We can distinguish adaptation strategies and adaptation techniques at this layer. Adaptation strategies specify how to choose relevant learning objects and how to order them, both taking into account the specific learner, especially her learning style. In this process pedagogical roles of learning objects and other relevant pedagogical metadata should be considered. Adaptation techniques define how to select suitable content fragments based on the learner's learning style and the relevant metadata of the content fragments, like the pedagogical roles and media types.
4. *Presentation layer:* On this level authors specify how the learning resources should be presented depending on the specific context, e.g. end user device. This can concern the number of content fragments presented in parallel on a particular device.

6 Conclusion

This deliverable is aiming to map the current situation in the area of interoperability for adaptive learning components. We have focused on semantic interoperability of user-adaptive systems, formal models and standards, as well as access to metadata. We can state that in this field we are far from achieving interoperability, since the different standards are not enough to realize it and therefore a mediation based or Semantic Web based approach is still to be devised to reach something. This puts also the impressive looking list of standards and tools in the field in a realistic perspective.

Interoperability in corporate settings has to include (Forte et al., 1999) also issues like distribution list (which functions can receive which documents) related to various structures in different corporations, the confidentiality level, and document classification schemes. In parallel with this document a deliverable on privacy and data protection in corporate learning has been produced. Further we want to continue with specification of personalized learning solutions at workplace and development of their prototypes interfacing with corporate training systems.

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