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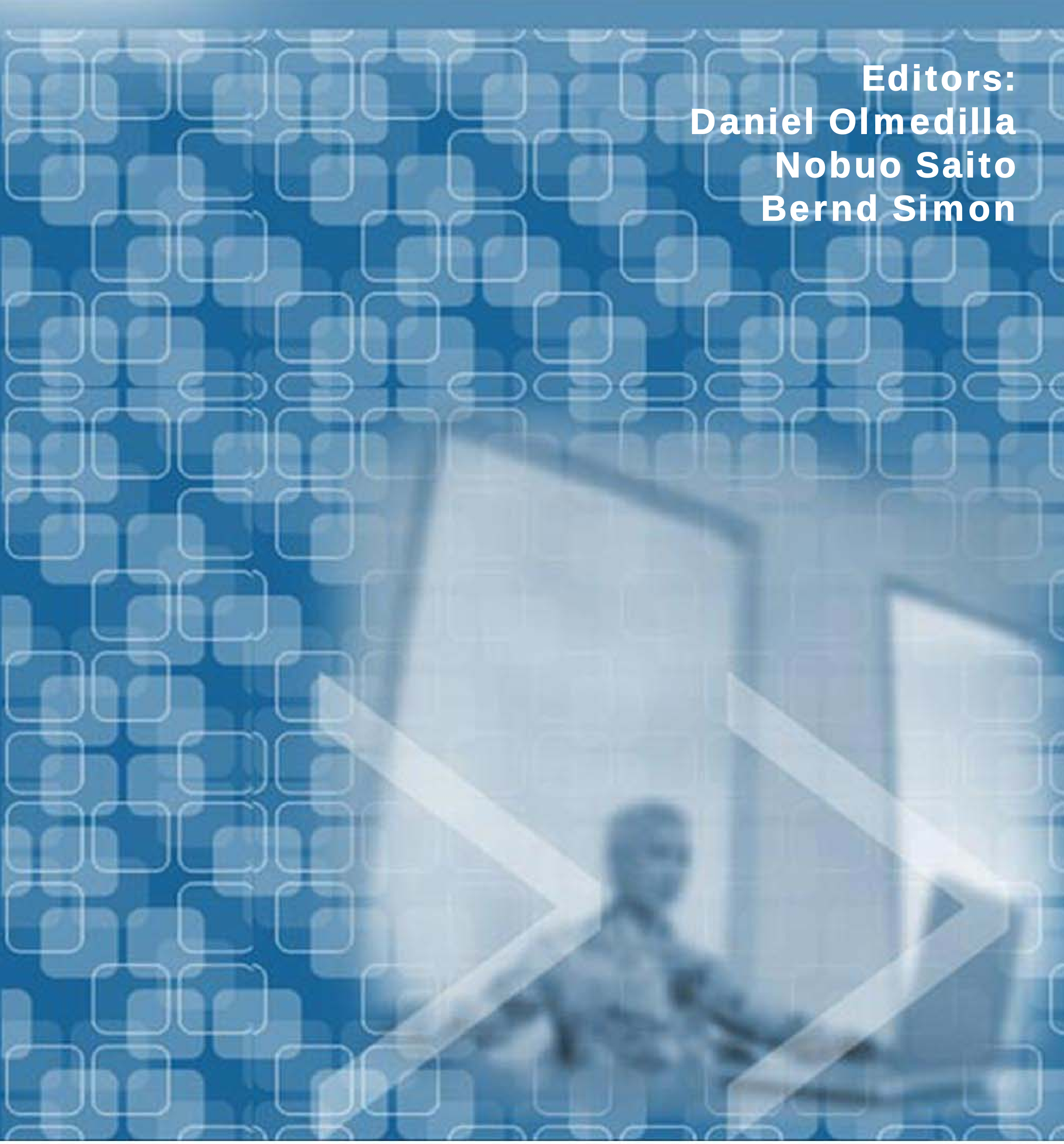

Proceedings of the 1st International Workshop on Interoperability of Web-based Educational Systems

In conjunction with the
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WWW2005, May 10-14, 2005, Chiba, Japan

Preface

Nowadays learning resources are increasingly available via web-based educational systems, such as learning (content) management systems, brokerage platforms for learning materials and courses, or knowledge repositories. With the dawn of various specialised e-learning tools, learning resources became more and more stored in closed environments, restricting accessibility to a closed user community. Due to the lack of interoperability quite often unwanted restrictions on the way knowledge is disseminated have been created. However, even in closed environments the demand for interoperability has reached a new level. Providers of learning management solutions are increasingly asked to interface with other systems, in order to exchange budget restrictions, learning resource descriptions, course bookings or report on newly acquired competency.

While standardization bodies and consortia such as ADL, CEN/ISSS, IEEE, IMS, and ISO have already identified the need for interoperability of web-based educational systems, wide spread adoption of standards and quasi-standards proposed by those institutions is still missing.

This workshop addresses the need for more consolidated research on interoperability of web-based educational systems. The workshop brings together researchers and practitioners from different communities such as e-learning, information systems, databases, and semantic web that are interested in making educational systems interoperable.

The workshop has managed to deliver a state-of-the-art overview of successful interoperability cases and provides guidelines for future research. In total 15 Papers have been submitted, from which 8 were selected as full papers. Additional 4 papers were accepted as short papers. Having received contributions from four continents the workshop has also shown that interoperability is truly a global phenomenon.

May 2005

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Educational Innovation via e-Learning- AEN and Japanese Strategy

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ABSTRACT

The Asia E-learning Network (AEN) was established in 2002. After then 3 international annual conferences were held and e-learning experiments between Japanese universities and 6 Asian universities, activities in 4 working groups, situation of each country were reported. Main activities of the AEN are concerned with interoperability technology, international standards and certification, professionals, quality assurance, management, validation, portal site. research trends and so on. But unfortunately there are still now digital divide among Asian countries.

As computerization, networking and the application of information technology have not yet been well integrated into the education sector, many people concerned still believe that mainstream education must be school education based on traditional face-to-face lessons. In regard to information technology, at most it is seen as one of many tools that support classroom lessons. The new paradigm is that internet and information technology represent the true nature of education and traditional face-to-face lessons in universities and schools are, so to speak, exceptional practices.

In this context the important issues are quality assurance of educational systems, tools and contents, setting up the national and international standards, collaboration across different sectors, copy rights, user protection, and blended learning.

On the background there found global needs on collaborations across different sectors such as academics, industries, governments, culture, languages, countries, ethnic groups and so on and solution via e-learning.

A Model and Infrastructure for Federated Learning Content Repositories

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ABSTRACT
In order to assist in the discovery and access of learning content from the diverse, extant collection of content repositories, we are developing a reference model that describes how to build an interoperable repository infrastructure through the creation of federations of repositories. Such federations provide a single point of discovery and access. They collect the metadata from the contributing repositories into a central registry. The CORDRA activities surrounding this work include development of a model of federated repositories, their behavior, services and interfaces, defined through a reference model. This reference model is a profile of a collection of open interoperability specifications detailing the characteristics and behavior of the federation. Individual communities of practice may then implement their own federation, with their own technology choices and policy and business rules, following the overall model, but tailoring it to their needs. The project also aims to build an operational infrastructure that will include a master federation of federations.

Categories and Subject Descriptors
H.3.7 [**Information Storage and Retrieval**]: Digital Libraries – *standards, systems issues.* K.3.1 [**Computers and Education**]: Computer Uses in Education – *computer managed instruction (CMI).*

General Terms
Management, Design, Standardization.

Keywords
Learning Content, Content Repositories, Registries, Federated Repositories, Digital Libraries, Interoperability Standards, Metadata, CORDRA, SCORM.

1. INTRODUCTION
In recent years, a variety of learning technology systems and interoperability standards (e.g., [16]) have been developed and adopted. All of these were aimed at increasing the reuse of "learning objects", reducing their development effort and providing interoperability of content across delivery and management systems. Additionally, there exists a diverse collection of both public and private content repositories and digital libraries containing these learning and content objects (e.g., [6, 12, 13, 15]).

Reference models such as SCORM [16] have been proven effective in providing interoperability of content and course materials across delivery platforms. Metadata standards such as IEEE LOM [10] and the Dublin Core [4] provide an effective way to describe and catalog individual content objects. But content and system interoperability combined with content tagging and management are insufficient.

For example, the SCORM framework specifies how to develop and deploy content objects that can be shared and contextualized to suit the needs of the learner, and it provides the means to tag content for later discovery and access in a distributed environment. But SCORM is *silent* about how content discovery and access are to be implemented. Currently, discovering and accessing content for use, reuse or remix is ad hoc: you need to know where the content is stored and how to search and access it from individual repositories, typically in idiosyncratic ways.

While there are several ongoing efforts aimed at building federations of learning content and content repositories, e.g., [5, 8] there is as yet no formal model of how to build such a federation, nor is there a common approach to creating a shared global infrastructure for learning content.

Thus, our goal is to develop a model of how to enable the next step in the evolution of e-learning, namely, how to solve the problem of seamless discovery and access to learning content. We approach this problem through the creation of interoperable registries of content and content repositories, i.e., establishing collections of repository federations, all conforming to a set of agreed-upon standards. Building upon existing technology from the worlds of learning content management and delivery, content repositories, and digital libraries, this model aims to identify and specify (not develop) appropriate technologies and existing interoperability standards that can be combined into a reference model that will enable learning content to be found, retrieved and reused.

2. CONTENT DISCOVERY and ACCESS PROBLEM
The technological and management problem we are trying to solve is that of how to provide access to learning content, under the base assumption that good learning requires ubiquitous content, which in turn implies the need for an operational content infrastructure. We recognize that while there is an existing body of content and a collection of content repositories, these do not interoperate in a seamless way. Furthermore, the successful

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adoption of the SCORM "reference model", i.e., a profile of a collection of interoperability standards targeted at a specific community of practice, illustrates that a similar approach could be used to provide an infrastructure aimed at the seamless discovery and access to content stored in the existing but diverse repositories.

We are motivated by a more direct problem. The government and military education and training sectors in many countries have begun to mandate the use of SCORM in the creation of learning content. They further require that organizations search for and reuse existing content when feasible and that they make existing content available for reuse. Thus, while SCORM provides the model for the content itself and the content delivery environment, it does not provide a model that can be applied to content or content repositories such that content can be easily discovered and accessed outside of courses. No model similar to SCORM is available for repositories, content discovery or content access.

Rather than simply mandating a specific architectural solution or system for content discovery and repository interoperability (in particular, how to combine repositories into an overall content infrastructure in an interoperable way), we promote the reference model approach. While the government and military sectors have some unique requirements, the general problem of content discovery, access and repository interoperability needs to be addressed across all education and training sectors. We posit that we can develop a general solution applicable and adaptable to all sectors.

We are taking a multipronged approach. We are building a set of specific implementations of federated content repositories for specific communities of practice. At the same time, we are developing and documenting a formal underlying reference model that can be applied and adopted broadly. Much of our actual work is derived from prior attempts (successful and unsuccessful) to build such federations, leveraging existing technologies and standards, and lessons learned [1, 2, 11, 14, 17]. Our broad goal is that this reference model can become the basis for a global content infrastructure.

As base requirements, we assume a content infrastructure must:

- support the discovery and access to content;
- provide content management;
- operate under the specific policies of the individual institutions, collections and repositories;
- work "at scale";
- be robust and reliable; and
- make business sense to those who will fund, develop and deploy it.

Within this infrastructure, we want to make content widely available, easy to find, independent of courses and seamlessly accessible. We want to enable reuse and remix, but maintain content in a managed environment, subject to appropriate rights management. We assume that existing systems and technologies must integrate or interface to be part of the overall infrastructure, i.e., the elements of the infrastructure will be built on diverse technology platforms that need to interoperate and integrate with other systems, but remain independent.

Thus, we are developing a model for a content infrastructure centered on the broad problem of content discovery and federated repository integration. Such a federated repository model addresses not only the problem of allowing the participants to remain independent except for their agreement to minimal "interfaces", but also provides a common, centralized method for discovery and access.

3. CORDRA

3.1 Framing the Model

Our working definition for the reference model underlying the content infrastructure is:

> *an open, standards-based model for how to design and implement software systems for the purposes of discovery, sharing and reuse of learning content through the establishment of interoperable federations of learning content repositories.*

We label this model *CORDRA*, and commonly expand the acronym as Content Object Repository Discovery and Registration/Resolution Architecture [3].

In developing the model, we start by restating a set of core questions that the overall solution must address:

- what are the requirements for learning content repositories that participate in a federation?
- what are the core policy and business rules that a repository and the federation must support?
- what are the minimal constraints on system architecture and design?
- what are the implications for consistent implementations (needed for interoperability)?
- what are the relevant technologies?
- what are the relevant specifications, e.g., web, search, libraries, identifiers, learning technology, …?
- how do we connect these technologies and specifications into a consistent framework and model?

The resulting model must support a set of core capabilities:

- "published" content will be widely available;
- content can persist outside of the context of a single course or other learning structure or delivery paradigm;
- content can be easily discovered;
- there will be standard mechanisms for content access;
- content can be managed (ownership, rights, access, provenance, persistence);
- operations are tailored to meet the needs of the participating organizations and institutions;
- use open standards-based interoperability; and
- support integration of and with current systems for repositories, management and content delivery.

Additionally, since we are attempting to model and build a large infrastructure, it is important that we consider some of the attributes of successful infrastructure development. By observing how infrastructures have evolved in the past, we hope to minimize problems. History has shown that successful infrastructures [7]:

- evolve from local to global. They start with a local system for local uses and users, and then connect with other local systems to build the broader network.
- grow in size and importance with demand. There is a cyclic feedback loop: more demand increases use and size, which increases demand, attracting more users, ….

- use primarily core, scalable, reliable, existing technology. Existing technology is refined, extended and adapted to build the infrastructure. No core technologies are created directly for the sole purpose of creating the infrastructure.
- have open connections and interfaces specified through minimal interoperability standards. Anyone who meets the stated interoperability requirements is permitted to join the network. Interconnection requirements are limited to only those essential for successful operations.
- seamlessly connect from source to sink. Provide a single model and approach for the user, eliminating technological impedance barriers between the interconnected elements and automating the flow of information or payload from its origin to its final destination.
- enable value-added services. Provide only core features in the common infrastructure, and support mechanisms for others to independently add their own services and features under their own business models.
- provide separate levels of functionality. Maintain independence, both in technology and management, of features such as generation, transport, delivery, and management.
- focus on the right users. Know who from the user community (developers, end-users, managers, individuals, businesses, etc.) are key players and provide the functionality that they need.
- handle peak demand and fractional use. Know what the peak demands are, and build a system to support those, but understand that individual users have smaller demands. Users will need only a fraction of the power of the infrastructure at any time.
- enable local operations and policy. Allow the participants in the infrastructure to operate under their rules and policies.
- provide differentiated services. Identify when a single level of service or model will not suit all users and provide appropriate different models for different groups, possibly at different costs associated with the level of service.
- apply appropriate policies and governance. Both local and global management of the infrastructure are critical.
- make appropriate business decisions. Participants will all have different value propositions, and the solution must be attractive to both providers and consumers.
- move to ubiquitous or universal service. Provide a system that can provide a minimal level of service to *all* users.
- build systems, not components or payload. Focus on the infrastructure itself, both as technology and management. Enable and rely on others to build the tools and components of the infrastructure and to provide the payload, data or information that moves through the network.

Moving from this historic background and through the requirements, we highlight five key assumptions underlying the development of CORDRA:

- there are sufficient interoperability standards. We assume the core standards exist, and that while they may need to be adjusted and extended, we do not need to first define a new set of core standards before we can begin to define the model and build operational systems.
- the core technology is stable. Again, we assume that the available digital library or repository, internet, and learning technologies are sufficiently stable for us to begin.
- there is sufficient demand, i.e., we are not premature in developing a solution to the problem.
- we can capture and express the key requirements and properly include these into the overall solution.
- the policy problems are solvable. Our experience in developing and deploying digital library and learning technology systems tells us that solving management and policy issues is critical, often overriding the technical issues.

More importantly, while we understand that there have been unsuccessful attempts to build major repository federations in the past, and that many of the digital library systems have not fulfilled the promise, we hope we are now at a new tipping point: demand, technology and standards have matured such that we can now be successful.

The amalgamation of assumptions, requirements and historic background together forms the basis for CORDRA. CORDRA itself is a label for three different items:

- a *model* of how to create local federations and a global learning content infrastructure;
- a *project* working to define and document the model with sample tools and implementations; and
- a *working* system – a global federation of content registries.

We describe each of these below, focusing primarily on the overall formal reference model.

3.2 CORDRA Model

CORDRA is designed to support the federation of existing content repositories where these are combined into a single source for content discovery and access. The formal model (the CORDRA reference model) can be used to design and implement such federations of repositories.

The overall CORDRA model for a single content federation is illustrated in Figure 1.

- Learning content remains in existing (local) content repositories that are managed and operate under their own local rules.
- Repositories and content (i.e., content metadata) are registered within the federation to enable discovery, access and management.
- The federation registry is a collection of system repositories that maintains a master catalog of all learning content metadata, the repository registry listing all repositories within the federation, and an additional repository with system data, models, etc.
- Content is located by searching against the master catalog. The catalog may also maintain additional indexing information, usage data, context, etc., that are used to rank and identify the most appropriate results to satisfy a discovery query. The other system repositories contain declarative and semantic models used in CORDRA operations.
- An identifier system provides an infrastructure for object identification, registration and resolution.
- A common services infrastructure provides the core technical and administrative services and overall software design paradigm used throughout a federation (authentication, security, rights management, business rule processing, etc.).

- End-user interfaces and application systems (search, discovery, authoring, personalization, customization, delivery, etc.) are used to catalog, find, manage and deliver learning content and content objects. These are built as value-added services on top of the core federation structure.

The CORDRA model is based on key characteristics, consistent with the requirements and background as illustrated in Figure 1:

- persistent, actionable (content) identifiers;
- individual content repositories;
- federated metadata;
- single point of search;
- service-oriented design;
- core, common services;
- a scalable infrastructure / technology base;
- value-added user services and applications; and
- open standards.

Within the model, a repository is defined as a persistent, managed store of content with a set of defined service interfaces used to integrate and interface it with the federation. There are no other stated technology requirements, i.e., we are silent on how to implement the repository or indeed if it is a software system, physical, or virtual. All repositories are registered as part of a CORDRA implementation. The content repositories that participate in the federation are operated and maintained independently of the federation itself.

Within the model, in addition to the individual content repositories, a federation has three system repositories:

- the *master catalog* or content registry, containing metadata instances of content from the individual contributing repositories used for all search and access;
- the *repository registry*, containing the descriptions (metadata, policies, access information, etc.) of all repositories in the federation; and
- the *system registry*, containing the machine processible descriptions of the CORDRA model and its implementation within the federation.

All of these repositories are registered in the repository registry, enabling a self-descriptive system.

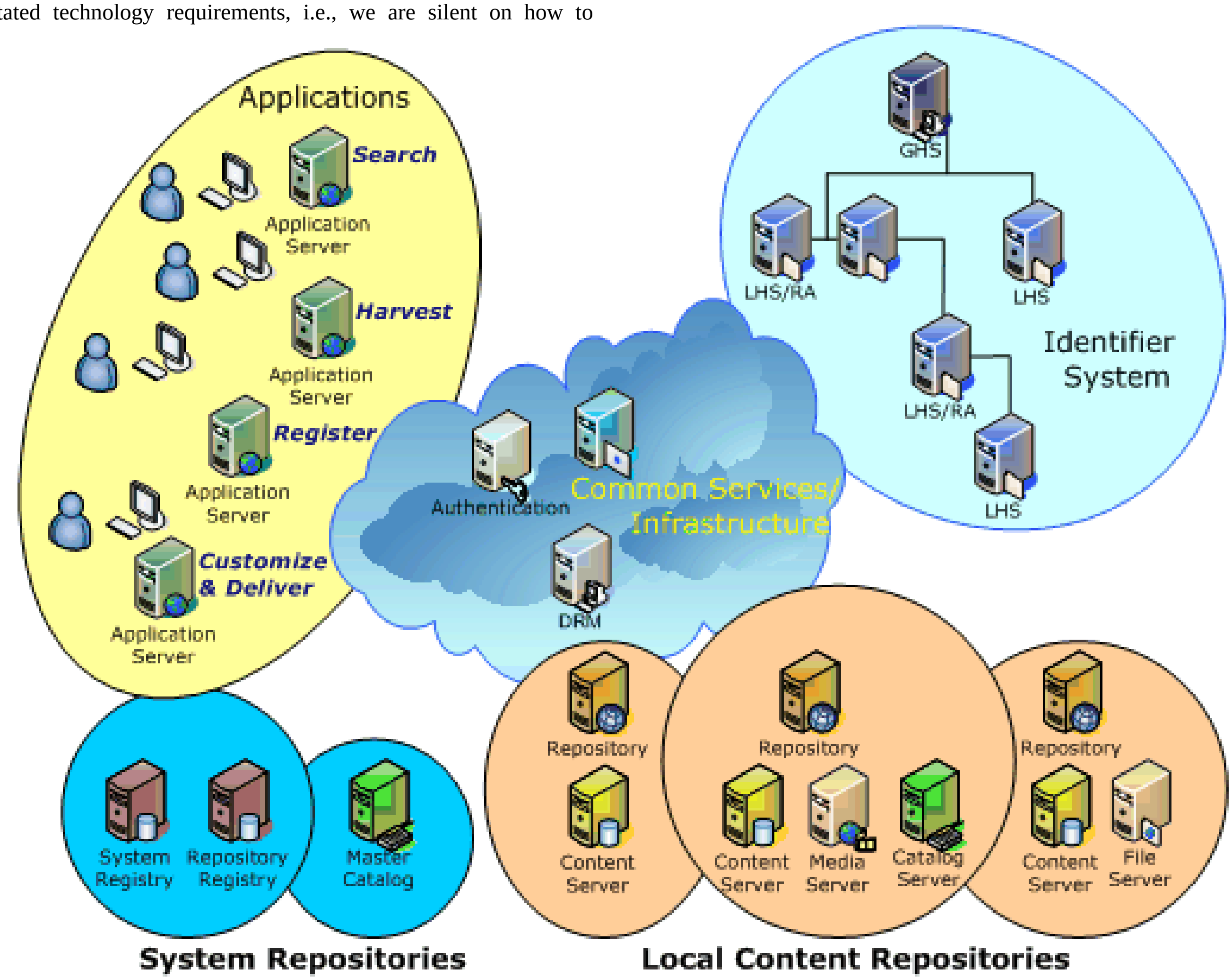

Figure 1: Model of a CORDRA Federation

A key concept of the CORDRA model is the federation of metadata from the individual source repositories into the single federation metadata registry. Based on prior work, we believe that such a model is scalable and provides robust, reliable quality of service and uncouples discovery from any idiosyncratic features of individual repositories. It also provides the means to easily build independent value-added services.

The model relies on a formal identifier infrastructure used to provide a persistent, unique "name" or label for each item. Identifiers are actionable, with multiple resolution, providing a mapping from the name to a set of information used in processing. There are collections of namespaces for identifiers; content collections use their own namespace; each federation has a namespace for elements used to define and operate the federation; and there is a CORDRA namespace for elements of the CORDRA model itself.

A set of common services are used to build a federation; e.g., identification, authorization, authentication; digital rights expression and management; policy and rules processing (workflow); search and harvest interfaces; identifier resolution; security. All of the service definitions are stored within the system registry. The overall model is based on a service-based approach (not necessarily a Service-Oriented Architecture [SOA]), defining operations and behaviors as services.

The applications and value-added services are built on top of the common services and the federation infrastructure. They provide a collection of service-oriented models with user interfaces or user agents to provide features such as content search, content registration, content harvest, repository registration, content delivery, and content assembly and customization. Since these services can be defined and built independently of the federation, we do not attempt to define or limit what someone may want to build, but rather try to enable a range of add-on features.

In the above, we described the model of a single content federation, i.e., a single collection of repositories. However, we want to enable the creation of many federations, each containing a different collection of repositories. More importantly, as noted above, we expect that each of these federations will need to operate under a different set of rules and policies, be implemented on a different technology base or platform, and use a different set of interoperability standards. For example, one federation may be public and one may be private; one may be built assuming content metadata is harvested from the repositories and another may require an active deposit and registration process. Likewise, one federation may rely on LOM metadata, and another may use Dublin Core to describe all content objects. Thus, we need to define CORDRA as a model to permit the development of federations under a collection of different technology, policy and management schemes.

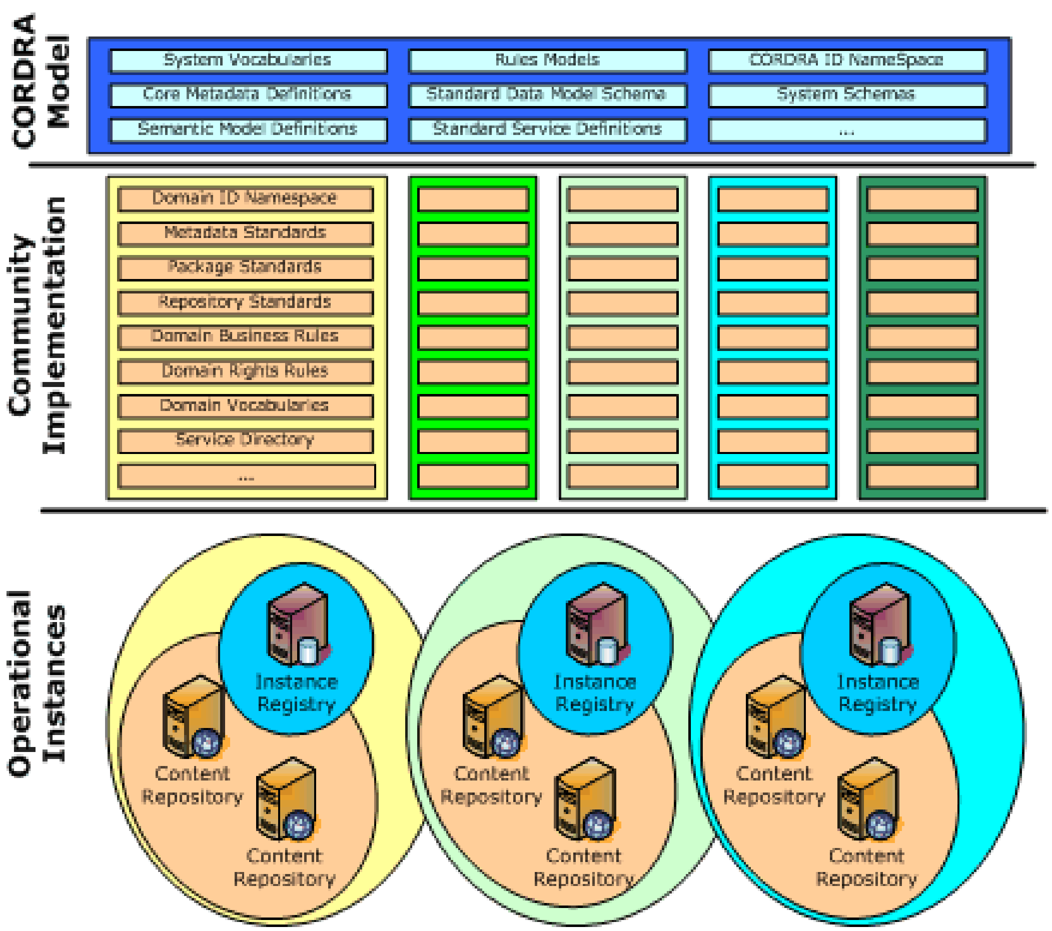

Figure 2: Layered CORDRA Model

Thus, the CORDRA model is defined at three discrete levels as illustrated in Figure 2.

- The *Core CORDRA Reference Model* defines the structure, features and capabilities of CORDRA without defining how to implement it within a particular community of practice. The core model includes the system vocabularies, rule representations, system data models and schemata, service models and their definitions, and the CORDRA metadata. These items are defined both in human- and in machine-processible forms, and are assigned identifiers from the CORDRA namespace. The core model is independent of any implementation or federation, but is used to define and describe each of the implementations and their instances.
- A *Community Implementation* describes a particular implementation of the CORDRA model. It specifies *the* set of data models, taxonomies, business rules, system structures, interoperability standards, etc., for a particular community. These models are defined in terms of the description and modeling features of the core CORDRA reference model. We anticipate many different implementations, and describe the initial ones below. At this level in the overall CORDRA model, the description of the federation does not specify operations or mapping to an operational infrastructure, i.e., the implementation defines *what* a federation does, not *how* to create and operationalize it.
- An *Operational Instantiation* defines the characteristics of a single running instance of an implementation for a particular community. These include the choice of binding of components to actual network names, namespaces, operational policies (backup, mirrors, etc.), hardware, software and operating system choices, etc. Any implementation may support any number of instantiations, e.g., production versus development systems. The characteristics of the instantiations are defined by the implementation and its community; they are not part of the CORDRA reference model.

3.3 Federated CORDRA: Federation of Federations

As described above, we have developed a model of how to create individual federations of content repositories, each federation being built to meet the needs of a specific community of practice. We expect that many communities will want to create their own implementations. However, creating multiple implementations still does not meet the goal of seamless access to ubiquitous content. Users still need to be aware of the different federations and need to directly access the appropriate registries for content discovery.

Rather, we desire a single point of access to all content, independent of repository or federation. Thus, the overall CORDRA model includes the concept of a *federation-of-federations*, denoted as Federated CORDRA.

As illustrated in Figure 3, Federated CORDRA is the collection of CORDRA community-specific implementations. It is defined through a registry of the corresponding CORDRA registries, i.e., a registry-of-registries (RofR). The central federation registry also includes within its system repository the definition of the various CORDRA system objects that are independent of any individual implementation.

Following our overall approach of building self-descriptive systems, the federation-of-federations registry is just another CORDRA implementation and follows the overall approach and reference model. Here the community is the global community of all other federations, and the implementation defines how all of the federations register their registries into the overall federation-of-federations registry.

We do, however, limit the model to a single level of federation, believing that for reliability and performance, the user should never be more than two steps away from content: federation-of-federations registry to an individual federation registry, and then from the federation registry to the content repository.

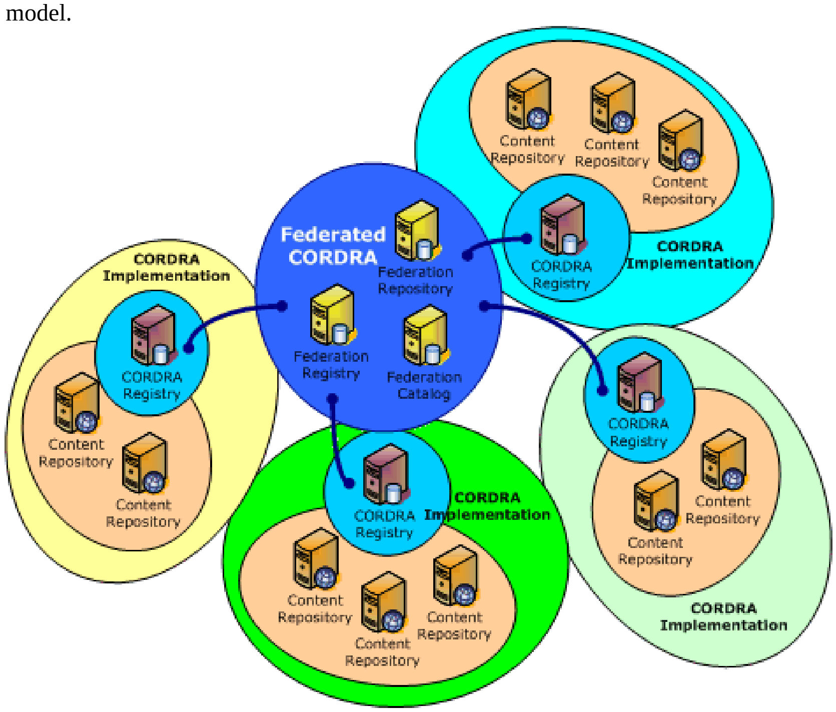

Figure 3: Federated CORDRA

We currently have not determined what will go into the registry-of-registries. Should we store all the metadata for all the objects in all the repositories in all the registries in all the federations? Or just the total list of all the repositories or just the list of registries? The primary function of the RofR is to be a single starting point for access and discovery. Starting at the root, how do you get to an individual content object? One can imagine searches being mapped from one federation to another; one can imagine search results that just summarize what you might find in the different federations; one can envision dispatching mobile agents across an array of identified federations to gather search results or even samples of content, etc. The ability to build various applications and searches on top of the RofR will depend on its content, but much of the functionality can be abstracted from the implementation details. The design and implementation will evolve as the infrastructure evolves, and as we learn what will or will not work.

3.4 CORDRA Project and Status

Work on the project has been underway since 2003. Our initial goal was to create a single instance of a federation of content repositories for the US military, operated by the Department of Defense (DoD). The primary objective of this federation was to support the discovery and access to SCORM-based learning content.

As we developed the initial design and plans for this federation, we recognized the need to separate the underlying model from the actual implementation, and further recognized that one single federation will not meet everyone's needs. Different communities will have different specific requirements, but it should be possible to create a general model, and develop specific versions of that model (profiling the generic profiles) for specific communities.

Thus, we differentiated CORDRA as the general model and the project description from the specific implementations. The US DoD implementation of CORDRA is now designated the ADL-Registry (ADL-R).

The ADL-R has been in development and testing since mid-2004. Elements of the system are based on prior work on systems such as Fedora and Cross-Ref [1, 2]. The ADL-R uses the Handle System [9] as a core component, and incorporates other off-the-shelf software, including commercial products such as database management systems, LDAP directory software, XML processors, etc., with elements from open source projects such as the Apache Project (Lucene, Apache Web Server). We currently anticipate that the ADL-R will go into production operations around mid-2005.

The ADL-R incorporates a set of core capabilities, focusing on the central content metadata and repository registry:

- content and metadata instances are identified with Handles;
- repositories and their core management policies are described and registered within the central registry;
- metadata instances, described using LOM, are deposited in the registry;
- simple and extended search operations are available to discover content and its metadata from the registry;
- search and query operations are available to discover policies and information about the repositories that are part of the federation;
- internationalization is supported throughout; and
- operational and status data are available.

In addition to the operational registry, we are developing a user portal for search and discovery. Other supporting elements include a test harness and test data; help desk support; system documentation; and the development of operational policies for the registry, the participating repositories and the organizations that deposit and manage content.

The ADL-R has multiple operational instances: a development environment with prototype system that includes developmental and test bed instances; and a production environment with primary and backup systems. Quality of service, performance monitoring, replication, backup, etc., are key aspects of making the ADL-R a robust, reliable, operational system.

We are beginning the development of a second CORDRA implementation for a different sector within the US Government. We aim to address a number of different topics in this work:

- understanding how to move from the existing ADL-R implementation to a new community;
- how to both capture the community's requirements and modify the core system to include their needs;
- developing web service interfaces;
- exploring access and rights management issues;
- exploring models for harvest, indexing and advanced search;
- developing an approach to capture and process local repository and registry policy and business management rules; and
- demonstrating value-added services for content creation, management and delivery.

As with the ADL-R, this implementation will demonstrate the overall model in a production environment and will help shape and refine the model. We anticipate that the results from this second implementation will eventually be folded back into the ADL-R.

We are also in the planning stages for other CORDRA implementations for other communities. Once we have a few operational implementations of federated registries based on the CORDRA model, we will begin the development of Federated CORDRA, the federation of federations.

Our approach is thus multipronged as stated above. We are developing and building operational implementations of CORDRA for specific communities in order to understand requirement and needs and to test our concepts. We take the results of this work to define and shape the overall model, allowing us to produce and refine the formal description of the CORDRA model.

The CORDRA project is thus the collection of all of these activities: defining the model, coordinating the various implementations, and providing a way to build the federation of federations. The project includes the dissemination of the CORDRA documents and outreach activities. Sample code, tools, test data, etc., will also be released to the community as part of the project.

Beyond the technical work, we continue to explore how to move CORDRA, as an idea, beyond its roots in specific projects. The long-term plan is to move the work on the model itself and the operations of the federation of federations to appropriate governance and stewardship bodies.

4. SUMMARY

Key requirements and how the work meets them can be summarized as:

- users want to easily discover learning content and want their content to be found: provide a "one stop" search interface;
- users want to find the right content in context: use appropriate indexing and ranking data and algorithms in conjunction with search;
- searchers want precision of search results, returning only what they need: use proper classification and good metadata;
- we need flexibility and an approach that will scale, and forcing new or rigid information, service and protocol models is unpalatable: use self-descriptive and semantic modeling;
- integration and interoperability with existing systems and applications are required and we cannot foresee all of the required capabilities: use a service-oriented approach;
- providing tailored operations for communities of practice to enable local policies and business rules, not define them: include discoverable and machine-processible policies; and
- ease of use is essential: develop supporting tools and user support and guidance.

CORDRA is an overall reference model that attempts to meet the goals, requirements and assumptions described herein. It defines how to build federated repository systems to support the discovery and access to learning content that operate through the federation of metadata from the contributing repositories. The CORDRA model and implementations of it are built on existing technologies, and the reference model is formally defined and represented through a profile of a collection of existing technology standards and specifications. In short, the CORDRA reference model is just a profile of interoperability standards and the additional glue needed to join them into a cohesive whole that can be successfully applied and implemented.

A community of practice selects a set of policies, rules, technology choices and decides on appropriate specifications for their needs. These choices are then reflected in the specific federation of repositories built for their needs. Each community then has its own federation registry used for content discovery and access (perhaps with multiple operational instances).

These individual community federations are then integrated into a global federation of registries, the federation-of-federations, that also follows from the overall CORDRA model.

Together, these elements define a model for a global operational learning content discovery and access infrastructure.

We are developing this overall infrastructure and model by working from individual implementations, testing and refining our work as we proceed. We combine our results into the formal model, open source tool set and documentation being released to the community.

5. ACKNOWLEDGMENTS

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The CORDRA activities are currently being coordinated by the Advanced Distributed Learning Initiative (ADL), the Corporation for National Research Initiatives (CNRI), and the Learning Systems Architecture Lab (LSAL). For more information, see http://cordra.net/

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A Simple Query Interface for Interoperable Learning Repositories

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ABSTRACT
In order to achieve interoperability among learning repositories, implementers require a common communication framework for querying. This paper proposes a set of methods referred to as Simple Query Interface (SQI) as a universal interoperability layer for educational networks. The methods proposed can be used by a source for configuring and submitting queries to a target system and retrieving results from it. The SQI interface can be implemented in a synchronous or an asynchronous manner. SQI abstracts from query languages and metadata schemas. SQI has been evaluated by several prototype implementations demonstrating its universal applicability, and is on the way to being standardized in the CEN/ISSS Learning Technologies Workshop. The latest developments of SQI can be followed at http://www.prolearn-project.org/lori/.

Categories and Subject Descriptors
H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval - Search process, H3.7 [Information Storage and Retrieval]: Digital Libraries - Systems issues, H.3.5 [Information Storage and Retrieval]: Online Information Services - Web-based services

General Terms
Management, Design, Standardization, Languages

Keywords
Interoperability, Application Program Interface, Learning Repositories, Querying, Web Services

1. INTRODUCTION
The Web puts a huge number of learning resources within reach of anyone with Internet access. However, many valuable resources are difficult to find in an efficient manner, because valuable resources are hidden in the closed and proprietary worlds of learning (content) management systems, streaming media servers and online collaboration tools.

Such systems are commonly referred to as learning object repositories being part of an educational web. Learning object repositories hold information on learning objects (i.e., metadata), in order to describe educational artefacts such as courses, online tutorials, lecture notes, electronic textbooks, tutoring sessions, quizzes, etc.

In this paper we propose a common query interface as one part of the solution for exploring the hidden educational web. The notion 'hidden web' refers to the web, which is hidden behind proprietary search interfaces and authentication mechanisms [14]. This proprietary world of interfaces, leads to a lack of interoperability. Interoperability can be defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [9]. To a user, the lack of interoperability, for example, means [16]:

- Applications and their data are isolated
- Redundant data entry is required.

In order to achieve interoperability on the educational web a common semantic model is required. The semantic model – also referred to as 'ontology' – should specify the properties of the learning resources accessible within the repository [20]. Each declaration of a learning resource property constitutes an ontological commitment to use the defined term in interactions with the repository.

Additionally, interoperable learning object repositories are based on common protocols, which define the interactions between repositories.

To achieve interoperability, different kinds of protocols can be used. The Learning Object Repository Interoperability Framework presented in Figure 1 distinguishes between core services and application services. Core services are needed, for example, to agree on a common procedure for uniquely identifying learning objects. Other core services are related with authenticating users and repositories, or with creating and managing sessions for interaction between applications.

Typical applications that make learning repositories interoperable are, for example, the indexing service, the harvesting service or the query service. The indexing service, as a kind of replication service, allows repository A to "push" learning object metadata to repository B. It supports distributed maintenance of metadata through insert, delete or update operations. The harvesting service is a service, where repository A "pulls" metadata from a repository B. The query service allows repository A to search repository B for suitable learning resources, so the metadata transferred matches a specific query. A contracting service assigns access rights to a learning object stored at a remote repository. The delivery service interacts with the repository

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where the learning resource is stored and delivers an electronic learning resource to the end user.

Application services make use of core services. For example, the core service session management might be required for the query service.

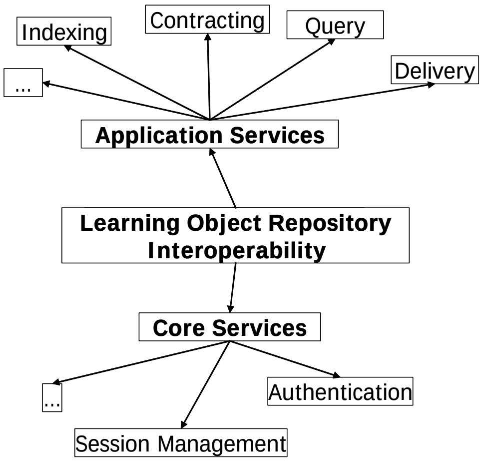

Figure 1. Interoperability Framework

Both, core and application services, require a common messaging infrastructure, which enables repositories to interact. XML RPC, Java RMI, and WSDL/SOAP are examples of such messaging services. A messaging service is based on a common network infrastructure and lower level protocols such as TCP/IP, HTTP, etc. Figure 2 depicts the various layers of Learning Object Repository Interoperability as described above.

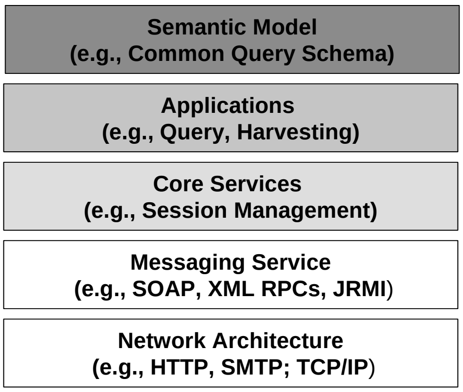

Figure 2. Interoperability Stack

Learning Management Systems (LMS), Learning Content Management Systems (LCMS), Knowledge Pools, or Brokerage Platforms are the kind of information technology the interfaces proposed herein are designed for. Within its focus on the query interface, this paper targets architects of educational networks, managers of learning resource repositories, stakeholders in learning object re-use, as well as researches in web services and system interoperability. However, although we refer to learning repositories interoperability with a special focus on learning object metadata, this query interface can also be used within other domains and application scenarios [12].

The remainder of this paper is structured as follows: While Section 2 is devoted to specification of the Query Service including Authentication and Session Management, Section 3 presents implementation of the API. Section 4 reviews related work. The paper concludes with a discussion of the status quo and outlines future work on the interface specification.

2. Simple Query Interface

An Application Program Interface (API) for query services needs to specify a number of methods a repository can make available in order to receive and answer queries from other applications.

To distinguish the requestor from the answering system in our scenarios, the term “source” is introduced in order to label a system which issues a search (the source of the query). The term “target” labels the system which is queried (the target of the query). Alternatively, the “source” can also be referred to as “requestor” and “target” as “provider”.

Metadata can be stored using different means, such as file-based repositories, (distributed) relational databases, XML repositories, or RDF tool kits, which use different query languages constituting a heterogeneous environment. In order to make learning repositories interoperable, not only a common interface needs to be defined, but also a common query language together with a common results format for learning object descriptions needs to be agreed on. Interoperability aspects such as common query schema, results format are part of the semantic model of an educational network (see Figure 2). This research focuses on the transport mechanisms required for querying, issues related to the semantic model are not within the scope of this paper.

The query service is used to send a query in the common query language to the target. Next, the query results, represented in the common results format, are transported to the source. On the implementation level, wrappers may need to be built to convert a query from a common query language X to a local query language Y and transform the query and the query results from a proprietary format to a common one and vice-versa.

Figure 3 illustrates an exchange process, where Learning Repository A (the source) submits a query to Learning Repository B (the target). It is assumed that both systems have agreed upon a common query language beforehand. The concepts used in the query statement are part of a common (query) schema. At Repository B, the interface component might need to transfer the query from the common query language to the local one. Also some mappings from the common to the proprietary schema might be required before submitting the search. This task is performed by a wrapper component. Once the search has yielded results, the results set is forwarded to the source, formatted according to a common results format.

The collaborative effort of combining highly heterogeneous repositories has led to the following requirements:

- The API needs to be neutral in terms of results format, query schema and query language: The repositories connecting can be of highly heterogeneous nature: therefore, no assumptions about these components of interoperability stack can be made.
- The API needs to support synchronous and asyn-chronous queries in order to allow the application of the API in heterogeneous use cases.
- The API needs to support, both, a stateful and a stateless implementation.
- The API shall be based on a session management concept in order to separate authentication issues from query management.

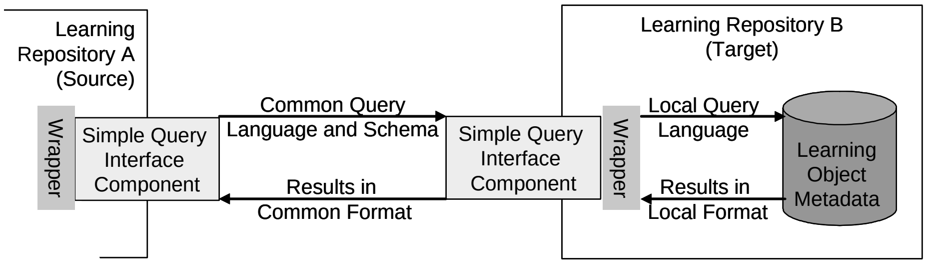

Figure 3. Communication between two Repositories

In addition, the design of the API itself is based on the following design principles:

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

Since one design objective of the API is to keep the specification simple and easy to implement, the API is labeled Simple Query Interface (SQI).

The following sub-sections describe each of the above mentioned design principles in more detail.

2.1 Query Language and Results Format

In order to make use of SQI to implement full query functionality, the API needs to be complemented with agreements about:

- the set of attributes and vocabularies that can be used in the query,
- the query language and its representation,
- the representation of list of learning objects that satisfy the query, and
- the representation of individual metadata instances on learning objects.

SQI is agnostic on these issues: Any agreement between two or more repositories is valid for SQI. Such agreements can, for example, be expressed by XML schemas or RDF schemas.

Although SQI does not directly contribute to overcome the differences of the various paradigms in metadata management (Z39.50, XML-based approaches, RDF community), it aims to become an independent specification for all open educational repositories.

2.2 Synchronous and Asynchronous Queries

SQI can be deployed in two different scenarios: In the synchronous scenario, the target returns the query results to the source. Results retrieval is therefore initiated by the source through the submission of the query and through other methods allowing the source to access the query results.

In the asynchronous scenario, results transmission is target-initiated. Whenever a significant amount of matching results is found, these results are forwarded to the source by the target. To support this communication the source must implement a results listener. The source must be able to uniquely identify a query sent to a particular target (even if the same query is sent to multiple targets). Otherwise the source is not able to distinguish the search results retrieved from various targets and/or queries previously submitted to a target.

Please note that the asynchronous query mode does not require an asynchronous handling on the messaging layer. It can also be implemented by two synchronous functions at the source and the target, respectively.

A query interface operated in synchronous mode can perform multiple queries per session (even simultaneously). In case of an asynchronously operated query interface, the source provides a query ID that allows it to link incoming results to a submitted query (the source might query many targets and each target might answer to a query by returning more than one result to the source). Multiple queries can also be active within a session in asynchronous query mode.

2.3 Session Management

The application interfaces make abstraction from authentication and access control issues. However, there is a need to authenticate the source in order to allow a target, for example, to link query policies to a source repository. For instance:

- Repository A is allowed to query Repository B without any limitations,
- Repository C is only allowed to retrieve 1000 query results per day from Repository D at a maximum.

Ideally, authentication is performed only once for a series of interactions. To accomplish this, a session token needs to be returned after successful authentication that can be used to identify the system in the subsequent communication.

Session management needs to be understood as a higher-layer management of configuration settings and authentication. The session ID serves as a mandatory element in the application interfaces in order to identify the requestor/source in all query commands.

Therefore, the SQI is based on a simple session management concept. A session has to be established before any further communication can take place. This specification separates query management and processing from authentication (and query policy management).

In case of a synchronously operated query interface, the source establishes a session at the target and uses the Session ID, which it obtained from the target, to identify itself during communication. Authentication does not need to be based on credentials, since also anonymous sessions can be created.

The specification introduces an incomplete list of possible means for establishing a session for the communication between two systems.

Once a session has been established, the source has the right to communicate with the target. In order to establish a session, a user name and password or any other credential may be required. The identification of a source repository can prevent candidate target repositories from opening up their systems to unknown partners, and enables query policies.

A session is valid until it is destroyed. Hence, it continues to be active after a query has been executed. Alternatively, a session times out when no communication takes place during e.g. 30 minutes. However, a session might be valid much longer than 30 minutes and sometimes might even require manual destruction.

The specification assumes the use of secure authentication, authorization, and encryption mechanisms such as those provided by state-of-the-art technology (e.g., SSL).

2.4 Stateful and Stateless Communication

Stateful and stateless are attributes that describe whether repositories are designed to keep track of one or more preceding events in a given sequence of interactions. Stateful means that the target repository keeps track of the state of interaction, for example, by storing the results of a previously submitted query in a cache. Stateless means that there is no record of previous interactions and that each interaction request can only be handled on the basis of the information that comes with it. The SQI specification allows implementers to opt for a stateful or a stateless approach.

2.5 Command-Query Separation Principle

SQI design is based on the "Command-Query Separation Principle". This principle states that every method should either be a command that performs an action, or a query that returns data to the caller, but not both. More formally, methods should return a value only if they are referentially transparent and hence cause no side-effects. This leads to a style of design that produces clearer and more understandable interfaces.

The Command-Query Separation (CQS) is a principle of object-oriented computer programming. It was devised by Bertrand Meyer a part of his work on the Eiffel programming language [21].

2.6 Simple Command Set and Extensibility

In order to make the interface easily extensible an approach, minimizing the number of parameters of the various methods rather than the number of methods is adopted. Variations of the interface (e.g., a separation between common query schema and common results format), can easily be introduced by adding a new function (e.g., setSupportedQuerySchema) while no change in the already implemented methods is needed. Hereby, backwards compatibility can be more easily maintained.

As a result, additional methods for setting query parameters like maximum duration and maximum number of returned search results were introduced. This design choice leads to simpler methods, but the number of interdependent methods is higher. However, default values can be used for many of these query parameter configuration methods.

2.7 Overview of SQI Methods

Table 1 provides an overview of the various methods that are described below from a workflow perspective. A detailed description of the methods is provided in the specification [15].

First, the source needs to create a connection with the target, for example by using createAnonymousSession. Once a session has been established, the query interface at the target awaits the submission of a search request. In addition, a number of methods allow for the configuration of the interface at the target. Query parameters such as

- the query language (setQueryLanguage),
- the number of results returned within one results set (setResultsSetSize),
- the maximum number of query results (setMaxQueryResults),
- the maximum duration of query execution (setMaxDuration),
- and the results format (setResultsFormat)

can be set with the respective methods. The parameters set via these methods remain valid throughout the whole session or until they are set otherwise. If none of the methods is used before the first query is submitted, default values are assumed. The specification provides default values for MaxQueryResults and MaxDuration, and ResultsSetSize.

Session Management
createSession
createAnonymousSession
destroySession
Query Parameter Configuration
setResultsFormat
setMaxQueryResults
setMaxDuration
Synchronous Query Interface
setResultsSetSize
synchronousQuery
getTotalResultsCount
Asynchronous Query Interface
asynchronousQuery
setSourceLocation
queryResultsListener

Table 1. SQI Methods

Next, the source submits a query, using either the asynchronousQuery or the synchronousQuery method. The query is then processed by the target and produces a set of records, referred to as results set. The query is expressed in a query language identified through a query parameter. In the query, reference to a common schema might be made. In synchronous mode the query results are directly returned by the synchronousQuery method. The getTotalResultsCount method returns the total number for matching metadata records found by the target operating. In case of an asynchronously operated query interface the queryResultsListener method is called by the target to forward the query results to the source.

In order to report abnormal situations (e.g., erroneous parameters or inability to carry out an operation), an SQIFault is provided, which can be thrown by all the SQI methods. A system of fault codes permits to document those abnormal situations.

3. Implementations

Since the first stable version of the specification was made available in March 2004 many learning repositories have taken advantage of SQI to connect them to the outside world. Under the auspices of the CEN/ISSS Learning Technologies Workshop the following projects took advantage of the SQI specification.

3.1 ARIADNE

The core of the ARIADNE Knowledge Pool System (KPS) [5] is a distributed network of Learning Object Repositories that replicate both (the publicly available subset of) content and metadata. On top of this core infrastructure, ARIADNE provides its members with a set of tools that are loosely coupled with the KPS [17]. Through these tools, the user community can transparently manage learning objects.

Currently, each node in this distributed network implements a relational metadata store, on top of which both a synchronous and an asynchronous SQI target are provided.

The synchronous target lowers the threshold for integrating a query API into a third party application that aims to provide access to the KPS. In this scenario, an application sends queries to one synchronous target and only downloads additional results when they are needed.

With the asynchronous target, interoperability with intermediary services is targeted. As these services usually distribute queries over a large number of repositories, asynchronous communication is more fault-tolerant. As all results are collected through one results listener, it is easier to manage and hence more convenient in this scenario.

In order to provide ARIADNE members access to other repositories, a federated search engine [18] has been developed. This engine offers a synchronous SQI interface to front-end applications. SILO, the ARIADNE search & indexation tool, uses this target e.g. to query a set of repositories. In the back-end, the federated search engine forwards the query to different SQI enabled repositories. Currently, searches are distributed into the following repositories: ARIADNE, EdNA Online, EducaNext, Merlot, Pond, RDN, SMETE, and VOCED. As all these repositories support different query languages, which do not always easily map into one another, we started with an approach where a least common denominator of all query languages was implemented. In this approach, the query only consists of search terms which are translated by each repository into a query it can process.

Currently, ARIADNE requires each partner to return a minimum of metadata fields, encoded as LOM XML: a URL, an identifier, a title and an identifier of the originating repository. The URL should resolve to the learning object. If access to the learning object is prohibited, the URL resolves to contact information. A repository identifier is necessary to give credits in a proper way to repository that yielded the results. Apart from the data elements mentioned above, all other LOM metadata fields are optional in the results.

3.2 CELEBRATE and ICLASS

The iClass adapter is a component of the Intelligent distributed Cognitive-based Learning System for Schools (iClass) [8]. It enables the end-users of "non-iClass" systems, such as the learning management systems and learning content management systems that are members of the Celebrate federation [19], to search and access iClass contents (i.e., metadata and learning objects). In iClass, metadata are stored in a peer-to-peer network of metadata repositories named "content server" and learning objects are stored in a peer-to-peer network of learning objects repositories named "content distribution system". Usually, obtaining a learning object is a two-step process:

1. Searching and evaluating metadata: Selecting a learning object that satisfies user needs on the basis of the description provided in the metadata;
2. Consuming the learning object: Getting the selected learning object at the location (usually a URL) provided in the metadata.

Using a standard and open interface is a strong requirement in order to enable as many learning systems as possible to search and access the iClass collections of learning objects. The simplicity of SQI, its ability to be used in combination with any query language and results format, and its asynchronous query mode make it a good candidate interface for searching the iClass content server.

In iClass, metadata provide an identifier of the learning object rather than its location. Actually, the adaptive and multimedia nature of the iClass learning objects combined with the peer-to-peer nature of the content distribution system makes it difficult to access learning objects directly. This is why an extra step is required to resolve the location of a learning object identified in the metadata. This "resolve-location" step is used to propagate a request for location from repository to repository until an instance of the requested learning object is found. The learning object is then moved to a streaming server close to the location of its requester and a URL from which the learning object can be consumed is returned by the content distribution system. Since this process has potentially a certain duration, the content distribution system answers to these requests asynchronously in order to ensure adequate performance of the caller, in this case the iClass adapter. It is only when a learning object is available at a given streaming server that its location is known and can be returned.

Since there does not exist an open interface for performing this step asynchronously and rather than create an ad hoc interface, it was decided to use SQI for this task as well by taking advantage of SQI independence in terms of query languages and results formats. This is achieved by adding a new "query language" (for requesting a location) and a new "results format" (for returning a location) to the list of languages and formats supported by the iClass adapter [12]. The new query language is named "`ICLASS-LO-ID`". A query in this ad hoc language consists of the requested learning object's identifier as found in the metadata. The results format is named "`URL`". A result in this format consists of a URL pointing to the requested learning object.

This solution permits the minimization of the cost of implementing a "resolve-learning-object-location" step for those learning object repositories that already use SQI for searching metadata. It is currently implemented as an extension of the SQI gateway of Celebrate.

3.3 ELENA's Smart Spaces for Learning

In order to achieve interoperability among heterogeneous educational systems, the ELENA project has implemented a novel infrastructure and software solution using various Semantic Web technologies. This infrastructure is built on the following corner stones:

1. A common API for querying, the Simple Query Interface (SQI) with a web-service based instantiation of the API,
2. A common semantic model for querying and results format presentation, instantiated in XML and RDF.
3. Re-usable components for integrating existing systems with a minimum effort based on query languages, such as QEL and XQuery.

The goal of this infrastructure is the realization of a Smart Space for Learning that allows us to integrate heterogeneous educational nodes in a semantic network and provide 'smart' access technology for it [16]. In combination with process-support for learning goal definition, personalized search, and feedback tools the educational semantic network (the 'space') plays a crucial role for supporting corporate personnel development. The broad variety of learning resource types available allows us to significantly widen the scope of learning resource choices. Hereby, potential learners are not stuck with the course offerings of a particular provider or are restricted to a particular learning format, for example, a costly classroom-based course, but can expand their search to several types of learning formats, for example, books from Amazon, and providers. One driving force for the development of this feature has been an extensive requirements analyze, which has lead to the need of integrating resources of heterogeneous formats, in educational search tools [6].

For all connected systems we created a mapping to the common schema, which enabled us to issue queries against this schema. We expressed the common schema in RDF and used QEL as a query language.

So far, we have connected several systems to our network that can all be accessed by the personnel development portal HCD Online [4]. For all systems we had to create a mapping to establish the connection between the local metadata representation and our common schema. This was a challenging task, since these systems not only use different local schemas, but also differ how they represent the metadata.

The ULI Campus stores the metadata in RDF files. Academic and commercial learning (content) management systems (e.g. EducaNext, CLIX) or course databases (course catalog of the Vienna Executive Academy) often store the metadata in relational databases. They again used DBMSs from different vendors, in our case Oracle, Postgresql, MySQL, and Firebird, which cause difficulties in the way query results are encoded. Other systems store their metadata in XML files (Metzingen Continuing Education Center, EduSource educational network of Canada). A query translation technique, that translates QEL queries into corresponding XQuery queries was developed. Based on this translation technique we were able to integrate also other systems (LASON, Knowledgebay) using a native XML database (eXist). Again a different approach was required for integrating the media store of Amazon. Amazon offers a Web Services interface, so we had access to their rich metadata, stored in a proprietary format. We developed a query translation of QEL queries into Amazon search objects, which enabled a smooth integration of the available metadata.

We faced different kinds of challenges when integrating entire P2P networks (Edutella). While other systems usually give synchronous answers to queries, in case of Edutella we had to handle asynchronous answers from the network.

4. Related Work

OpenURL [3] as well as the Content Object Repository Discovery and Resolution Architecture (CORDRA) [2] 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 [11, 22] 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 [23]. 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 [1]. 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 [10] 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 [7] 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 [13]. 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.

5. Limitations and Discussion

This paper presented the specification of the Simple Query Interface and the rationale behind its development. Although the effectiveness of the specification has been proven by several implementations, some issues still need to be further investigated.

Status Management: Methods supporting search status management could be added, for example, for cancellation of search, or query status reporting. This would allow a user at a source to cancel a search processed by a target. Similarly, query status reporting would enable a user at a source to be informed about the progress of a search processed by a target.

Explain Method and/or Capabilities Schema: No method for retrieving the capabilities of an SQI node is provided. One option here is an "explain" method. Such a method would return an SQI Profile Record that holds information on the query languages and results formats supported. Alternatively, a set of methods such as getSupportedQueryMode, getSupportedQueryLanguages, getSupportedResultsFormats, could be provided. Still another alternative is to use the SQI API itself to retrieve descriptions of the capabilities of a target (similar to the way that system tables can be queried in SQL databases). Hereby, the API could be used to answer questions like: Which query languages are supported? Which schemas are supported? Which query modes are supported? How many learning resources are available? In which format are results available? A schema describing these capabilities would be needed.

In order to be able to set all SQI parameters (queryLanguage, maxQueryResults, maxDuration, resultsFormat etc.) at once, without having to call the various individual methods separately, an additional setQueryParameters method could be introduced

SQI can be used for exchanging other things than learning resource metadata such as (language versions of) vocabularies, or evaluation data about training service providers, etc.

It would be important to find means for controlling ranking mechanisms when it comes to querying a set of targets. This would reduce the amount of data transfer, since metadata that is probably not of high user interest would not be transferred. At the same time, the quality of the results of such search would be significantly improved. Ranking mechanisms also need to be discussed in the light of privacy regulations and the capabilities of the query / retrieval semantics used on top of SQI.

6. Concluding Remarks

In order to achieve interoperability among learning repositories, implementers require a common communication framework for querying. This paper proposes a set of methods referred to as SQI as a universal interoperability layer for educational networks. At the time of writing 15 educational systems were registered at a preliminary SQI registry available at http://www.prolearn-project.org/lori/ and new implementations are ongoing.

The SQI case also shows how a standardization effort can go hand in hand with implementation work. While implementation feedback influences the standard development, only the umbrella of a standardization project can catalyze interoperability initiatives.

7. Acknowledgements

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Interoperability for Peer-to-Peer Networks: Opening P2P to the rest of the World

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ABSTRACT

Due to the information growth, distributed environments are offered as a feasible and scalable solution where Peer-to-Peer networks have become more relevant. They bring many advantages as high flexibility for peers to join or leave the network dynamically, scalability, autonomy and high resilience against peer failures. However, the use of proprietary interfaces within the network and the requirement that peers must implement them to join makes P2P networks unable to interact with other systems and environments, isolating the network as a whole. In this paper, we report on a solution based on a proxy-based architecture and semantic mappings in order to allow the sharing of content between peers within a P2P network with content from other systems outside the network.

Categories and Subject Descriptors

H.3.3 [**Information Systems**]: Information Storage and Retrieval—*Information Search and Retrieval*; C.2.4 [**Computer Systems Organization**]: Computer-Communication Networks—*Distributed Systems*

General Terms

Distributed Environments, Interoperability

Keywords

Peer-to-Peer, P2P, Proxies, Mapping

1. INTRODUCTION

The World Wide Web has become a common medium for communication among people for private, academic and business affairs. As a consequence, the amount of digital material that is sent along and stored in the network increases rapidly. Obviously, learning is not indifferent to this trend, and the amount of Learning Objects (LO's henceforth) in schools, academy and business continues to grow rapidly. As a consequence of this evolution, the focus shifts to new questions, like for example "Where shall the LO's be stored?", "Who manages them?" or "Are they easily findable?".

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In the past, due to the lack of storage capacity and network bandwidth, especially in most desktop computers, dynamic sharing of information from end user machines was prohibitively costly. As a consequence, networks of computers were mostly reduced to set of powerful connected servers. In this configuration, it is relatively simple to know which servers are available and which information is available where to whom. This is also the typical architecture in business coalitions where several companies share their assets within a network of e.g. partners.

On the other hand, with the boom of Web-based file-sharing services (e.g., Napster, Gnutella, Morpheus), peer-to-peer (P2P for brevity) networks have become more relevant. The advantages of the P2P approach include: high flexibility for peers to join or leave the network dynamically, scalability (recently it was shown that for really large networks, a hybrid solution with super-peers scales better [13]), autonomy as peers do not relinquish control over their resources and high resilience against peer failures. The main disadvantages are that P2P networks require constant management, as peers join and leave continuously (producing an extra load on the network and may slow response times during search) and the use of proprietary interfaces within the network (what usually means that only peers implementing such interfaces can query for or provide content in the network).

Obviously, peers must implement specific P2P network interfaces in order to join them. This means an extra effort for systems willing to connect which already have a different query interface. This barrier makes P2P networks unable to interact with other systems and environments. In this paper, we report on a solution for interoperability in the Edutella P2P network [12] in order to allow the sharing of content from peers within the network with content from other systems and environments outside the network. Our approach is based on a proxy-based architecture as well as on modules that provide semantic mappings capabilities.

The paper is organized as follows: in section 2 we introduce the P2P network we based our work on. The general requirements for interoperability of systems and the assumptions we made for our work are described in section 3. Section 4 describes our proxy based architecture and section 5 introduces the module with semantic mappings. The current configuration of our network is presented in section 6. Finally, section 8 concludes the paper and discusses further work.

2. EDUTELLA

Often, learning object providers do not want to abandon control over their resources to a common server, even among the members of a coalition. The same concern about abandoning control also often applies to individuals, who may not want to give away their content to any centralized repository. Distributed environments have shown to be a feasible solution for interconnection, integration and access to large amounts of information that deal with this issue. P2P networks are an example of the impact this distribution of information might have in the sharing of information. In such networks, peers can offer various services to the user that range from search and delivery to personalization and security services. In addition, they present a solution to the information growth where every learning resource provider offers its information but does not loose the control over it.

The Edutella P2P network [12] was developed with these principles as main design requirements. Edutella [12] is a schema-based P2P network for an open world scenario in which LO's are freely offered (at not charge) and everybody is able to join (no agreement with an existing member of the network is required). It has various service facilities implemented like for example query or publishing/subscription. Schema-based means that peers interchange RDF meta-data (data about data) among each other but not the resources themselves, that is, they interchange information about e.g. title, description, language and authors of a resource. This information can be queried using the QEL query language [14] (a Datalog based query language). Metadata interchange and search services provide the basic infrastructure needed to retrieve information about resources and services.

3. REQUIREMENTS AND ASSUMPTIONS

It is important to note that we consider in this paper only the sharing of metadata about LO's. While this metadata is typically available, the learning object itself might not be. Therefore, we do not deal with negotiations for the actual use of LO's by users here.

Admittedly, providing transparent access to all available repositories would be easy if all players would use the same metadata profile, query language, storage layer and communication protocol. However, this is not going to happen in the very near future due to the lack of a standard and the proprietary solutions adopted by most of them.

In the following, we explain what requirements LO's repositories must satisfy in order to achieve interoperability and which are the assumptions within our network.

Common Communication Protocol and Interface
Repositories provide different access methods and interfaces, over, among others, Web Services, different Remote Procedure Call methods, HTTP forms or even other appropriate solutions. In order to be able to communicate to each other, it is needed that they agree on a common protocol and a common interface. In this paper, we built on the methods specified in the Simple Query Interface [20] initiative (SQI for brevity), a rapidly maturing standard, using its Web Service binding.

Common Query Language
At the lower levels of data management, metadata is stored in different kinds of repositories, such as relational databases, RDF repositories, file systems, XML stores, etc. On top of this lower level, repositories expose their content through different search and query languages. Some examples are SQL, XQuery, QEL or CQL. In our system we have several wrappers implemented in order to provide access to the most common repositories (relational databases, RDF repositories, RDF files, etc...). For all them, the wrapper receives a query in QEL and transforms it into the local query language.

Common Metadata Profile
Although IEEE LOM [1] is becoming a standard for e-learning metadata, many repositories are based on specific profiles that may include extensions and specific value spaces. This means that a mapping needs to be provided [11]. This need even increases when content do not focus only on one domain but extend the content to cover several of them. There are then two possibilities here: either each system maps its schema to a second system schema (in which case we reach semantic interoperability by means of pair of mappings [2]) or a common global schema is provided and both systems must map into that common schema. Section 5 provides a longer explanation and describes a module we developed which allows both approaches.

It is important to notice that although we assume the configuration described above it could be perfectly possible to use a different query language than QEL, a different communication protocol than Web Services and a different interface than SQI though our implementations currently do not support it.

4. PROXYING INTEROPERABILITY

P2P networks are dynamic networks where peers can act as server and client indistinctly and peers might freely join and leave the network over the time. Obviously, peers must implement the specific P2P network interface in order to connect to it. This means an extra effort for systems willing to connect which already have a different query interface. This barrier makes P2P networks unable to interact with other systems and environments.

In order to solve this problem, we based our solution in proxies that are used to connect peers in a P2P network with the "outside" world. This proxies bridge two systems with different capabilities by means of implement the protocol and/or interface supported by each system respectively. This way, a proxy is able to to forward requests and responses from one system to another.

Nowadays, many systems provide their services/resources via Web Services and therefore we implemented proxies able to bridge the proprietary JXTA/Edutella protocol[1] and interface into a Web Service protocol based on the Simple Query Interface.

Taking the P2P network as a reference, there are two different desirable scenarios [18]:

1. An external consumer/client wants to query content in the P2P network. For example, let us suppose that

[1]Here we use the term "proprietary" to emphasize that this protocol is not standard for P2P networks but it does not mean it is not open. In fact, JXTA/Edutella is opensource and anyone can use it easily.

we would like to offer the content of a P2P network on a web site. The first solution would be to make the web server join the P2P network. However, the load of the server would increase considerably and even some problems could arise in case the server wants to provide content from more than one network (it would need to join all of them). A cleaner solution (and the one we follow in this paper) is to forward the query from the Web Site to the P2P network by means of e.g. Web Services and retrieve the answer with the same mechanism.

2. An external provider wants to offer content to the P2P network. We assume that providers that have already implemented a Web Service based interface will not want to spend time and money in developing the proprietary interface of the network. In contrary, they would like to reuse the one they have which would also ease its administration (as only one interface needs to be maintained).

According to these two scenarios, there are two different types of proxies. The former scenario requires the so-called "consumer proxy" and the latter the so-called "provider proxy" (names are assigned according to the role they play). A consumer proxy acts as a mediator between an external client that wants to query the network and the P2P network itself. A provider proxy acts a mediator in order to provide the content of an external provider into the P2P network.

4.1 Consumer Proxy

As described above in scenario 1, in some cases it is needed to be able to query a P2P network without the need of joining it. A consumer proxy is a peer which is part of the P2P network (and therefore it is able to send queries and receive the answers from it) and which is also able to receive requests and send responses using a different protocol and interface. This way, an external client is able to query the P2P network through the proxy.

In our implementation, a consumer proxy mediates between the Edutella/JXTA and Web Service protocols. As depicted in figure 1, it is responsible for

1. Receiving queries from external clients via SQI

2. Forwarding the query to the Edutella network using the JXTA/Edutella interface

3. Collecting the results sent from peers within the network using the JXTA/Edutella interface

4. Forwarding those results to the requester system via SQI

This simple mechanism allows any system to query the content of the Edutella P2P network without needing to implement its specific interface.

In addition, the proxy can return the results to the client application

- Asynchronously. The results are sent to the client as soon as they arrive to the proxy. This is the typical mechanism in distributed environments as not all the results are generated at once but they must be gathered from the different systems in the network.

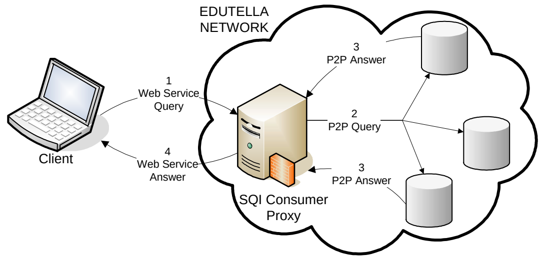

Figure 1: Consumer Proxy

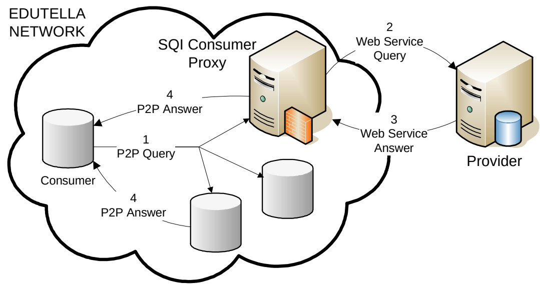

Figure 2: Provider Proxy

- Synchronously. The results are gathered at the proxy and sent together to the client. Although this is not the intuitive way for a distributed environment it could be desirable in some scenarios (e.g., in mobile devices we do not want our device to receive a new message everytime a new result arrives to the proxy but better ask for new results in a proactive manner).

4.2 Provider Proxy

In order to fulfil our scenario 2 a second type of proxy has been developed. This provider proxy is a peer connected to the P2P network which also is able to send requests and receive responses by means of a different protocol and interface. Therefore, it is able to forward queries to external providers and receive their answers providing their content to the network.

As in the the case of consumer proxies, our provider proxy mediates between the Edutella/JXTA and Web Service protocol. As depicted in figure 2, it is responsible for

1. Receiving queries from peers in the network using the JXTA/Edutella interface

2. Forwarding them to the external provider via SQI

3. Receiving the results from the external provider via SQI

4. Sending them back to the peer that sent the query using the JXTA/Edutella interface

Due to the asynchronous nature of a P2P network, it is possible for the provider proxy to receive the results from the external provider in a synchronous (e.g., in case the external provider is a relational database) or asynchronous (e.g., if the external provider is another distributed environment) way.

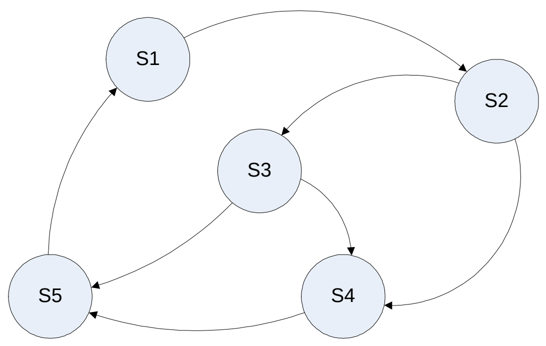

Figure 3: Graph representing 1-to-1 mappings among sources

5. SEMANTIC MAPPINGS

In previous sections, there have been described some of the basis for interoperability, namely common protocol and interfaces (or the use of proxies as presented in section 4) and common query language (or the use of appropriate wrappers). Although these elements ensure that two systems are able to talk to each other it does not guarantee that they will be able to understand each other due to the possible use of different schemas/ontologies.

Nowadays, there is a big effort on standardization of domain ontologies. For example, Dublin Core [4] is intended as standard for cross-domain information resource description and LOM [1] describe attributes required to fully/adequately describe a Learning Object. Unfortunately, still many proprietary schemas are used in each domain (e.g., database schemas within companies). For example, Dublin Core suggests using the attribute “creator” to describe the responsible of making or writting a resource. While many repositories probably follow this suggestion when annotating their resources, others might use e.g., their own attribute “author” instead. In order to bring interoperability among them, data integration in the form of semantic mappings is needed. In this context, a semantic mapping is a transformation from one data model to another data model according to a set of rules (mappings).

In a distributed network we can distinguish among several integration possibilities:

- If no virtual and unified schema is assumed in the network, then systems within the network must provide pairs of mappings between each two systems. Then the distributed network can be seen as a directed graph (as shown in figure 3) in which each arrow represents an available mapping from one node to another. Then, they can be applied transitively in order to infer new mappings which were not explicitly defined. This is specially useful in P2P networks as it is usually not possible to enforce a unique and common schema. Authors in [2] study this approach and provide algorithms to estimate the correctness of the inferred mappings.
- If a virtual and unified schema is assumed, there are two approaches for providing integration between the global schema and local schemas at the sources:
  - Global As View (GAV) [7]. In this approach, the global schema is expressed in terms of the data sources (en example is depicted in figure 4).
  - Local As View (LAV) [23]. In this approach, each source is defined as a view over the global schema. This way, the global schema is specified independently from the sources (an example is depicted in figure 5).

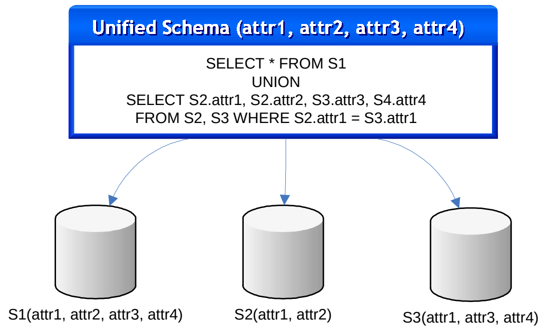

Figure 4: Global As View approach

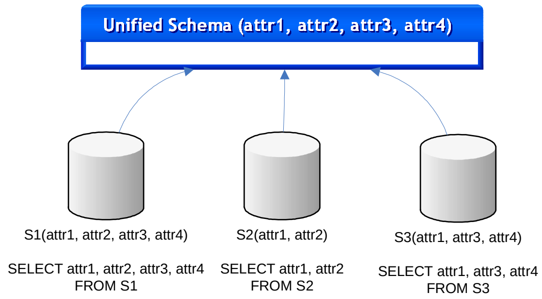

Figure 5: Local As View approach

A discussion of both GAV and LAV is provided in [10] as well as an introduction to “query rewriting” mechanisms. Query rewriting is the process in which a query expressed in the global schema is reformulated into another query according to a set of mappings. This is the mechanism we have used in the mappings module we describe subsequently.

Query Rewriting Module

In order to provide semantic interoperability in our network, we have developed a module which transforms a query q_1 into a query q_2 according to the set of mappings specified. This module is intended to work on pairs of mappings without a unified schema or in Local As View integration approaches.

QEL, the language we use in our network, is based on datalog. In addition to standard datalog constructs, QEL includes some built-in predicates. Taking into account that in our network only metadata (in RDF) is queried and exchanged, the most important one is

qel:s(Subject, Predicate, Object)

which according to the QEL specification [14] “is true if Subject and Predicate are anonymous or non-anonymous RDF resources, and Object is a non-anonymous or anonymous RDF resource or an RDF Literal and the triple Resource

Predicate Object exists in the RDF data". For example, a query like

?- qel:s(X, dc:title, 'Artificial Intelligence').

will return all the resources which title is "Artificial Intelligence". Other useful built-in predicates are $qel : like(X, Y)$ ("used to determine whether an RDF literal or URI contains a string as a substring"), $qel : lessThan(X, Y)$ and $qel : greaterThan(X, Y)$ which are used to compare two RDF literals.

Given this short introduction to the language, let us present the following simple query that we will use for our examples in the rest of the section:

@prefix qel: <http://www.edutella.org/qel#>.
@prefix dc: <http://purl.org/dc/elements/1.1/>.
@prefix lom: <http://ltsc.ieee.org/2002/09/lom-rights#>.
?- qel:s(X, dc:title, Title),
qel:s(X, dc:description, Description),
qel:s(X, dc:creator, Creator),
qel:s(X, lom:cost, Cost),
qel:s(X, dc:subject, Subject).

This query retrieves all the resources with title, description, creator and subject attributes from Dublin Core and the cost from LOM. The first lines of the query with prefix "@" define the namespaces.

Given such a query, we identified the following requirements

- The query specifies a property[2] that does not exist in the source but the source has an equivalent property which could be used instead of. For example, if one data source has its own schema where it uses the property "abstract" instead of the property "description" from the Dublin Core standard.

- The query specifies a property and one value according to a specific taxonomy and the source uses a different taxonomy. For example, if the query searches for resources with dc:subject following the ACM classification [3] and the data source does have dc:subject but it follows the Dutch Basic Classification [5].

- In general, if one of the attributes is not available at the data source, the whole query fails[3]. However, it might happen that although the source does not have explicitly such an attribute, all its resources would share the same value if it existed. For example, assume a repository where all the resources are offered for free. This repository does not have the property "lom:cost" because it is not needed. However, in case one query contains this attribute, the whole query would fail (even if the constraint in the query is "lom:cost = No" which is actually true though it is not annotated). In such a case, it is desirable to assign a default value to all the resources in the data source without having to explicitely annotate all the resources of the repository.

In order to satisfy these requirements we developed a module that performs two types of mappings and one extra transformation: property mapping, property-value mapping and default value transformation (see table 1 for the whole list of mappings and [15] for technical details).

[2]In the paper we will use property and attribute indistinctly
[3]Here we assume that only conjunctives queries are sent. Edutella and QEL support disjunctive queries but we will omit them here because of simplicity

Property Mapping

A property mapping specifies how one property in the query must be reformulated. Its general syntax is

$$(X, p1, Z) \leftarrow (X, p2, Z)$$

When the mapping module receives a query that contains the triple $qel : s(X, p1, Z)$ it rewrites it into $qel : s(X, p2, Z)$. Using our example query and taken into account the requirement in which the source does not contain the property "dc:description" but "own:abstract" (where own stands for their local namespace), it is possible to define the following mapping:

$$(X, dc : description, Z) \leftarrow (X, own : abstract, Z)$$

This mapping is currently a 1-to-1 mapping, that is, there is only one triple at each side of the mapping (separated by the left arrow) but it is also possible to specify 1-to-2, 2-to-1 and 2-to-2 mappings (see table 1). For example, suppose the author in the source is encoded using the property full name from the vcard ontology [19]. In such a case, we need the following mapping

$$(X, dc : creator, Z) \leftarrow (X, dc : creator, Y), (Y, vcard : fn, Z)$$

in order to abstract from the internal representation at the source.

Property-Value Mapping

The mapping described above assumes that one property is completely mapped into another one. However, mapping can be brought to the granularity of values. A property-value mapping applies only when a query contains not only a specific property but also a specific value for that property and then both of them map into other (possibly the same) property and value. Its syntax is

$$(X, p1, v1) \leftarrow (X, p2, v2)$$

For example, assume that our example query uses the ACM classification in the property "dc:subject" and our source does have the property "dc:subject" but annotated with the Dutch Basic Classification taxonomy. We could use several mappings of the form

$$(X, dc : subject, 'Software/Programming\_Languages') \leftarrow$$
$$(X, dc : subject, 'Computer\_Science/Programming\_Languages')$$

to specify how the different values from the ACM taxonomy map into the Dutch Basic Classification.

In the same way as the property mapping, it is possible to extend this 1-to-1 to 2-to-1, 1-to-2 and 2-to-2 mappings.

Default Value

Property and property-value mappings provide rules which define how some triples are reformulated into another triples. The way default values work is a bit different. The properties especified in default values do not exist in the source repository and therefore they must be removed (not just reformulated) in the new query.

Following this approach, when a query is received by our mapping module, if there exists in the query any occurrence

Table 1: Types of Mappings

Mapping type	Description
1-to-1 property mapping	$(R, p1, O) \leftarrow (R, p2, O)$
1-to-1 property-value-value mapping	$(R, p1, v1) \leftarrow (R, p2, v2)$
2-to-1 property mapping	$(R, p1, O), (O, p2, L) \leftarrow (R, p3, L)$
2-to-1 property-value mapping	$(R, p1, O), (O, p2, v1) \leftarrow (R, p3, v2)$
1-to-2 property mapping	$(R, p1, L) \leftarrow (R, p2, O), (O, p3, L)$
1-to-2 property-value mapping	$(R, p1, v1) \leftarrow (R, p2, O), (O, p3, v2)$
2-to-2 property mapping	$(R, p1, O), (O, p2, L) \leftarrow (R, p3, O), (O, p4, L)$
2-to-2 property-value mapping	$(R, p1, O), (O, p2, v1) \leftarrow (R, p3, O), (O, p4, v2)$
Default value	$(p \leftarrow v)$

of a property specified in the default values, this ocurrence is temporarily removed. This way, the query is sent to the local repository without that property (otherwise the query would fail) and a resultset is returned. However, this resultset still does not contain the default values that were requested (the properties previously removed) and therefore they must be added. Therefore, default values are added to each of the rows in the resultset returned by the repository.

For example, following with our example query, suppose that our source repository does not have the property "lom:cost" but all the resources in the repository are free of charge. We can then define the following default value

$$(lom : cost \leftarrow' No')$$

This way, any triple in the query referring to the property "lom:cost" would be removed before the query is sent to the repository and added subsequently to the returned resultset together with the default value "No".

6. DRAWING UP THE WHOLE PICTURE

Using the elements described previously in this paper, it has been possible to bring interoperability to Edutella providers (Media Library, Nature and Technology and Confolio System), external consumers (ARIADNE) and external providers (ULI and ARIADNE) within the context of the EU Network of Excellence Prolearn [17]. The picture with the whole architecture is depicted in figure 6 and the following subsections provide a brief description of each of the systems involved.

6.1 Edutella Nodes

In this section we introduce some of the existing peers which are currently connected directly to the Edutella P2P network. All of them are mapped into a common schema (LAV approach). In addition, all the modules used by the peers (including the mapping modules) make use of the highly configurable java library provided in the Edutella project and that it is available from the Edutella CVS (at `http://edutella.jxta.org/`). Some of them, like the mapping modules, are implemented in a way that they can also be used in environments where the Edutella P2P network is not present.

6.1.1 Media Library - Swedish Educational Radio and Television

The media library is a joint project between the KMR group-[9] and the Swedish Educational Radio and Television-[24] - UR in swedish - to provide their educational resources in the form of television programs, radio shows, instructional material, web sites, physical distributions on CDs and videos etc. The educational resources are expressed using the RDF-binding of IEEE/LOM, qualified Dublin Core and some extensions specific to UR. For storage solution we use SCAM-[16] which is a layer on top of Jena2 providing access control on metadata records and a more high-level API. A database provides persistance according to the Jena2 database layout. Queries in the QEL language is directly translated to SQL and passed to the database. We use a library called GETSQL[4] for doing the translation. GETSQL can handle disjunction, rules, most of the constraints, outer join, and also the retrieval service [6] of Edutella.

The peer does two kinds of semantic mappings:

1. simple to qualified Dublin Core mapping. Most queries ask for a title via the predicate dc:title and expects a literal as object. In the Qualified schema there is an intermediate rdf:Alt containing language translations of the title. The mapping is done by rewriting the query to contain an intermediate variable that is not visible in the result.

2. a property-value mapping between two swedish taxonomies, one for the library community and the other for the SLI (Swedish Learning material on the Internet) community.

6.1.2 Nature and Technology - Swedish National Agency for Education

This peer provides educational resources provided by Swedish highschool teachers to be shared. The educational resources are of several kinds, e.g. experiments, articles, projects, tests. The resources are expressed with simple Dublin Core and a few extra properties. The classification is done via the SLI community's taxonomy. The storage solution is SCAM and the GETSQL library is used to translate the QEL queries to SQL here as well. The mappings provided are similar as for the media library with the difference that here we translate from qualified to simple Dublin Core.

6.1.3 Confolio system - portfolios hosted at Royal Institute of Technology

The confolio system is another application built on top of SCAM. It provides users with a directory structure where

[4]GETSQL is expanded to 'Generic Edutella query language Translation to SQL' and is available from Edutella CVS. Its modular design allows the database and database schema to be changed easily.

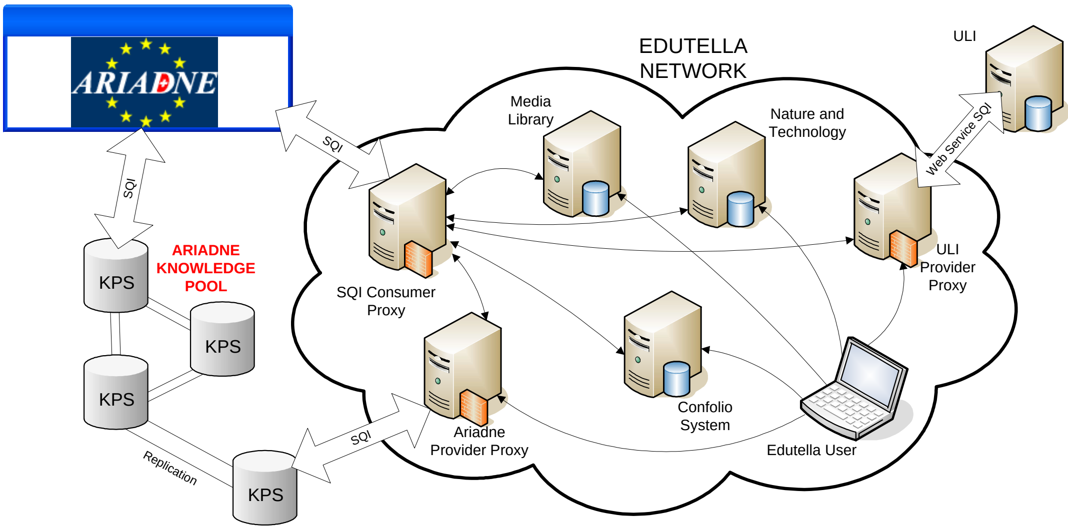

Figure 6: Whole Architecture

they can upload files, store links, or just pure metadata e.g. events, persons, books, concepts. The confolio system allows you to define what kind of metadata that you want to provide for a specific type of resource (multiple types on a resource results in the union of the metadata). A consequence of this flexibility is that there is no specific schema since it depends on what people are doing with the system, on the other hand there is a lot of reuse of Dublin Core, IEEE/LOM etc.

6.2 External Consumers - ARIADNE

In its aim to facilitate both academic education and corporate training, the ARIADNE Foundation supplies its members with tools and methodologies for producing and reusing learning objects. The core of these services is a distributed network of repositories that replicate content and metadata. Doing so, each node contains a copy of all metadata instances. The LO's however can only be replicated to other servers if no download restrictions apply to them. This infrastructure, also known as the Knowledge Pool System, enables the ARIADNE user community to transparently manage learning objects.

The ARIADNE Knowledge Pools offers a client-server approach, where applications can query the ARIADNE knowledge pool through a web services layer. As metadata is replicated in this distributed network, there is no need to federate queries in ARIADNE. However, in order to provide these applications with access to a bigger pool of learning objects, a federated search layer has been built on top of different SQI targets (Edutella, ARIADNE, Merlot, Celebrate) enabling applications to search beyond the borders of the ARIADNE knowledge pool.

Technically, ARIADNE contains metadata information of LO's stored in a relational databases, and the results returned while answering queries is delivered as XML instances following the LOM standard. This information is transformed by means of XSLT stylesheets in order to conver it into RDF.

Currently, ARIADNE is connected to Edutella as external consumer (Edutella content is offered in ARIADNE) and as provider (the content of ARIADNE is offered in Edutella) [21]. As a provider, currently only an ARIADNE KPS node is interconnected and, as a consequence, only ARIADNE material (and not from other systems connect to ARIADNE) can be queried from the Edutella network. Figure 6 shows the current configuration.

6.3 External Providers - ULI

The course repositories ULI [22] (Virtual Computer Center Curriculum in Germany) has been developed under the ULI project (University teaching network for computer science) which tries to establish an exchange of course material, courses and certificates in the area of computer science. Resources include Course-s and Unit-s of study.

Though the courses usually differ in the kind and amount of learning materials they use, their use of learning resources is surprisingly homogeneous. The average course is divided in 6 to 7 units or knowledge modules which themselves can be split into 3 to 7 learning resources. This leads to an average number of about 35 learning resources per course, with a learning resource being the slides of the lecture, a video or any other set of pages dealing with on subject.

Technically, ULI repositories are based on RDF files with Dublin Core and LOM metadata and they are currently accessed by means of the RDQL query language. In addition, mappings and default values have been specified in order to convert to a global schema.

7. RELATED WORK

In [18], the authors describe the two scenarios, consumer proxy and provider proxy, and implemented a translation from the JXTA protocols to Web Services and viceversa. In this paper, we enrich our proxies with the possibility of mapping query languages and schemas. In addition, [18] does not use any specific interface but wrap the java objects while in our approach we are using the SQI standard innitiative.

[8] presents an interesting approach for interoperability of Learning Repositories. Authors briefly present an "ECL Gateway" which is similar to our idea of proxies. They im-

plemented a translation between ECL and a P2P protocol. In our paper we extend this idea separating the two different scenarios, consuming and providing information, and describing in detail how proxies work and how mappings can be performed. In addition, we add our work on default values which, to our knowledge, has not been described yet in any paper.

8. CONCLUSIONS AND FURTHER WORK

In this paper, we showed how by means of proxies and semantic mapping it is possible to connect a P2P network like Edutella with other systems outside the network. These proxies provides the necessary mediation between the different protocols and intefaces and semantic mappings overcome the problem of schema heterogeneity. Both together allow external systems to query and provide content in the network avoiding the isolation of P2P networks from the rest of the world.

In this paper we have focused the interoperability problem on search. However, although this is of course the most important service, there are still some other issues that must be researched. One of the main topics we plan to research on in the future is distributed ranking algorithms. Currently, a lot of research has been done around web ranking (e.g., on the Web) and merging of ranking lists (e.g., on meta-search engines). However, the former assumes that relationships of the form of links exist among resources in different repositories and the latter assumes that there exist overlapping in the content different repositories offer and rank. Unfortunately, this does not apply in a P2P network and the only existing measures are based on trust/reputation of the peers.

In addition, a challenge for the Local As View mappings described in this paper is how they would work in combination with Edutella Retrieval. Edutella Retrieval [6] is a recent addition in Edutella which allows information to be retrieved without requiring it explicitly in the query which would unneccessary eliminate valid matches. Since what is retrieved is not explicitly stated in the query it is far from obvious how to detect which mappings to apply.

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Query translation between RDF and XML: A case study in the educational domain

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General Terms

RDF, XML, Semantic Web, eLearning

ABSTRACT

RDF is used as a central building block for the Semantic Web. Considering providers of learning resources, it is commonplace to store and exchange meta-information in XML rather than RDF. Instead of transforming meta-data artefacts into RDF, we integrate these meta-data by translating users' queries issued against RDF into queries over XML meta-data. We demonstrate the applicability of our query translation method in a concrete application scenario taken from the educational domain.

1. INTRODUCTION

The World Wide Web becomes more and more a marketplace for various informational goods and services. Providers of educational materials and services intensively use the Web as distribution channel and search engines help learners to find and access appropriate learning resources. The Semantic Web vision [1] depicts a possible alternative to this situation: Learning resources are described with a set of meta-data linked to some ontology and human searchers can issue queries against these ontologies to bring to light the learning resources needed. There are still many efforts needed to turn this vision into reality, even for a limited domain.

In this paper we concentrate on one particular issue we faced when trying to realize an Educational Semantic Web. The W3C has established several working groups to create standards for meta-data formats and ontology representation (RDF [2], OWL[3]), but currently there is a considerable amount of meta-data about learning resources available which is exported into and exchanged in XML rather than RDF. Therefore, we sought for a technique to integrate these meta-data with meta-data already represented in RDF. In particular, we analyzed how to transform queries expressed in a specific query language designed for RDF, QEL (Query Exchange Language, [4]) into corresponding XQuery queries [5] that can be evaluated over XML repositories.

The paper is organized as follows: Section 2 describes the context and motivation of our work. In Section 3 we analyze mapping strategies originally proposed for integrating XML sources and their applicability to our problem. Section 4 then introduces our transformation method. Section 5 presents related work and Section 6 concludes the paper.

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2. ELENA – INTEGRATION IN AN EDUCATIONAL CONTEXT

In the scope of ELENA[1] we are developing a mediation infrastructure for learning services including web-based, but also traditional courses and learning materials. A common use scenario is the following: Providers offer meta-data about learning materials and services at their web portals. The web allows users to search for, visit and scan these pages for relevant courses or learning materials. Our goal is to improve this situation and provide an infrastructure that enables users to search for relevant information and create their own marketplace for learning resources. This joint effort can be seen as a step towards an Educational Semantic Web, as envisioned for example in [6].

The mediation infrastructure, called Smart Spaces for Learning [7, 8], integrates meta-data provided by a number of learning service providers. Though it is not intended to build a web-scale application, the integrated information opens way for personalized services and intelligent applications. An operative prototype designed for a human resource development scenario using the mediation infrastructure is available at http://www.hcd-online.com/ubp.

The currently connected providers cover a large spectrum of heterogeneous sources, ranging from *EducaNext* [9], a web-based knowledge brokerage platform, and *ULI*[2], a German academic network for sharing learning resources, to *Amazon*'s media store[3] or the Edutella P2P network [10].

2.1 Integration Architecture

Learning object repositories hold information on learning objects (meta-data). Our research was motivated by the need to integrate the meta-data available at distributed and heterogeneous learning repositories.

We apply the Learning Object Resource Interoperability

[1] See http://www.elena-project.org
[2] See http://www.uli-campus.de
[3] See http://www.amazon.com

(LORI) framework [11] which has lately become subject of an international standardization process. LORI is a layered integration architecture, which defines services to achieve interoperability among learning repositories. The framework includes core services, for example authentication, session management and application services like query management or provision facilities.

In most of the systems we aim at integrating meta-data already stored in RDF (*real* RDF repositories) or being bridged to RDF (*virtual* RDF repositories). The latter case we experienced with various systems storing, providing or exchanging valuable meta-data in XML. The providers of these learning repositories cooperate during the integration process in different manners, either by publishing their locally used meta-data schemes or by providing mappings to ELENA's common schema.

3. MAPPING STRATEGIES

In this section we review some generic mapping strategies originally outlined for the integration of XML only. We examine these methods briefly and evaluate in how far they are applicable to our integration scenario.

The automated or assisted process of creating mappings of two different representations of data is called *representation matching*. In our paper we assume that mappings are created manually unlike discussed in [12, 13]. The conceptualization and representation of *matchings* or *mappings* differ in various domains of application, e.g. schema integration, data warehousing and data mining, knowledge base construction and finally information integration systems [12, 13]. We restrict our work to the domain of information integration aiming at incorporating heterogeneous XML sources into a RDF environment. Therefore, we consider conflicting or at least varied structured representations of meta-data characterizing learning resources as subject to our integration method. These meta-data representations might be either encoded in XML described by Document Type Descriptions (DTDs) or XML Schemata (XML/S) or in RDF described by RDF Schema (RDF/S). This concrete run-time scenario has also been coined *semantic query processing* [13] as opposed to the practice of establishing mappings when designing federated information systems.

The term *mapping* denotes a set of *mapping statements* consisting of *mapping elements* and *mapping expressions* with the former declaring correspondences between representation or syntactic elements of the source representations. The latter describe the very nature of these relationships. Mappings might be either organized as *mapping relations* or *mapping tables*. The latter denote relations allowing for the usage of variables [14].

3.1 Mapping between different XML representations

Aguliera et al. [15] compare several approaches for mapping XML data. Here we outline their cases and analyze whether they can be applied to our RDF scenario. The mapping strategies discussed consider different levels of structural information and distinguish three types of mappings between XML trees.

Nevertheless, the mapping strategies are derived from general tree-structured data so that they can equally be applied to other data models than XML. As the following sections will show, various follow-up approaches, in particular borrowing from conceptual modelling, have applied these mapping strategies in their specific integration scenarios. The terms *node* and *path* are considered as general as possible for the purpose of the following evaluation. It will turn out that the actual conceptualization of nodes and paths for the respective mediating representations differ considerably from approach to approach depending on the underlying data models.

3.1.1 node-to-node (tag-to-tag)

When establishing correspondences between individual nodes – referring to XML elements in this case – mappings do not consider the document structure. Therefore, they do not take into account semantic information expressed in structural configurations. Mapping relations resulting from node-to-node mappings consist of tuples of mediating nodes and multiple corresponding nodes in the local information representations. The query translation algorithm simply replaces the label of a mediating node with its local correspondences in the respective query body issued against the mediating schema.

Figure 1 illustrates this mapping style for two mediating nodes, a learning resource and its title. A *node-to-node* mapping relation would thus be defined as MR1 whereas the resource's title would be identified by the local sources' elements in MR2:

```
MR1(LearningResource, Publication)
MR2(Title, Title)
```

If we consider both the mediating schema and its local sources being expressed in XML, a query over the mediating schema might be expressed in XPath as e.g. */LearningResource/Title*. An algorithm based on these mapping relations would, for instance, generate a corresponding XPath statement over local source A of the form *//Activity/ActivityLabel*. As for local source B, the translation would result in a corresponding query *//Publication/Title* with the latter being invalid considering the structure of this repositorium. Therefore, node-to-node mappings will certainly result in erroneous query transformations as the mappings and mapping relations do not reflect the structural configuration of the underlying information sources.

Node-to-node mappings or *atomic element-level mappings* [13] are thus easily perceivable but considerably limited in terms of mapping precision and mapping complexity. The increased complexity is due to the multiplicity of node-to-node mapping resulting from the entire set of possible correspondences.

3.1.2 tree-to-tree

This mapping strategy resembles characteristics of defining and creating *views* in a relational setting. Views as notion and concrete technique have been discussed both as derived and encapsulating constructs, for example rules or classes, and as *subschemas* of any underlying schema-like representation. In either case, views are essentially query definitions or unions of individual query bodies over a targeted schema. Tree-to-tree mappings are comparable to defining views inasmuch as any node in the mediating representation points to a set of concrete, isolated queries over the various source representations. The union of these individual query definitions bound to individual mediating nodes describe the entire mediating representation and thus

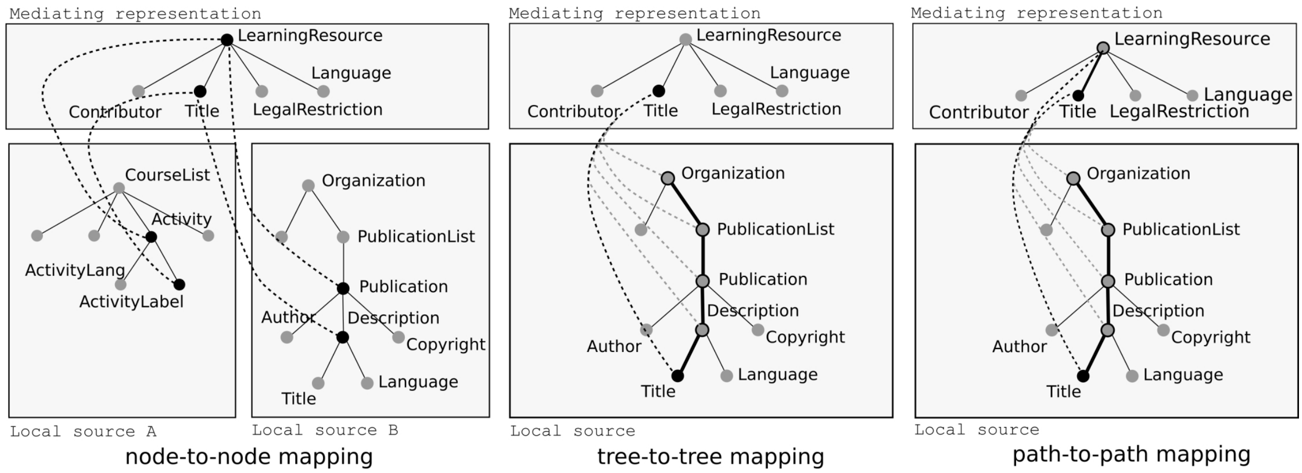

Figure 1: Mapping strategies

its structure. Tree-to-tree mappings may therefore be conceived as an ordered set of node-to-path mappings from the mediating representation's perspective in a global- as-view setting. In Figure 1 only such a single node-to-path mapping stands representatively for additional ones needed for each node of the mediating representation. To sum it up, tree-to-tree mappings are stored queries or unions of subqueries over local information sources, XPath expressions in this case. Figure 1 depicts such a scenario. The mapping relations outlined above for local source B transform into:

```
MR1(LearningResource, /Organization/
    PublicationList/Publication)
MR2(Title, /Organization/PublicationList/
    Publication/Description/Title)
```

The query */LearningResource/Title* would therefore be translated into a single view-generating query. Unless the established mapping relations are extended to mapping tables, this basic practice of tree-to-tree-mappings would create a certain redundancy in terms of irrelevant mapping elements i.e. path constructs. This becomes evident when considering that *MR1* is implicitly reflected in any mapping pointing to subtrees below the entry node. Introducing an appropriate variable syntax and therefore extending mapping relations to mapping tables would allow for a certain reduced mapping complexity. These more flexible mapping tables could take the following form:

```
MT1(LearningResource, /Organization/
    PublicationList/Publication)
MT2(Title, MT1/ActivityLabel, MT1/Title)
```

This mapping strategy, similarly described as *higher-level* or *non-atomic element-level mappings* by [13], considers a high level of structural information. These view-like mappings do not cause redundant or irrelevant mapping statements for a single local source. Nonetheless, they do not allow for any factorization between mappings of different local sources although there might occur considerable structural similarities within a common domain, as the educational one for instance.

3.1.3 path-to-path

The next available mapping strategy aside from node-to-node and tree-to-tree mappings is called *path-to-path*. In this case correspondences between paths in the mediating representation and paths in the various local source representations are created.

The conceptualization of path constructs varies considerable in various approaches adopting the path-to-path strategy depending on the data models used for the mediating representation and local information sources. Early contributions defined them as conventional XPath location paths or derivates thereof considering only XML element types, so called *tree paths* [16, 17]. XPath location paths as mapping elements are not limited to XML-like mediating representations. A recent approach uses location paths as mapping elements to create correspondences with a mediating representation based on the datalog model (see [18]). Follow-up approaches (see e.g. [19, 20, 21]) employed conceptual models (Entity-Relationship model, ORA-SS and others) as mediating representation and offer a different path concept. Amann et al. [21] identify for instance two types of so called *conceptual paths*: On the one hand *role paths*, on the other hand *concept paths*. The former are either constituted by single roles, i.e. ER relationship types, or a conjunction of single roles, also referred to as *derived* roles as they link two distanced concepts directly. Concept paths consist either of a single ER entity, i.e. concept, or a chain of concepts and roles. Considering paths in RDF we adopted the concept of *triple paths* as mapping element for ELENA's mediating representation (see Section 4.1 for details).

Mapping between paths resembles and combines major characteristics of the previously sketched techniques: On the one hand it inherits the property of node-to-node mappings allowing multiple occurrences of a mapping element, for example nodes and paths respectively, within the same set of mapping relations. On the other hand they increase the degree of how much structural information is considered, though to a lesser extent than tree-to-tree mappings. They incorporate rather substructures than the entire structural configuration of mediating and local representations into the mapping.

An example for path-to-path mappings can be constructed within the scope of Figure 1. The path /LearningResource/Title can be mapped to the local path //Organization/PublicationList/Publication/Description/Title for local source B.

As compared to tree-to-tree mappings, this last strategy does not preserve the structure of entire (sub-)trees but rather the structural context of single nodes. At the same time it allows for the factorization of mapping elements, i.e. path constructs, as path structure might reveal considerable similarities for a single and even different local sources. Therefore the path-to-path approach represents an option that inherits advantages of both previous strategies and allows for the design of a mapping language convenient for the human integration engineer.

4. TRANSFORMING QEL QUERIES INTO XQUERY

4.1 Mapping language

In the following sections we outline a language for setting up mappings between elements of ELENA's mediating representation expressed in RDF and local educational information sources casted in XML. The mapping information is then used by the query translation algorithm in order to transform QEL into corresponding XQuery queries.

A single mapping is an XML application which comprises three logical sections: a header section and two body sections.

4.1.1 Defining the target

We distinguish between logical and physical information sources. A logical source may contain several physical ones, a logical information source does not necessarily correspond to a single XML document. A logical entity might be either casted in a single XML document or scattered across a collection of XML documents. The header section of the entire mapping requires to state a single, logical information source.

The header section may take the following form when applied to information source B in Figure 1, assuming first that we are dealing with a both logically and physically sole information source:

```
<q2xq:source id="pub" document="sourceB.xml"
    contextNode="/Organization/PublicationList/
    Publication" />
```

The *q2xq:source* element contains three attributes. First, name allows for defining a name for a physical – and under the current assumption also logical – information source . The second attribute provides information on the storage name of the XML information source, i.e. a XML Document either physically stored in the SQI target's filesystem or in a native XML data base system such as *eXist* [22]. The last attribute, *contextNode*, marks the node of entry or rather the *absolute context node* for the resulting XQuery query statement. It is absolute insofar as it serves as absolute point of reference for the subsequent mapping statements in the second body section.

Take the example of local source B in Figure 1. The source's structure embeds the actual learning resource, i.e. the Publication element, into a superordinate element, i.e. PublicationList, that can be structurally and semantically neglected in the subsequent correspondences between identified mapping elements. In this respect, the header section provides an optional selection of relevant subtrees of the source's document structure and thus facilitates establishing the actual mapping statements. In terms of the resulting XQuery expression, the header element will be casted in a FLWOR expression. In other words, the values of *document* and *contextNode* will constitute the required input expression of such a FLWOR statement.

We now drop the initial assumption the logical information source under consideration consists only of a single physical XML Document. We continue our considerations assuming a logical source that is splitted up into several physical carriers. Just imagine the aforementioned example featuring a publication list and publications being a generic XML dump of a relational storage system. In that case, the original relations publication list and publications will constitute two separate XML documents to be joined.

```
<q2xq:source id="publist" document="sourceB_1.
    xml" />
<q2xq:source id="pub" document="sourceB_1.xml"
    />
```

In order to combine these two physical data sources into a single logical one, the proposed mapping language provides another bridging facility to XQuery's FLWOR expression and its WHERE clause [23]. By expanding the header section with *q2xq:source* elements for each physical information source, the query translation algorithm is instructed to create a *join* between them.

4.1.2 Setting-up mapping statements

Referring to the methodological taxonomy presented in Section 3, we opted for a path-to-path mapping strategy for the reasons already discussed. Therefore, the mapping elements to be related to one another are *path constructs*.

Paths in RDF: In a general sense, a RDF path is considered a sequence of the form *node - predicate - node* as depicted in [2]. To put it differently, paths are equated with the concept of triples in RDF and corresponding serialization formats such as N-Triples [24] for instance. Therefore, RDF paths can be conceived as directed sequences of the form *subject node - predicate or property edge - object node* and might be coined triple paths.

Triple paths especially fulfil the requirement of unambiguity in order to be used as mapping elements. The RDF model can be seen as a directed, vertex- and edge-labelled graph. The labels attached to graph edges correspond to RDF predicates or properties. This raises the issue of unambiguity of edge labels or predicates as the multiple occurrence of predicate titles is not restricted or prohibited in the RDF syntax.

Consider first that path constructs in RDF are only identified by their predicates' labels. This assumption can be represented in a N-Triples-like style with <∗> denoting an arbitrary, unspecified node element:

```
<*> <predicate> <*> .
```

Consider the two examples given in Figure 2. Both cases refer to the case of a publication list linking to publications but in two different settings. Setting 1 shows a publication list (n_1) that contains a single publication (n_2) both having either one or more detailed descriptions (n_3, n_4, n_5) attached. Setting 2 exhibits a publication list (n_1) containing two publications (n_2, n_3) with both of them being described in further detail (n_4, n_5) but having the same title (n_6). The fact that these two settings point to the multiple occurrence of semantically identical predicates, both at the same or different structural levels, might be considered an artifical construction. Whereas it is not appropriate with respect to designing mediating representations for meta-data, it is not restricted or prohibited in the RDF model as such. Therefore, this assumption is satisfactory to outline the problem of unambiguity. When identifying paths in RDF only by edge

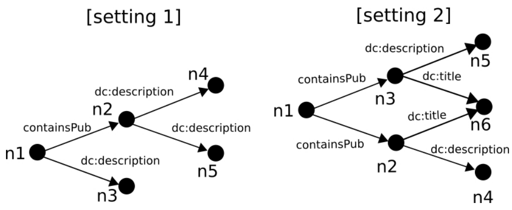

Figure 2: Unambuigity of paths

labels, only two distinct paths can be identified in Setting 1, i.e. containsPub and dc:description. Establishing a single correspondence between dc:description and a corresponding XML element at the local information source containing description information about a learning resource would not be unambiguous as it would be equally applied to describe the entire publication list. Even establishing multiple correspondences would not resolve the problem as they could not be assigned uniquely.

In order to resolve the problem of unambiguity, a first step could be the further identification of paths by considering further subject or object nodes:

<subject> <predicate> <*> .

<*> <predicate> <object> .

In Setting 1 the predicate path dc:description could only be located twice provided that the source node, i.e. the subject, is considered. When identifying a path by its target node, i.e. the object, all three occurrences could be uniquely determined. The latter is not correct when applied to Setting 2 as the predicate path dc:title could not be characterized clearly by its target node. Therefore, considering only a single identifier, either subject or object node, does not allow to construct unambiguous correspondences with mapping elements at the local information sources that hold in both settings.

Concluding from that, resolving the issue related to identifying paths unambiguously can only be achieved by pinpointing paths both by their source and object nodes, i.e. the subject and object connected. We therefore consider in accordance with the RDF specification *triple paths* the appropriate path construct and mapping element in the scope of our mapping language. Triple paths are thus RDF predicates extended by two *node identifiers*.

<subject> <predicate> <object> .

The first body section of a mapping thus contains an unambiguous set of triple paths, expressed in a straight forward XML format. Referring to Figure 1, the triple paths that are derived from the simplified mediating representation describing learning resources are shown in Example 2 at lines 6-9.

The triple notation is entirely adopted with the attribute *id* of each triplepath element serving as the binding variable to the right-hand or XML side of the mapping statements.

Paths in XML: Considering XML and the query model targeted, i.e. XQuery, path constructs are gathered from XQuery 1.0 and XPath 2.0 data model. XQuery path expressions are considered proper *location paths* as in XPath 1.0 [25] and are therefore identical to XPath 2.0. Nonetheless, the common data model of XQuery 1.0 and XPath 2.0 introduces various modifications compared to XPath 1.0. These include ordered sequences of nodes as return type of path expressions instead of unordered node-sets and both limitations and extensions in terms of location steps available, e.g. a reduced set of axis, generalized predicate statements and minor syntactic deviations in terms of comparison operators etc [23]. The proposed mapping language thus allows for the usage of XQuery path expressions or XPath 2.0 location paths as mapping elements with respect to local XML sources.

We refer to the mapping statement depicted in the path-to-path scenario in Figure 1 for the following remarks. The establishment of a correspondence between the RDF triple path <LearningResource><dc:title><Title> and the semantically analogous XML location Path /Organisation/PublicationList /Publication/Description/Title is realized in the second body section of a mapping. This section binds the afore-created descriptions of RDF triple paths to the corresponding location path and completes the mapping statements as such. The right-hand-side mapping element and the necessary binding to the first body section are achieved by the q2xq:mapping elements shown in Example 2 at lines 11-27.

The mapping language thus describes mapping statements as a binding between two XML elements. The left-hand or RDF side is represented by a *q2xq:triplepath* element in the first body section, the right-hand or XML side is casted into a *q2xq:mapping* element in the second body section. The latter allows for declaring a XPath location path in a specific XML document by referring to the header section and its target definitions by passing the respective value to the attribute *source*.

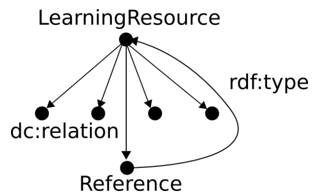

Figure 3: A cyclic mediating structure

Mapping of graph cycles: Concluding this section on the expressivity of the mapping language proposed, we would like to drop the simplifying assumption about directed acyclic graphs and consider the case of simple cycles in the RDF mediating representation. The description of the mediating RDF structure in terms of triple paths allows for the representation of graph cycles with cycles forming predicate paths such that the first node of the path corresponds to the last. Consider an extended example of the mediating representation given in Figure 1. Meta-data on learning resources are likely to comprise description information about related or even recommended learning resources, e.g. references. In that case the mediating representation in Figure 1 could be enriched by an additional node *Reference* representing a learning resource in the scope of ELENA's common schema: This cycle can be easily represented by two triple path statements. Cycles having a predicate path length greater than 1 may be represented as well. Cycles can be recognized by looking for a node occurring at least once as subject and once as object in two distinct triple paths. A mapping for the cycle in Figure 3 takes the following form:

```
<q2xq:triplepath id="A" subject="
    LearningResource" predicate="dc:relation"
    object="Reference" />
<q2xq:triplepath id="B" subject="Reference"
    predicate="rdf:type" object="
    LearningResource" />
```

Note that in a global-as-view setting such a self-referential structure has to occur and find its correspondence within a single logical local source. The actual mapping element at the local XML source depends on the realization of the conceptual self-reference in terms of document structure. In XML this might be achieved for instance vertically by nesting elements of the same type in a recursive way or horizontally by making use of ID-IDREF relations. Both can be reflected in XQuery syntax, either using recursive functions in the former or ID-IDREF-based navigational functions built in XQuery such as *xf:id* [5] in the latter case. The representability of cyclic structures is nevertheless limited to simple cycles. On the one hand this is due to the manual generation of mappings and thus to the human perception of complex cyclic structures. On the other hand the processing of complex cycles in RDF has to be considered non-trivial as documented for instance in [26, 27].

4.2 Query translation algorithm

Our query translation algorithm transforms the input QEL query into a XQuery query by making use of the mapping rules. Regarding the global-as-view approach adopted in ELENA, query transformation basically consists of a translation of an input into an output query to be evaluated over a local XML source. Query transformations in local-as-view settings are usually referred to as *query rewriting* and involve an incomparably more complex transformation.

4.2.1 A primer for QEL

Query Exchange Language (QEL) is a query language specially designed for RDF, and is based on datalog. The QEL specification provides two different encoding styles, on the one hand datalog-QEL, on the other hand RDF/XML-QEL [4]. For reasons of clarity, the following section is in accordance with QEL's datalog notation. Consider a simple QEL query over the mediating representation described in Figure 1:

Example 1: A sample input QEL query

```
@prefix qel: <http://www.edutella.org/qel#>.
@prefix lom-rights: <http://ltsc.ieee.org
    /2002/09/lom-rights#>.
@prefix dc: <http://purl.org/dc/elements/1.1/>.
?- qel:s(LearningResource,dc:title,Title),
qel:like(Title,'%education%'),
qel:s(LearningResource,dc:contributor,
    Contributor),
qel:s(LearningResource,dc:language,Language),
qel:s(LearningResource,lom-rights:
    copyright_and_other_restrictions,
    LegalRestriction).
```

The given datalog-QEL query might be intuitively interpreted as the following request: *Give me the title, the contributor or provider, the language and possible legal restrictions of all learning resources containing the term "education" in its title.*

The key concept borrowed from datalog are predicate expressions with QEL distinguishing between *matching* and *constraint* predicates. The most important pre-defined **matching predicate** in QEL is *qel:s* denoting a so called *statement literal*. The underlying common data model considers RDF data being organized in triple structures of the form *subject - predicate - object*. The range of allowed value types for subjects, predicates and objects are in accordance with the RDF specification [2]. The QEL matching predicate (*qel:s*) resembles this structure of RDF triples and serves as matching or binding facility to be used in queries. Corresponding to the range of value types in a RDF triple, each argument in a *qel:s* construct might be filled with an appropriate value type. Literals are thus proper values in datalog predicate expressions, URI references correspond to constant names. In addition, arguments can represent variables identified by capitalized names. Predicate expressions that contain variables as arguments are also referred to as *query literals*.

When examining the first matching predicate in Example 1 qel:s(LearningResource,dc:title,Title) both subject and object are variables whereas the predicate corresponds to a proper URI reference. Variables in qel:s constructs are bound to the entire spectrum of possible subject and object values stored in a RDF triple repository. Therefore, the qel:s construct taken from Example 1 selects all triples that contain the RDF predicate "dc:title" without any further restrictions.

Apart from matching predicates, the QEL syntax comprises another category of pre-defined predicates. This set of predicates helps constraining further the selection of matched triples based upon comparison operations on the RDF triples' values. They are referred to as **constraint predicates** and provide conventional value-based comparisons such as equals-, like-, greater-than- and less-than operators and verifications for node types and language encodings [4]. The construct qel:like(Title,'%education%') in Listing 1 shows such a value constraint, a like-operator more precisely, on all matching triples pre-selected by the *qel:s* construct mentioned before.

4.2.2 Translating a simple QEL query

In the following, we outline an algorithm to transform a QEL query as depicted in Example 1 into a corresponding XQuery query according to the mapping example given in Section 4.1. The entire mapping can be found in Example 2 attached to this paper. The translation algorithm is guided by the syntactic structure of XQuery's FLWOR expression (see [5]). QEL queries require to iterate through instances of learning resource elements. The analogous iteration can be achieved by a FLWOR expression in XQuery.

The translation algorithm uses only FOR, WHERE and RETURN blocks. The algorithm is therefore organized in three block declaring steps with the latter two distinguishing between a phase of *query parsing* and a phase of *mapping correspondences*. The parsing of the input QEL query aims at identifying relevant query elements, particularly *constraining* and *matching* constructs. In addition, all mapping statements relevant to this specific query elements are identified. The binding phase refers to the construction of an output XQuery query based on the previously identified QEL constructs and mapping statements.

Declaring the FOR clause: In a first step, the algorithm parses the mapping information of the header section of a given mapping file (see Section 4.1.1). Each *q2xq:source* element is considered and based on its attributes' value a FOR block is created. A XQuery FOR construct binds custom variables to some sort of input expression, e.g. the input function *doc* in our case. This input function returns the document node or some sub-level node of the physical XML document identified by both the attribute *document* and *contextNode*, pointing to a specific subtree as entry point for the iteration. This node of entry is bound to the variable defined by the attribute *id*. The heading mapping element given in Example 4.1.1 is thus transformed into the following partial XQuery expression:

```
for $pub
doc("sourceB.xml")/Organization/PublicationList
    /Publication
```

Provided that several q2xq:source elements are recognized they are attached to this initiating FOR block in terms of an additional variable-node binding and can be used to create joins between multiple XML documents at a later stage.

Declaring the WHERE clause: In a next step, the algorithm aims at extracting relevant constraint predicates in order to build a WHERE clause. This WHERE statement eliminates XML elements which do not match certain conditions. First, the algorithm identifies required mapping statements to map the constraining RDF elements. Then, the XPath location paths expressed in the identified mapping statements are attached to the previously defined path variables being context nodes. The XML element identified thereby serves as basis for the conditional operation. The extracted constraint predicate constructs specify the nature of these filtering conditions with conventional comparison operators (e.g. qel:equals, qel:greaterThan) being transformed into their XQuery equivalents (e.g. "=", ">"). More complex operators such as *qel:like* are equated with specific built-in functions of XQuery, *contains()* for instance. The constraint predicate statement qel: like (Title,'%education%') in Listing 1 would therefore be transformed in to the following WHERE clause:

```
where fn:contains($pub/Description/Title,"
    education")
```

The WHERE block is equally relevant when considering the transformation of conjunctions, disjunctions and negations expressed in the input QEL query.

Declaring the RETURN clause: The closing block, the RETURN clause, builds the result of the previously defined for-where expression. In other words, it exclusively returns tuples that match the constraints and allows for casting them in an user-defined XML output format. The latter is determined by QEL which requires a specific result format serialized in RDF/XML. The entire QEL result block comprises two interrelated sections, on the one hand the actual QEL *ResultSet* in terms of a RDF sequence containing result values, on the other hand another RDF sequence carrying the QEL result variables [4]. The two collections are related insofar as the sequential ordering determines the binding of result variables in the latter to the result values in the former. In order to populate these two result sections, the algorithm needs to identify all *matching predicates* of the input QEL query. Unlike datalog, QEL determines the order of result tuples. The *qel:s* constructs contain the information needed, particularly the result variables.

The two result sections are produced by another parsing and binding procedure. At first, the algorithm examines the input QEL query for all *matching predicates* and extracts their respective RDF *objects*, the result variables in QEL's terminology. By finding all mapping statements and thus location path correspondences to the triple paths represented by the matching predicates the first section is constructed. Each matching predicate is transformed into a RDF list item (*rdf:li*) whose value is determined by a corresponding XML element. This is identified by an absolute XPath location path composed of the context node variable and the location path from the respective mapping statement. Finally the object element of the respective matching predicate is added to the sequential list of result variables and thus bound to the previously rendered value. The entire output XQuery query resulting from the QEL query in Example 1 and the underlying mapping in Example 2 are attached to this paper. The two result section described above are shown at lines 14-29.

4.2.3 Issues

At this stage we would like to discuss important aspects concerning more complex transformations. They include brief accounts on the correspondence of negation operators as well as transforming conjunctive and disjunctive QEL queries into their XQuery representations.

Negation: As there is no negation of matching predicates available in QEL, negations in a limited sense may exclusively be applied to constraint predicates. In the course of parsing the input QEL query when declaring the WHERE clause the identified constraint predicates are checked for QEL's negation operator ("-"). Following this, they are transformed similar to non-negated constraint predicates where the negation operator ("not") is added. The negated constraint predicate – qel:like (Title, '%education%') would therefore be transformed into not(fn:contains ($pub/Description/Title ,"education"))

Conjunction: Conjunctions in QEL are represented by comma-separated sequences of predicate expressions [4]. Once again matching and constraint predicates have to be distinguished: Conjunctive sets of the former as given in Example 1 pre-select a set of triples subject to further restrictions. Conjunctions between constraint predicates are directly translated into a logical AND operator in the WHERE clause of the corresponding XQuery.

Disjunction: Disjunctions are expressed as in datalog: several rules with the same *rule head*. The rule head itself is a query literal on the left-hand side of a rule definition while at the right-hand side an arbitrary order of query literals, both matching and constraint predicates, can be specified.

A disjunction comprising constraint predicates is transformed into conditional elements of a WHERE clause, connected by a logical OR operator.

5. RELATED WORK

Several fields of research emerged as relevant and related to our efforts. In the educational domain, in particular in the scope of Edutella, Qu and Nejdl [28] staged a comparable approach to integrate a SCORM meta-data repository stored in XML with a RDF-based P2P infrastructure by means of – though not exclusively – query translation. The entire integration involves first a replication and modification of the targeted XML repository into a generic RDF-graph-based meta-data view which is represented in a XML serialization of RDF triples. Second, they offer a complementary wrapper implementation that translates between users' QEL and XQuery queries over the replicated, normalized and XML-encoded RDF meta-data repository. Their contribution differs at least in two aspects: On the one hand they provide a technique to integrate arbitrary common RDF representations and QEL queries with a specific and complex local meta-data representation (SCORM) whereas we provide a facility to target arbitrary and less complex local XML meta-data storages through a specific and pre-defined RDF mediating representation. On the other hand their approach reflects an integration scenario which allows replicating entire repositories with our translation technique being applicable to more restricted scenarios where only pre-selected meta-data are exposed by integration partners.

In the more general discussion on integrating heterogeneous XML sources some key approaches can be distinguished. One group applies XML itself as mediating representation. Their relevance to our efforts results from their analysis of mapping strategies, already discussed in Section 3. Important contributions in this group include Xyleme [17, 29, 15] and Lee et al. [30]. A second group of authors [20, 21] criticize the use of XML as a mediating schema and proposed conceptual models for the integration of XML sources instead. Although they use self-defined conceptual models or ER derivates, they adopt the mapping strategies developed for XML. Relevant projects include STyX [20, 21] and ORA-SS [19].

Finally, we identified several approaches using the RDF graph model, i.e. either RDF or RDF/S, as mediating vehicle for integrating XML. PEPSINT [31] is a Peer-to-Peer system based upon a super-peer infrastructure and a global RDF ontology against which RDQL queries are evaluated. Depending on the target's meta-data model the original RDQL query is either simply reformulated according to mapping rules or syntacticly translated into a XQuery query over a XML repository. In a global-as-view setting the mapping is realized - in contrast to our solution - semi-automatically both at the global and local stage. First a local RDF/S ontology is generated for each RDF and XML repository with the local ontology preserving structural or nesting information of XML trees. At the local level PEPSINT applies a tree-to-tree mapping strategy as each concept in the local RDF/S ontology is mapped to a XML location path. In a second step, a node-to-node mapping is established between single concepts of the global and local RDF/S meta-data representations. Based upon this *combined* mapping strategy the query translation algorithm provides for a translation back and forth between XQuery and RDQL. Contrasting to PEPSINT, query translation in ELENA is performed only in a single direction (from RDF to XML).

Another research project focusing on integration of RDF and XML is SWIM [18]. The SWIM server hosts the mediating and query transformation facilities, which integrate not only XML meta-data but also relational databases. SWIM does not apply the mediator-wrapper architecture but it relies on a single wrapper solution. This implies that SWIM is based on a centralized mapping methodology whereas ELENA and PEPSINT operate in a decentralized manner with respect to mappings and query translation. This requires the employment of a single mapping methodology which provides the expressivity to represent all data models subject to integration. SWIM achieves this by using a datalog-based mapping language which incorporates XPath location paths as datalog atoms. As for query transformation, the proposed algorithm translates between RQL over the virtual mediating RDF/S representation and XQuery queries over local XML repositories.

Piazza [32] is also a mediating infrastructure that enables the integration of XML data into a RDF-based environment. Zachary et al. adopt a local-as-view integration technique and apply an extenstion to XQuery as mapping language to expose XML meta-data as virtual RDF repositories. Due to the usage of an extended XQuery syntax they propose a necessary query evaluation algorithm. In contrast to Piazza our approach can be applied to any standard XQuery processor.

Other aspects relevant to our work are handling RDF cycles and designing mapping languages. Barton [26], for instance, applies indexing to RDF structures and resolve cycles in this context. Various mapping languages are proposed in the context of integrating heterogeneous XML sources. A rule-based XML syntax called LMX (Language for Mapping XML) has been applied by [33] underlining its applicability for the tool-assisted mapping generation by human integration engineers. Other approaches on integrating XML use datalog syntax [18], RDF/XML [34] and XQuery [32] as mapping languages.

6. CONCLUSION AND FUTURE WORK

We realized a query translation method, and successfully integrated XML data with a RDF-based application based on a manually created mapping language. These efforts involved an analysis of existing XML mapping techniques that we adapted for our RDF-XML scenario, resulting in a XML-encoded mapping language and a corresponding query translation algorithm. We were able to translate all user queries in our application and integrate entire XML meta-data repositories into ELENA's RDF environment. The mapping language enables engineers to design complex mappings, however in case of big structures it can become impracticably complex. Translating QEL queries and evaluating the resulted XQuery performed equally well as processing the same QEL query on a RDF meta-data set of the same size.

We did not formally analyze the soundness of our method. Therefore, we are currently pursuing a number of research directions to identify limitations to our prototype implememtation. If we also formalize the application specific constraints, such a formal proof is thinkable. In the context of meta-data integration we consider this kind of translation technique complementary to the use of emerging versatile query languages [35] applicable both to RDF and XML.

Acknowledgements

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Example 2: A sample mapping

```
<?xml version="1.0" encoding="iso-8859-1"?>
<QEL2XQueryMapping xmlns:q2xq="http://www.elena-project.orf/ns#q2xq">

        <q2qx:source id="pub" document="sourceB.xml" contextNode="/Organization/PublicationList/Publication"/>

        <q2xq:triplepath id="A" subject="LearningResource" predicate="dc:contributor" object="Contributor" />
        <q2xq:triplepath id="B" subject="LearningResource" predicate="dc:title" object="Title" />
        <q2xq:triplepath id="C" subject="LearningResource" predicate="lom:copyright_and_other_restrictions" object="LegalRestriction" />
        <q2xq:triplepath id="D" subject="LearningResource" predicate="dc:language" object="Language" />

        <q2xq:mapping>
           <q2xq:lhs triplepath="A" />
           <q2xq:rhs source="pub" locationpath="/Author" />
        </q2xq:mapping>
        <q2xq:mapping>
           <q2xq:lhs triplepath="B" />
           <q2xq:rhs source="pub" locationpath="/Description/Title" />
        </q2xq:mapping>
        <q2xq:mapping>
           <q2xq:lhs triplepath="C" />
           <q2xq:rhs source="pub" locationpath="/Copyright" />
        </q2xq:mapping>
        <q2xq:mapping>
           <q2xq:lhs triplepath="D" />
           <q2xq:rhs source="pub" locationpath="/Language" />
        </q2xq:mapping>

</QEL2XQueryMapping>
```

Example 3: A sample output XQuery query

```
xquery version "1.0";
<rdf:RDF
         xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:edu="http://www.edutella.org/qel#"
         xmlns:RDF/S="http://www.w3.org/2000/01/rdf-schema#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
 <rdf:Description>
    <rdf:type rdf:parseType="LearningResource"/>
    <rdf:type rdf:resource="http://www.edutella.org/qel#ResultSet"/>
    {
          for $pub doc("sourceB.xml")/Organization/PublicationList/Publication
          where fn:contains ($pub/Description/Title, "education")
            return
                 <edu:result>
                         <rdf:Seq>
                                 <rdf:li> { string($pub/Author) } </rdf:li>
                                 <rdf:li> { string($pub/Description/Title) } </rdf:li>
                                 <rdf:li> { string($pub/Copyright) } </rdf:li>
                                 <rdf:li> { string($pub/Language) } </rdf:li>
                         </rdf:Seq>
                 </edu:result>
                 <edu:resultVariables>
                         <rdf:Seq>
                                 <rdf:li rdf:resource="#Contributor"/>
                                 <rdf:li rdf:resource="#Title"/>
                                 <rdf:li rdf:resource="#LegalRestriction"/>
                                 <rdf:li rdf:resource="#Language"/>
                         </rdf:Seq>
                 </edu:resultVariables>    }
  </rdf:Description>
</rdf:RDF>
```

Improving Interoperability Through Better Re-usability

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ABSTRACT

Interoperability among heterogeneous systems can be reached by adopting and combining at least two strategies: one interface-oriented and the other model-oriented. The first one refers to the idea of defining well-known interfaces that systems should expose. The second one refers to the idea of having standard, semantically-rich data model shared by various systems. The SCORM standard supports the model-oriented integration strategy by offering, among the other features, a rich data model that can be used to define and share *Learning Objects*. We argue that, despite the fact that it is the most emerging and promising standard, SCORM does not address properly some key issues, such as specification of metadata and LO composition. As we discuss in this paper, such issues affect directly the possibility of re-using instructional materials both within the same e-learning system and, even more, across different systems. Within the Virtual Campus approach we have proposed some extensions to the SCORM object model that aim to address the above issues.

Categories and Subject Descriptors

K.3.1 [**Computers And Education**]: Computer Uses in Education

General Terms

Standards for interoperability, metadata models

Keywords

SCORM, Learning Object, metadata, composition, aggregation, sequencing

1. INTRODUCTION

Interoperability among heterogeneous systems can be reached by adopting and combining at least two strategies: one interface-oriented and the other model-oriented. The first one refers to the idea of defining well-known interfaces that systems should expose. By exploiting such interfaces, systems can call each other services thus enabling exchange of data, execution of queries on remote data, etc. The Simple Query Interface (SQI) [10] is an example of such an interface for the e-learning domain.

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The model-oriented strategy refers to the idea of having standard, semantically-rich data models shared by various systems. Sharing the same data model enables the possibility of reusing the same data in different systems, and dramatically increases the interoperability among such systems.

Within the context of e-learning, SCORM [1] offers, among the other features, a rich data model that can be used to define and share *Learning Objects* (LOs). We argue that, despite the fact that it is the most emerging and promising standard, SCORM does not address properly some key issues, such as specification of metadata describing LOs, and composition of LOs. As we discuss in this paper, such issues affect directly the possibility of re-using instructional materials both within the same e-learning system and, even more, across different systems.

The assumption we start from is that an e-learning system (or a set of interoperating e-learning systems) addresses the needs of three main classes of actors: Authors, Teachers, and Learners. Authors design and build courses, possibly modifying and composing LOs; Teachers enact and manage courses, exploiting available LOs; finally, Learners attend courses by consuming LOs, possibly, with the supervision of Teachers. Given such a scenario, we distinguish between two kinds of re-use activities: *re-use for authoring* and *re-use for teaching*. The former activity, at authoring time, requires a data model for LOs that is rich enough to support re-use of parts, creation of LOs that reassemble existing ones, modification of the workflow that defines the way LOs will be executed (*sequencing* in the SCORM terminology). The latter, at the time a course is given, requires mechanisms and metadata that simplify the publication of the LOs and their enactment.

In this paper, based on the experiences we gained within the Virtual Campus project [6], we propose some extensions to SCORM aiming at supporting re-use for authoring by empowering the mechanisms for LO composition and at supporting re-use for teaching through the definition of proper metadata for LOs. The paper is structured as follows. In Section 2 we discuss some limitations of the LOM metadata specification, and propose our extensions. In Section 3 we discuss about the limitations of the SCORM content aggregation model, and introduce our approach. In Section 4 we focus on enhancing the SCORM aggregation/navigation model, presenting our model for LO composition. In section 5 we present Virtual Campus as a proof-of-concept platform. In Section 6 we discuss some related approaches aiming at offering mechanisms for composition of instructional material. Finally, in Section 7 we draw some conclusions.

2. METADATA SPECIFICATION

The Learning Object Model (LOM) offered by SCORM is based on the idea that instructional material is enveloped in metadata describing the instructional material itself. The union of the instructional material and of the corresponding metadata is a Learning Object (LO). Examples of LO metadata are the *Language* of the instructional material, the *Description* of the LO content, etc.

While experimenting with LOM, we have realized that it has the following weaknesses:

1. The exact meaning of some metadata is difficult to be specified (e.g., Semantic Density, Difficulty, etc.) As a result, Teachers tend to fill them with values that are in the middle of the available scale, making them completely useless.

2. Some important aspects about LOs cannot be expressed. As an example, there is no way to say whether a given LO has been designed to support group study or individual study.

3. The defined metadata are not fully machine-processable. Some of them are defined as free-text (e.g. Installation Remarks,) while others rely on vocabularies which are not precise enough to allow for a full-automatic processing.

The LOM has been clearly defined in order to improve search and discovery of instructional material. However, we argue that metadata can also be exploited to support many other activities. In particular, we think at the following ones:

A Automatic configuration of software needed for fruition of a LO. Following the metadata specification, the platform could automatically configure pieces of software *required* for the LO to be viewed and exploited by Learners. As an example, a video streaming server required by a given LO could be automatically configured in order to work with the e-learning platform.

B Automatic configuration of software *supporting* the LO fruition. As an example, Teachers could configure the system in such a way that LOs requiring asynchronous communication are provided with a forum, the ones requiring synchronous communication can exploit a chat, while cooperative LOs can take advantage of a shared, versioned repository. Notice that such a pieces of software are not part of the LO requirements as they just represent supporting tools.

C Tutoring. Metadata expressing instructional requirements can be useful to provide Learners with personalized automatic tutoring. In fact, they could be used to support selection of the most appropriate LO for a learner, depending on his personal preferences and attitudes.

D Evaluation. Metadata could be used by Teachers in order to analyze and evaluate the effectiveness of LOs.

Our extensions to the LOM mainly aim at providing support to all the aforementioned activities, explicitly expressing some LO properties the LOM does not consider.

In particular, as for the software needed for LO fruition, the LOM seems to concentrate on the specification of the client-side expected characteristics (browser and OS), but does not address to issues of describing the server requirements as well. Thus, in order to support automatic configuration (point A), we modify the LOM metadata 4.4 Requirements, adding a new field expressing whether requirements regard client- or server-side. Moreover, we propose to adopt the CC/PP [13] (Composite Capabilities/Preference Profiles) standard to express requirements and capabilities clients and servers have to meet.

We have also extended the LOM with some additional metadata that are summarized in Table 1. We can state the level of supervision a given LO requires (e.g., if a tutor should be available during fruition of the LO) whether the LO requires group (cooperative) study, whether some artifacts have to be created at the end of fruition, whether the LO requires communication facilities among Learners, and whether the communication or cooperation have to be synchronous or asynchronous.

Such metadata can have various uses. In particular, they can help addressing the issues related to point B, for instance, if the cooperation attribute is set, based on the information contained in the Techinical attribute, the runtime platform could automatically configure a version-control server which makes it easy for Learners to work on shared documents. In addition, if the supervision mode is set to tutored, an up-load facility could be configured in order to allow Learners to send created documents, and Teachers to manage and evaluate them.

The aforementioned metadata can also effectively support both automatic tutoring of Learners and LO evaluation (points C and D), since they permit to collect information on Learners' preferences and attitudes. As a result, profiles can be built and exploited to guide the tutoring process.

In addition to the introduced extensions, our modified LOM supports the concepts of *non-electronic LO*, *preconditions*, and *postconditions*. In the following we discuss these extensions.

In our model, LOs can represent either digital contents available in the LO repository or live lectures held in classrooms, the metadata Access Modality and Place highlight this difference. In doing so, we give the opportunity to seamlessly mix electronic and regular learning.

Finally, we can specify properties which must hold before the execution of a LO (Preconditions), as well as properties which will be true at the end of LO fruition (postconditions or, as we call them, Learning Objectives). Both Preconditions and Learning Objectives can predicate on data stored in the Learner' profile, and on Time.

3. CONTENT AGGREGATION

The goal of the SCORM Content Aggregation Model (CAM) [2] is to provide mechanisms that allow instructional materials to be aggregated. The CAM is based on three components: Assets, Sharable Content Objects (SCOs), and Content Organizations. Such components are enacted by means of the SCORM Run-Time Environment (RTE) [3]. The RTE "describes a common content object launch mechanism, a common communication mechanism between con-

Field name	Field description
Supervision Mode	The level of supervision on Learners' activities: "none" (no supervision), "tutored" (a tutor is available; during fruition learners can explicitly request his/her supervision), "supervised" (the supervisor is always present during the instructional process), "driven" (Learners act in a passive way, by strictly following the Teacher's instructions.)
Cooperation Attribute	Whether Learners should take the LO in cooperation.
Communication Attribute	Whether Learners will be provided with communication facilities, while exploiting the LO.
Synchronism Attribute	In case of a cooperative or communicative LO, it specifies if the LO must be taken synchronously by all learners or asynchronously.
Group Cardinality	The cardinality of the group involved into the fruition of the LO. Meaningful group cardinalities are "1" (self-study), "2" (pair study, both learner-learner and learner-instructor), "m" (group study). Note: 2 is the minimum group cardinality for cooperative LOs and the maximum one for non-cooperative LOs.
Artifact Attribute	Whether the LO requires Lerner(s) to produce an artifact.
Access Modality	*Situated* (in a specific physical location, e.g. a live lecture held in a classroom), or *Digital*
Place	The physical location name. If Modality is *Digital*, this field is ignored
Precondition on time	Constraints on time that have to hold before the LO is taken.
Precondition on user profiles	The skills and knowledge a learner must have in order to exploit the LO. It can also predicate on administrative constraints that have to be fulfilled by the user before exploiting the LO (e.g., he/she must have payed the enrollment fee.)
Learning objective on time	The min/max amount of time required/allowed to complete the LO.
Learning objective on user profiles	Educational objectives of the LO in terms of skills a learner can obtain by exploiting it. It can also express objectives that are not strictly educational (e.g. the fact that the learner achieves some kind of degree by completing the LO.)

Table 1: Examples of Virtual Campus LOM extensions to the IEEE LOM.

tent objects and [the server], and a common data model for tracking a learners experience with content objects." Assets are defined as "the most basic form of a learning resource (...). [In other terms, they] are an electronic representation of media." Assets can be grouped to produce other Assets. A SCO is "a collection of one or more Assets that represent a single launchable learning resource." They represents "the lowest level of granularity of a learning resource" that communicates with the RTE. Notice that, since Assets do not interact with the RTE, they cannot be launched. Finally, a Content Organization is a tree composed of so-called Activity items which can be mapped on SCOs or Assets (see Figure 1, extracted from the CAM specification.) All of these components can be tagged with LOM metadata.

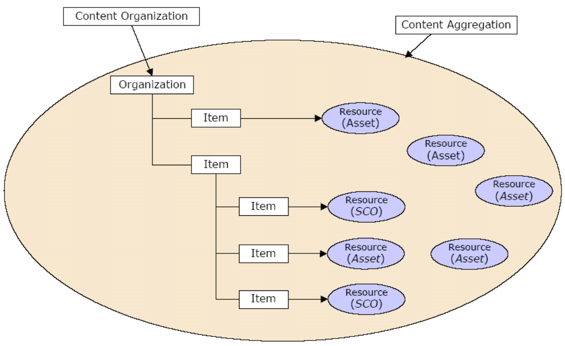

Figure 1: SCORM Content Organization.

All of the aforementioned components could be named as "Learning Object," as they provide contents, optionally described by means of metadata. However, SCORM actually do not provide a clear vision of what a Learning Object should be, since the model defines three diverse kinds of objects, with diverse re-usability properties and limitations.

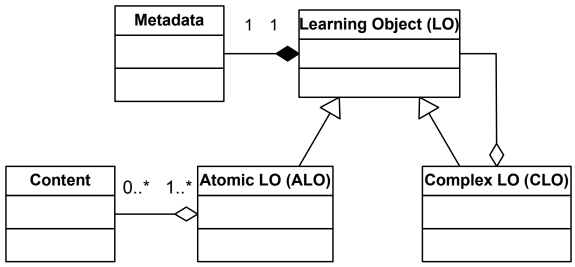

Figure 2: The Virtual Campus LO model.

Such a non-homogeneous model has an impact on the possibility of re-using LOs in different contexts.

In our approach we overcome such a problem by defining an unique model for Learning Objects, allowing simple and powerful recursive composition. In particular, as shown in Figure 2, we define an *Atomic LO* (ALO) as a LO whose instructional material is a file (we call it *content*) and a *Complex LO* (CLO) as a LO whose instructional material is an aggregation of Learning Objects. Being a LOs, a Complex LO can be threated exactly as any other LO. Indeed, it has associated a set of metadata, some of which can be automatically derived from the metadata of the component LOs (e.g., Size) and some others that need to be manually inserted by the author of the Complex LO.

4. SEQUENCING AND NAVIGATION

An important aspect of e-learning is to allow the Teacher to define a path through the LOs that would guide the Learner in the way she/he takes the instructional material. Such a path can be specified in term of rules that state, for instance, the precedence relationships between LOs, the fact that some LOs may be optional, etc.

The SCORM Sequencing and Navigation (SN) book [4] is focused on this issue and defines the required behaviors and functionality that the system must implement to process sequencing information at run-time. More specifically, it describes the branching and flow of Activities in terms of an Activity Tree, taking into account the Learners interactions with LOs and a sequencing strategy. An Activity Tree represents the data structure that the system implements to reflect the hierarchical, internal representation of the defined Activities. Moreover, SN defines a Cluster as a specialized form of a Activity that has sub-activities.

Relying on the aforementioned concepts, SCORM SN defines several Sequencing Control Modes (e.g., Sequencing Control Choice, Sequencing Control Choice Exit, Sequencing Control Forward Only), Sequencing Rules (a set of conditions that are evaluated in the context of the Activity for which the Sequencing Rule is defined), Limit Conditions (conditions under which an Activity is not allowed to be delivered), etc.

In our opinion, SN specification is far too complex to be effectively implemented. Moreover, the idea to separate content specification and sequencing specification, on one hand makes the standard more flexible but, on the other hand, further complicates the implementation.

We propose the integration of both aggregation and sequencing in a single specification that we call *LO composition*.

In our approach, Authors define each CLO in terms of a graph where nodes univocally represent LOs (either Atomic or Complex) while edges represent relationships between LOs (see Figure 3). Rounded-corner rectangles inside a CLO represent particular CLOs called *Inner CLOs*. They provide a mechanism to aggregate LOs, but, differently from other CLOs, they do not have an identity and cannot be reused outside the context of the CLO in which they are defined. They can indeed participate in any relationship connecting two generic LOs.

Relationships indicate the presence of instructional constraints between two LOs in the context of a containing CLO (outside that CLO, the relationship is no longer valid). A generic relationship from x to y in the context of z, with x, y being LOs (either Atomic or Complex) and z a CLO (on Inner CLO), is represented by an arrow from x to y inside z, labeled with the relationship name. The relationships are named *IsRequired*, *IsAlternativeTo*, *References*, and *IsRequiredOnFailure*. Their meaning is summarized in Table 2, where, for the sake of brevity, we omit the indication of the CLO where the relationship takes place.

The example shown in Figure 3 defines two different CLOs. The first one, "Mathematics," is composed of several LOs. "Basic concepts" and "Algebra" are both required by the inner CLO enclosing "Calculus", "Geometry", and "Limits", so they should be taken in the first place. The "History of mathematics" is left as an optional activity and, in case it is taken, it must follow "Basic concepts" that references to it. "Exam" is a special kind of LO that we call Test-LO (it is labeled with T). It is used to model assessments learners have to go through. If they are failed the whole CLO have to be repeated.

The second CLO, "Engineering first year," is composed reusing "Mathematics" as well as some other LOs. Learners

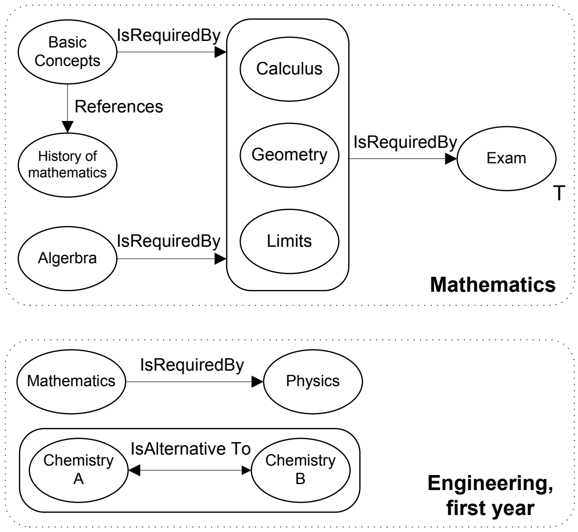

Figure 3: CLO definitions.

have to complete "Mathematics" before entering "Physics," while "Chemistry A" (or alternatively "Chemistry B") can be taken anytime with respect to the Mathematics and Physics pair.

It is interesting to note that "Mathematics", being reused in this context, appears as a black-box. Its internal complexity is hidden thus allowing for an easy composition. Even more interesting is the fact that, in such a representation, the less arcs are drawn, the more freedom is left to Learners. As an extreme example, a simple collection of LOs, with no arcs at all, permits the design of a course in which all possible paths are allowed.

LOs can be (re)used either to define other LOs or to provide them to the learners. Before making them available to learners, LOs go through two more steps where all details needed for enactment are provided. In the first step, the Teacher can further constrain the fruition paths of a learning object. Such additional constraints are defined on a workflow representation of a CLO that is automatically obtained from its original definition.

For instance, Figure 4 shows the workflow representations of the two CLOs defined in Figure 3. In this representation, LOs are mapped into activities that represent the fruition of the corresponding LOs. The syntax is similar to a UML activity diagram. In particular, simple arrows connecting activities represent a sequence, vertical bars enclose parallel activities, and diamonds are used to indicate alternative activities. The stereotype <<Optional>> denotes the fact that the corresponding path is not mandatory.

If needed, the Teacher can customize the automatically derived workflows by performing any of the following actions:

1. elimination of alternative paths by selecting a single path or a subset of the available ones;

2. elimination/forcing of optional activities;

3. forcing the order of fruition in case of parallel activities.

All these operations preserve the consistency between the

Relationship	Description
IsRequiredBy	*A IsRequiredBy B* indicates that LO *A* must be completed before starting LO *B*; i.e., the Learner has to possess *A*-related knowledge in order to achieve a correct understanding of *B*. However, the *IsRequiredBy* relationship does not mean that Learners must complete *A* *immediately* before *B*: Learners are allowed to make use of other LOs after *A* and before *B*'s fruition.
IsAlternativeTo	*A IsAlternativeTo B* indicates that *A* and *B* are mutually exclusive, although they are both valid since their instructional function is considered to be identical. Two LOs connected by an *IsAlternativeTo* relationship are automatically enclosed within an Inner CLO.
References	*A References B* indicates that *A* cites *B* as a source of more details on a topic related to *A* itself. Taking *B* at fruition time is not compulsory: Learners can thus decide whether to make use or to ignore this information. Many *References* can enter or depart from the same LO. In this case, Learners can make use of one or more of the corresponding LOs.
RequiresOnFailure	A *RequiresOnFailure* relationship always connects a Test-LO with some other LO. If the Test-LO is failed, then the LO at the other end of the *RequiresOnFailure* relationship has to be taken by the learner. If no *RequiresOnFailure* is specified, learners failing a Test-LO have to re-start the fruition of the whole CLO.

Table 2: Relationships between Reusable-Level LOs.

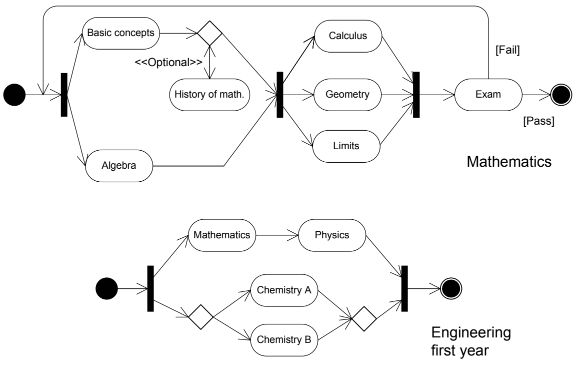

Figure 4: Workflow description of CLOs.

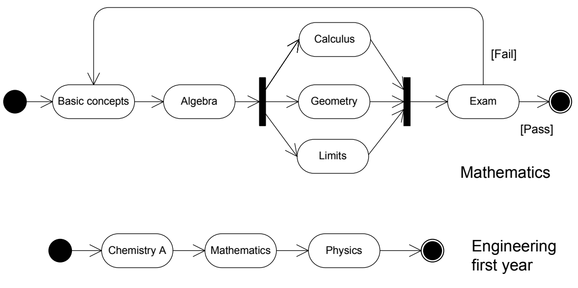

Figure 5: Customization of workflows.

resulting workflow and the corresponding high-level description since they further constrain the way LOs are used by Learners.

Figure 5 shows a possible customization of workflows depicted in Figure 4.

In the last refinement step for LOs, the Teacher transforms a LO (usually a CLO) in such a way that it can be offered to Learners as a course. This is accomplished by specifying information needed to enact the LO, such as the course edition, the enrollment method, start and end dates, the course calendar, announcements, the Teacher's name, the list of already enrolled students, etc. At this point the Course is ready for fruition and can be published.

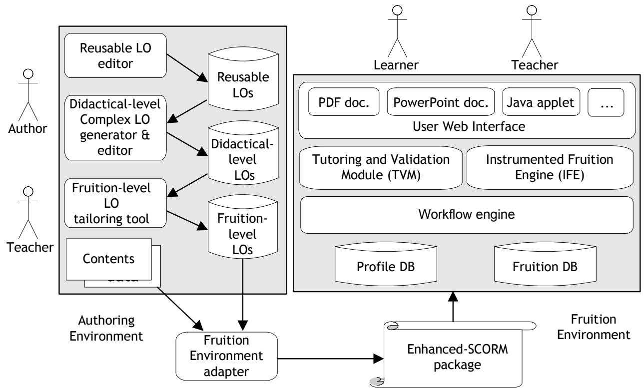

Figure 6: Virtual Campus high-level architecture

5. THE VIRTUAL CAMPUS PROJECT

Relying on the aforementioned concepts we developed Virtual Campus, an e-learning platform for the design, deployment, fruition, and evaluation of learning materials. As for the design phase, its main objectives are to support re-use and composition of LOs and to enable the definition of the fruition flow for a given Complex LO. As for the fruition phase, the main objective it to support various learning modalities (individual or cooperative, distance or co-presence, etc.) and to provide some tutoring features that help the Learner when needed.

The Virtual Campus platform is composed of two main subsystems (see Figure 6): The Authoring Environment, and the Fruition Environment.

The Authoring Environment provides Teachers with a graphical editor (see [6]) to define ALOs and CLOs. Then, an automatic generator produces a first version of the workflow associated to a CLO and then supports Teachers in customizing it by means of a specialized workflow editor. Finally, a LO tailoring tool supports the insertion of all fruition-related details. See Figure 7 and Figure 8.

CLOs and Courses can be both serialized in a SCORM package in order to support export of data toward other e-learning platforms. Our extensions to the SCORM models have been organized within a SCORM package in such a

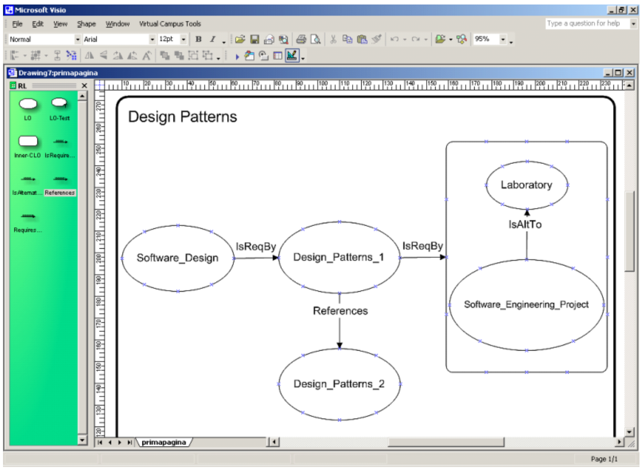

Figure 7: The CLO editor.

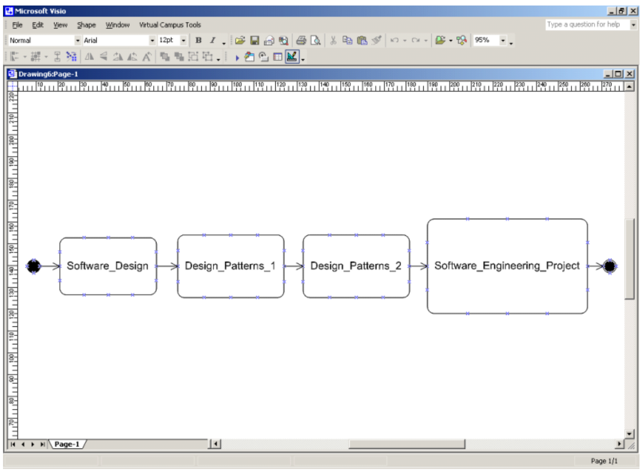

Figure 8: The workflow editor.

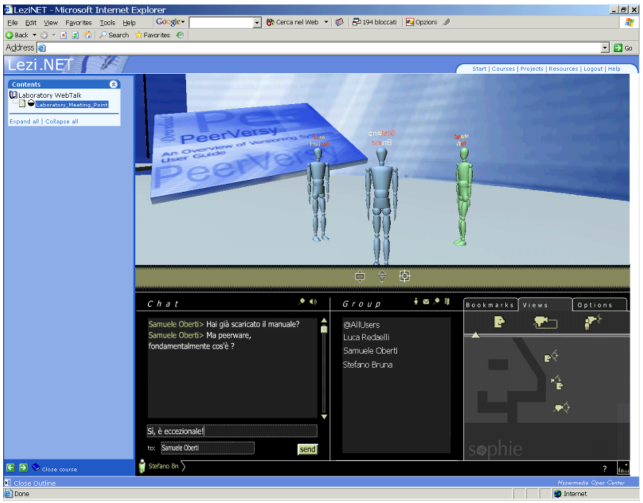

Figure 9: The Fruition Environment showing a co-operative LO

way that other SCORM compatible platforms would ignore them, but they would still be able to import the atomic LOs belonging to the package.

The Fruition Environment is based on a RTE-compliant engine (called IFE) that enables fruition of LOs by Learners. IFE also supports the sequencing of CLOs (see [7] for details.) by exploiting a workflow engine that “executes” the fruition workflow associated to a CLO, thus guiding Learners and Teachers in the execution of the activities related to the usage of the LO. See Figure 9.

A tutoring module (called TVM, see [9]), starting from usage data, defines models for some aspects of LOs and Learners and, relying on them, provides Teachers with reports and graphics about the performance of the Virtual Campus platform and about learning behaviors of her/his students. In the cases when Learners could choose among multiple paths through LOs, TVM tries to provide them with suggestions about the most appropriate instructional path to follow.

6. RELATED WORK

Our approach to improve re-usability is centered on supporting LO composition. The language we propose is based both on the usage of relationships at the higher level of abstraction, and on a workflow-like representation at a more detailed level. In the following we present the approaches we are aware of in the two areas.

6.1 Relationship-based systems

These systems allow teachers to define a course structure by means of logic relationships among the course components. MediBook [12] is an example of such systems. MediBook is tailored to the medical domain; the important medical concepts are formalized and related to each other by semantic relationships. In turn, LOs are associated with concepts and are connected through so-called *rhetorical relationships* (e.g. LO-A *deepens* LO-B, LO-C *is-part-of* LO-D). MediBook uses the LOM standard to define LOs metadata and to store rhetorical relationships. Learners can navigate through both the rhetorical relationships structure or the semantic relationships structure. In this last case, they discover LOs starting from the associated concepts.

An alternative approach, described in [11], uses a sort of "direct prerequisite" relationship to order LOs (e.g. LO-A *is a direct prerequisite for* LO-B). The matrix associated to the resulting graph shows the total number of direct and indirect prerequisites between two LOs. When learners choose a LO to exploit, it is possible to calculate the list of required LOs. An integer-programming model is then built, taking into account further constraints (e.g. the time effort required by a given LO). By minimizing the model target function, some LOs are removed from the list. A sequencing procedure determining the "best" schedule on the remaining LOs is then executed.

A similar approach, described in [5], uses the same relationship and adds weights in order to represent the difficulty to access a given topic coming from a previous one. To choose a path, learners select it from the whole graph provided by the system. Each route is associated with a numeric index weighting the "effort to learn" the target topic.

6.2 Workflow-based systems

These systems allow teachers to define a course structure as a workflow. Flex-eL [8] is an example of such systems. Flex-eL provides a process-modeling tool to capture the learning process and view it as a stream of activities (a so-called "process template".)

It is also possible to have more than one process template for the same course. Whenever a student enrolls in a course, a new instance of the learning process is created by the system. Rather than making all the course material and activities available to the student at the beginning of the course, Flex-eL coordinates their availability and completion by utilizing its embedded workflow functionality. When the appropriate learning activity is completed, a new activity is assigned to the work list of the associated person.

While each of the aforementioned systems has some similarity to our approach, none of them exploits LOs, and in particular CLOs, as a unit of reuse. Moreover, they are not integrated with SCORM and do not try to exploit both relationships and workflows in a unified authoring cycle.

7. CONCLUSIONS

We see SCORM as a good opportunity to support interoperability among e-learning tools since it enables the definition of a data model that can be shared among them. However, we have noticed some weaknesses in such a data model. These weaknesses mainly concern the way LOs can be structured and made available for reuse.

In our vision all the learning resources have to be thought as LOs, so that they are described by proper metadata and can be recursively composed. Thanks to the recursive composition mechanisms, reuse both within a single platform and among platforms can be greatly enhanced: A LO at any level of composition can be re-used and composed in another context. The definition of proper metadata can support not only browsing and re-use of LOs, but also installation and execution of them.

The Virtual Campus project aims at providing an implementation of the aforementioned concepts. Moreover, it tries to enhance the SCORM run-time environment, exploiting a workflow engine to guide Learners through the instructional paths.

As a future work we plan to include the SQI specification into Virtual Campus. We believe, in fact, that the combination of an improved LO model and a standard interface is the most promising answer to the interoperability issue. Another aspect that merits further investigation is the definition of proper guidelines to support Authors and Teachers in the design of LOs. Clearly, the more their LOs correspond to fine granularity learning materials, the more such materials are reusable and applicable in various contexts. Indeed, the mechanisms to compose fine granularity LOs are essential in this case in order to avoid all difficulties of having a huge, non-organized collection of LOs.

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On Interoperability of Ontologies for Web-based Educational Systems

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ABSTRACT

Interoperability between disparate systems in open, distributed environments has become the quest of many practitioners in a variety of fields. Web-based educational systems are not an exception, but provide some unique characteristics. In this perspectives paper we argue for the role of multiple ontologies in support of Web-based educational systems and speculate on the efforts involved in achieving interoperable systems. We draw our criticism from our involvement in interoperability tasks between ontologies for Semantic Web systems and elaborate on the role of communities of users in interoperability scenarios.

Categories and Subject Descriptors

H.3.5 [**Information Systems**]: -Online Information Systems -Web-based services;; D.2.12 [**Software**]: -Software Engineering-Interoperability;; I.2.m [**Artificial Intelligence**]: -Miscellaneous

Keywords

semantic interoperability, ontologies

1. INTRODUCTION

Interoperability has always been the Achilles heel when deploying large scale, independently developed systems. Interoperability is a pre-requisite for maximizing sharing of data, information, and ultimately knowledge between disparate systems. Homogeneous groups of engineers have been resolving this issue in familiar environments, like organisational intranets, using either manual or semi-automatic methods. However, the popularity of Web-based approaches and the advent of the ambitious Semantic Web changes the landscape for interoperable systems: interoperability needs to be achieved in an open, distributed environment, involving heterogeneous groups of engineers from distinct organisations following different design processes.

Nowadays, an Artificial Intelligence (AI) technology which emerged in the late eighties as a means for sharing knowledge between knowledge based systems, ontologies, is advocated as the preferable solution for enabling interoperability. Their applications vary across a wide range of fields, including Web-based Educational Systems (WBES). For instance, in the post-workshop report for a recent specialized event on the use of ontologies in WBES[1], the authors argue for using a "common vocabulary for domain knowledge representation" which enables WBES interoperability. These are also known as ontologies. Further, Simon and colleagues [20], summarize neatly the role of ontologies in WBES engineering with respect to achieving interoperability of educational artefacts:

> "Educational artefacts are understood as descriptions of educational service types (e.g., a course catalogue or an evaluation service) or instances of educational services and resources (e.g., a particular course, an assessment activity or an online text book). When an educational node forwards an educational artefact to another educational node for further processing, both nodes need to speak a common language. Hence, an ontology needs to be designed to provide a *lingua franca* common trade language for learning resources [. . .]."

In this paper, we advocate the use of ontologies – as our dedicated WBES colleagues – however, we will argue for the use of multiple ontologies to support a WBES, which is in line with the Semantic Web's *modus operandi*. This changes the focus for interoperability: first it has to be achieved at the underpinning ontologies level, which in turn will enable entire systems' interoperability.

Initially though, in section 2, we will review the arguments made for and against the use of a single, global ontology, to which all systems adhere to, and interoperability is based on. We will then argue for the role of communities in driving the ontology building and sharing exercise (section 3), before presenting some concise examples from our own experiences when dealing with real world deployments of ontology-based systems (section 4). We wrap up this short perspectives paper by pinpointing to potential research directions for the field of WBES with respect to interoperability in sections 5 and 6.

2. ON THE INEFFICIENCY OF A GLOBAL ONTOLOGY

WWW2005, May 10–14, 2005, Chiba, Japan.
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[1]Accessible online from:
http://www.win.tue.nl/ laroyo/ICCE2002_Workshop/proc-Workshop-ICCE2002.pdf

Early ontology work suggested that they are suitable for achieving interoperability between disparate systems. In the mid nineties, the seminal article from Uschold and Gruninger provided supportive evidence of this claim [21]. This is best illustrated in a compelling figure of the authors which we redraw in figure 1.

As we can see from that figure, the presence of an ontology makes it possible for two disparate systems (in this example, a *method library* and a *procedure viewer*) to communicate, and ultimately share knowledge albeit they use different vocabularies.

This has been the dominant approach in the nineties. It has been applied to some of the long lasting knowledge sharing projects[2], as well as to a plethora of smaller knowledge sharing tasks. It is effective, once the ontology is up and running, and evidently has a knock-on effect on sharing and design costs [22]. However, it is not efficient: designing the "perfect" ontology that will accommodate all needs is not an easy task. There are irreconcilable arguments among engineers about how and what knowledge should be modelled when trying to build a comprehensive ontology for a given domain. Even when an overcommitted group finally resolves the disputed issues and releases the ontology, there are often inappropriate interpretations of its constructs by users or simply lack of appropriate tools to reason over it.

Furthermore, the emergence of the Semantic Web, made it possible to publish and access far more ontologies than knowledge engineers ever thought that it would be possible to build! Consequently, ontologies proliferated and made publicly available and accessible by large audiences. This brought forward a number of issues regarding scalability, authoring, deployment, and most importantly: interoperability of ontologies themselves. This is different from having a single, consensual ontology upon which interoperability will be based and engineers have to work out on how their systems will communicate with that ontology. There is a call for ontology to ontology interoperability, which includes the acknowledged problem of *ontology mapping*.

Ontology mapping though, is not an easy exercise. As it has been reported in a large survey of ontology mapping systems, [11], "[...] ontology mapping nowadays still faces some of the challenges we were facing ten years ago when the ontology field was at its infancy. We still don't understand completely the issues involved, however, the field evolves fast and attracts the attention of many practitioners among a variety of disciplines.". This resulted in a wide variety of potential solutions to the mapping problem, most of which though, are not fully integrated with the design phase of an ontology neither developed with a view to integration with other solutions. This ad-hoc manner of tackling the problem reveals a mundane need, as it was reported in a specialists' event for semantic interoperability and integration: "[...] it was stressed that domain ontologies need to be built and vetted by domain experts and scientists, as those built by computer scientists were usually rejected." [13].

In the next section, we elaborate on the role that communities can play to alleviate this tension between abundance of inappropriate domain ontologies delivered by engineers and the need for multiple user-certified domain ontologies.

[2]Like the 15 year effort to design, develop, deploy, and maintain CyC ontology – www.cyc.com)

3. EMPOWERING USER COMMUNITIES

In the context of a WBES, users can be seen as the "learners", so to speak, who are interested in accessing and using a wide variety of learning material. From a knowledge modelling point of view, this material is typically encoded as learning objects in some form of an ontology, in the ideal case. A typical *modus operandi* for deploying a WBES would then be for knowledge engineers to characterize, classify and offer learning objects to learners for immediate consumption. However, this ignores - to a certain degree - input from the learners. Although there would be a requirements specification phase where users (learners) can have their say, this is different from having learners engaged in the entire loop of an ontology lifecycle that supports a WBES. As it was concluded in the integration specialists' report: "[...] ontology generation should be done by community members rather than a handful of skilful engineers. That raised the question of how to increase human involvement in the process: it was argued that socially-inspired computing is different from social engineering, a norm in everyday practice at organisations." [13].

The quest is then to find appropriate mechanisms which will enable a targeted set of dedicated users, learners who use WBESs in our case, to modify and customize the WBESs underpinning model, an ontology. This in turn, will have immediate effects in the usage of the WBES, by maximizing user acceptance and usage; and eventually facilitate interoperability with other similar WBESs because learners themselves will highlight which parts of the WBESs are meant to be interoperable.

To the best of our knowledge, there is no working example of this idea of interoperable WBESs, however, there are notable examples of engaging vast communities of users in tasks which are typically seen as a "knowledge engineers job". For example, the work of FOAF network[3] begun as an amusement exercise for few, and nowadays involves a vast number of dedicated users who instantiate and optimize a large, common ontology for describing social network relationships. Another notable example in the Web realm, is the unprecedented success of Blogs which are already flooding the Web. Despite being loosely engineered and controlled, they are written and maintained by millions of users. Finally, there is a variety of (Semantic) Web machinery out there which could be used by large communities of users, like the RSS vocabulary.

Stepping back from technical details on how learners could be involved in ontology management, we look at appropriate theoretical frameworks that describe formally the engagement of users with ontologies. The most visible work in this front, is the Information Flow Framework (IFF) provided by Kent [14]. Kent argues that IFF represents the dynamism and stability of knowledge. The former refers to instance collections, their classification relations, and links between ontologies specified by ontological extension and synonymy (type equivalence). Stability refers to concept/relation symbols and to constraints specified within ontologies.

An ontology, Kent continues, has a classification relation between instances and concept/relation symbols, and also has a set of constraints modelling the ontology's semantics. In Kent's proposed framework, a community ontology is the basic unit of ontology sharing; community ontologies share

[3]www.foaf.org

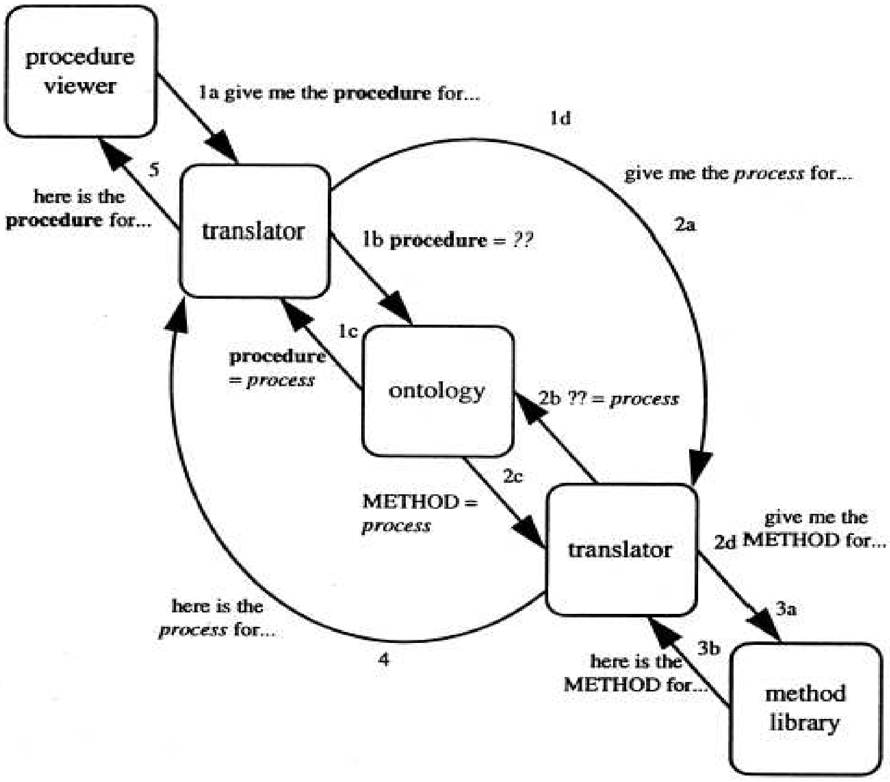

Figure 1: Using an ontology to achieve interoperability.

terminology and constraints through a common generic ontology that each extends, and these constraints are consensual agreements within those communities. Constraints in generic ontologies are also consensual agreements but across communities. Kent assumes two basic principles,

1. that a community with a well-defined ontology owns its collection of instances (it controls updates to the collection; it can enforce soundness; it controls access rights to the collection), and
2. that instances of separate communities are linked through the concepts of a *common generic ontology*,

and then goes on to describe a two-step process that determines the *core ontology of community connections* capturing the organisation of conceptual knowledge across communities (see figure 2). The process starts from the assumption that the *common generic ontology* is specified as a logical theory and that the several *participating community ontologies* extend the *common generic ontology* according to theory interpretations and consists of the following steps:

1. A *lifting step* from theories to logics that incorporates instances into the picture (proper instances for the community ontologies, and so called *formal instances* for the generic ontology).
2. A *fusion step* where the logics (theories + instances) of community ontologies are linked through a *core ontology of community connections*, which depends on how instances are linked through the concepts of the common generic ontology (see second principle above).

The applicability of Kent's framework in WBESs is evident from the fact that individuals and organisations involved in WBESs normally share a generic view of the domain and extend it according to their own special needs. Such a generic view offers the basis for a global *common generic ontology* (see Figure 2). Meanwhile, each participant of WBESs usually possesses a collection of data that can be partially projected onto the generic ontology. This collection of data – playing the role of *community instances* in IFF – provides the ground on which mapping between local, community, ontologies can be performed.

Kent's framework is purely theoretical and only parts of it have been engineered in certain, limited, contexts. However, it does highlight the role of communities in knowledge sharing by controlling instantiation of ontologies and providing extensions to commonly agreed ones. This way of using ontologies makes it possible to instantiate them with user-provided data, thus revealing the *operational* semantics (how instance data are to be used in accordance with a community's view) rather than the *intended* semantics (specified at design time by a knowledge engineer).

We already argued that there are no known examples of WBESs that employ the idea of empowering user communities for achieving interoperability, however, there is early work in applying this idea to certain instantiations of the interoperability problem which we review in the next section.

4. WORKING EXAMPLES

Four years ago the UK's Engineering and Physical Sci-

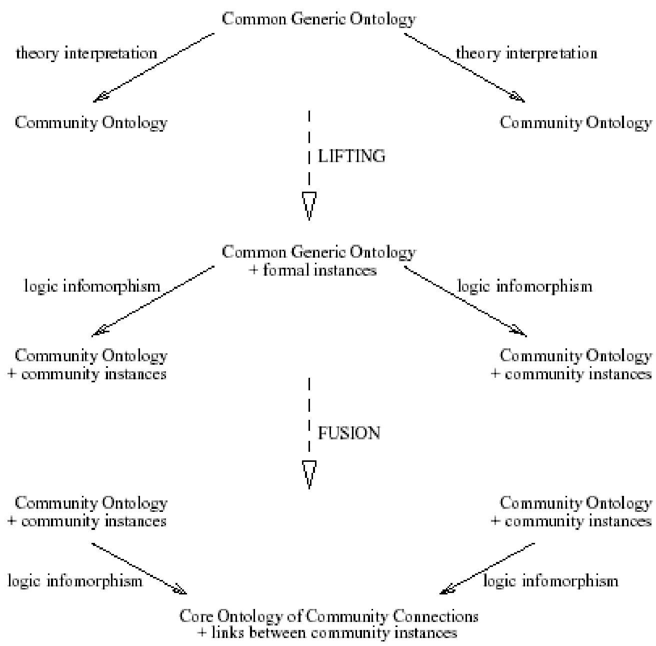

Figure 2: Kent's two-step process for conceptual knowledge organisation.

ences Research Council (EPSRC) funded an Interdisciplinary Research Collaboration (IRC) consortium of five leading British Universities to research Advanced Knowledge Technologies (AKT)[4]. AKT is focussing on the use of Knowledge Management (KM) technologies on the Semantic Web. One of our motto is to *practice what you preach*, so we were keen to experiment with a number of KM technologies in our own consortium setting. The aim was to help new workers familiarize themselves with AKT and the problem domain. A number of audio/visual digital technologies were used, ranging from video recording/playback to live Web-casts of our regular AKT workshops. This material was archived, processed, and made available to new members of the group as a learning material. In that sense, we deviate from the traditional view of using only course material (notes, exercises, references, etc.) as content for WBESs. We see a WBES as a tool for learning in an organisational setting that is not necessarily restricted to the University education domain, as is the norm.

Our preferable option for managing this material was to semantically annotate it using an underpinning ontology. As we envisaged that all content that will be characterized by this ontology should ultimately be shared by a variety of disparate systems, we opted for a single, global ontology. The resulting ontology, AKTive Portal and AKTive Support[5], represents one of the few well crafted, working examples of state-of-the-art Semantic Web technology [19], and supports award-winning applications like the 2003 Semantic Web Challenge winner. However, as we argued in section 2, the global ontology approach has its unbearable costs: it took us the best part of 3 years to finally settle with a version that was both commonly agreed by all stakeholders and most importantly, functional across a variety of systems that use it. Our conclusions were that this sort of global ontologies do have an effect in reducing reuse costs and help achieving interoperability but they are expensive to built and maintain.

We also had experiences with using small, domain ontologies, to support dedicated organisational learning systems. For example, *MyPlanet* is a Web-based personalized organisational learning system which we deployed in the early years of AKT to help learners browse and customize material related to organisational news [9]. The effort involved in building that system was considerably lower than the one in the AKTive Portal and Support ontologies case, however the impact on learners' experiences was limited due to the restricted scope of the underpinning domain ontology (describing only one kind of learning material - organisational news).

These two exemplar cases of using large, global ontologies and small, domain ontologies defined the two ends of the engineering effort spectrum in our experiments. As these efforts had no user involvement (with the notable exception of *MyPlanet*'s profiling mechanism that kept users engaged in the maintenance process), we experimented with technologies that allowed us to engage users in all phases of ontology management. In particular, Alani and colleagues describe a community-oriented approach for managing ontology-based Organisational Memories (OM) [1]. In our scenarios, OMs were used in a variety of settings, most of which address organisational learning and e-learning research. The approach we used is based on the *communities of practice* idea but we tuned it to manage an ontology. We were keen to engage

[4]More on www.aktors.org

[5]Accessible online from www.aktors.org/ontology

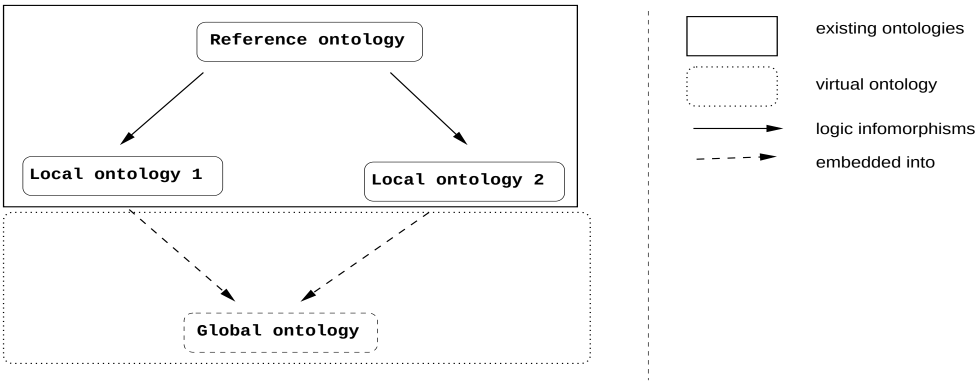

Figure 3: IF-Map scenario for ontology mapping.

users in the process, in particular, to have them instantiate the OM with ontology constructs of their interest. Thus, we set the experiment in our own organisation to have real world instances, like the University's underpinning ontology. Our conclusions with using this technology was that user involvement helped instantiate the OM with the appropriate ontology constructs, however, we do not have concrete conclusions about the impact of this approach to interoperability as there was only one underpinning ontology used. On the contrary, this sort of claim has been made by Schmitz and colleagues [18] when ontologies were deployed to support e-learning repositories (similar to our OM) in distributed environments and found that interoperability was achieved but in their case there was no user involvement in the process.

Our involvement with multiple ontologies also made us consider the ontology mapping problem, a key enabler for achieving interoperability, especially on the Semantic Web. We worked with Information Flow theory, proposed by Barwise-Seligman [2], and developed a system, *IF-Map*, that incorporates ideas from information flow between types (classes) and tokens (instances) of distributed systems. In Figure 3 we illustrate *IF-Map*'s underpinning framework for establishing mappings between ontologies.

The solid rectangular line surrounding `Reference ontology`, `Local ontology 1` and `Local ontology 2` denotes the existing ontologies. We assume that `Local ontology 1` and `Local ontology 2` are ontologies used by different communities and populated with their instances, while `Reference ontology` is an agreed understanding that favours the sharing of knowledge, and is not supposed to be populated. The dashed rectangular line surrounding `Global ontology` denotes an ontology that does not exist yet, but will be constructed 'on the fly' for the purpose of merging. The solid arrow lines linking `Reference ontology` with `Local ontology 1` and `Local ontology 2` denote information flowing between these ontologies and are formalised as *logic infomorphisms*. The dashed arrow lines denote the embedding from `Local ontology 1` and `Local ontology 2` into `Global ontology`.

In Figure 4 we illustrate the underlying workflow process of *IF-Map*[10]. It consists of four major steps: (a) ontology harvesting, (b) translation, (c) infomorphism generation, and (d) display of results. In the ontology harvesting step, ontology acquisition is performed. A variety of methods are applied in this step: use of existing ontologies, downloading them from ontology libraries (for example, from the Ontolingua [5] or WebOnto [4] servers), editing them in ontology editors (for example, in Protégé [7]), or harvesting them from the (Semantic) Web. This versatile ontology acquisition step results in a variety of ontology language formats, ranging from KIF [6] and Ontolingua to OCML [16], RDF [15],OWL, Prolog, and native Protégé knowledge bases. This introduces the second step, that of translation. The authors argue: "As we have declaratively specified the IF-Map method in Horn logic and execute it with the aim of a Prolog engine, we partially translate the above formats to Prolog clauses.". Although the translation step is automatic, the authors comment: "We found it practical to write our own translators. We did that to have a partial translation, customised for the purposes of ontology mapping. Furthermore, as it has been reported in a large-scale experiment with publicly available translators [3], the Prolog code produced is not elegant or even executable.". The next step is the main mapping mechanism – the *IF-Map* method. This step finds *logic infomorphisms*, if any, between the two ontologies under examination and displays them in RDF format. The authors provide a Java front-end to the Prolog-written *IF-Map* program so that it can be accessed from the Web, and a Java API to enable external calls to it from other systems. Finally, they also store the results in a knowledge base for future reference and maintenance reasons.

In this section we highlighted our experiences with using large or small, single or multiple ontologies, use of community-oriented systems and dedicated ontology mapping mechanisms. In the next section, we speculate on potential research routes for WBES interoperability, in particular, in multi-ontology environments like the Semantic Web.

5. GUIDELINES FOR FUTURE RESEARCH

The issues we highlight in this section are not restricted to specifically WBESs interoperability but address a wider range of issues with regard to WBESs: multi vs. single ontology support, Semantic Web enabled WBESs, semantic interoperability, community driven WBESs, versatile content for WBESs. All of them though, are glued together with a vision of how they can affect interoperability among WBESs. For each of these core themes, we pinpoint to potential routes for future research.

- **Multi vs. single ontology support:** one of the

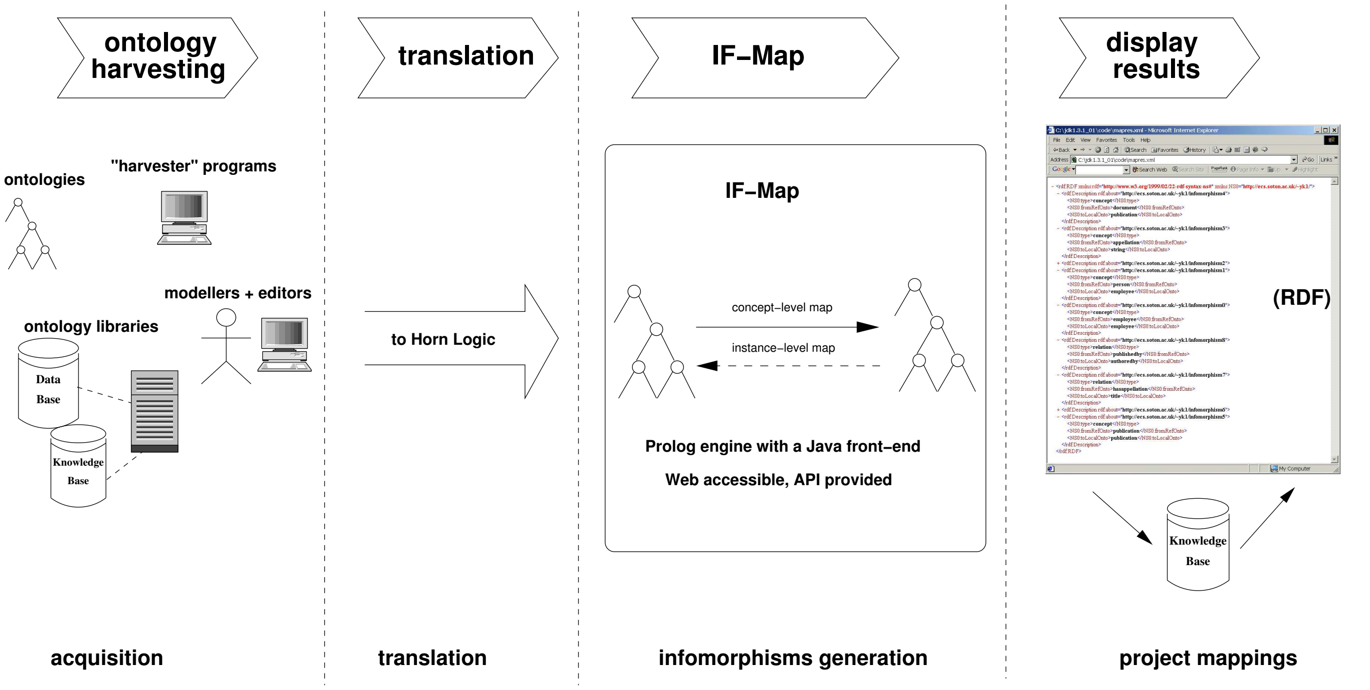

Figure 4: The IF-Map architecture.

trends we experience in developing ontology-supported systems is that we often have to underpin the system's functionality with more than one ontology. The advent of the Semantic Web made that easier to implement as more ontologies are available and accessible online than ever before. The arguments for and against using multiple ontologies are difficult to quantify as it depends on the quality and usage of the ontology in the system. For example, the use of a multiple ontologies structure in the award winning Computer Science AKTive Space application [19] made a difference when dealing with large, heterogeneous data sets extracted from a variety of online resources. These were only made possible to integrate by integrating multiple ontologies describing their semantics. The resulting integrated ontology, however, is a heavy solution (see section 4 for information about the effort involved) and it would have been inappropriate for a simple WBES that employs only a handful of data resources, originating from a single domain and addressing a single educational application (like a University online course). The issue of whether a single or multiple ontologies are better to support WBESs, needs to be viewed under the angle of well defined use cases where the ontological support requirements are clearly identifiable. To the best of our knowledge, such a requirements analysis for WBESs does not exist. Some intuitions though, with respect to scalability of large repositories supporting such systems are provided in [8].

- **Semantic Web enabled WBESs:** the advent and increasing popularity of the Semantic Web poses new challenges but also provides opportunities and solutions for WBESs interoperability. On the positive side we have an abundance of potentially supportive ontologies for a WBES easily accessible and immediately available. Further, Semantic Web initiatives for addressing interoperability issues are well under way and the first mechanisms for supporting this already exist, like specialized ontology mapping built-in constructs for OWL ontologies. On the negative side, the sheer volume of available ontologies and the distributed and loosely controlled structure of the (Semantic) Web sets new challenges for ontology usage in WBESs: authority and version control, trust and provenance, inconsistency and incompleteness, are among the most prominent issues to address before using Semantic Web ontologies in a WBES.

- **Semantic interoperability of WBESs:** a re-occurring theme from the past found new ground in the Semantic Web realm. Semantic interoperability aims at revealing and using semantics to achieve interoperable systems. On the contrary, the bulk of the work done in interoperability, in general, uses syntax only. The crux of the problem is that semantics are often not explicitly stated in artefacts but rather tacitly exist in a designers mind. Semantic interoperability is a knotty problem and as research suggests [12], we are far from having a universal, sound solution in the near future. It affects a variety of systems, including WBESs. We believe that WBESs do not pose any specific requirements for semantic interoperability, albeit an arguably uniform description of their underlying domain (educational artefacts), but they could benefit from semantic interoperability mechanisms especially when multiple, distinct ontologies are used to support them.

- **Community-driven WBESs:** this is one of the directions of WBESs research that could lead to fruitful results for interoperability in general. The unique characteristic of WBESs is that they appeal to large audiences. Hence, vast numbers of learners are immediately available for feedback. How these learners could be used to inform requirements for, or even tune, interoperability algorithms is still at an early research stage. However, user evaluation is a powerful feedback mechanism and WBESs provide a fertile ground for implementing large scale evaluation strategies. Our experiences with communities involvement in the design process of ontologies shows that it benefited and optimized the final artefact, but time and resource constraints should be accounted for.

- **Versatile content:** lastly, but not least, we see content issues as high in the agenda of future WBESs research. Traditional views of educational systems accommodate a rather limited domain of learning: that of University (or similar) online courses. The Web-based extension adds more resources to the traditional view and changes the mode of delivering those courses, but the perception remains the same: offering online courses, in the majority of cases. We advocate that nowadays, a wide variety of content is available online, not necessarily restricted to online courses material: story telling, experiences' reports, social networks, organisational newsletters to name only a few of the many different modes for engaging learners to learning tasks. These ways use versatile content which should be modelled and represented under the same roof, to make it processable by a WBES. Although an ontology will be the preferable choice for modelling this versatile content, interoperability needs arise at the very beginning of using it: distinct content resources will have to be glued together. Therefore, any mechanisms that address content aggregation and management issues should be consulted and possibly employed by interoperability practitioners. We point the interested reader to the work done in the context of the PROLEARN[17] initiative to provide an interoperability framework for learning objects repositories for a discussion on mechanisms to harvest learning content from a variety of resources[6].

6. CONCLUSIONS

In this paper we reviewed the role of single and multiple ontologies in support of WBESs. We argued for the role of communities in informing requirements for interoperable Web-based systems. We highlighted potential research directions for the WBESs community which could benefit Web-based systems communities in general. We would like to wrap-up this paper with a motto: there is a need for achieving interoperability of the means which are portrayed as an interoperability solution for WBESs in the first place: ontologies. And we believe that despite the long road ahead in resolving this knotty problem, WBESs have some unique characteristics which could help improving Web-based interoperability solutions.

[6]LorInteroperability initiative accessible from http://ariadne.cs.kuleuven.ac.be/vqwiki-2.5.5/jsp/Wiki?LorInteroperability

7. ACKNOWLEDGMENTS

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Defining Several Ontologies to Enhance the Expressive Power of Queries

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ABSTRACT
The use of ontologies is a key step forward for describing the semantics of information on the Web. It is becoming more and more important to make the information machine-readable, since the volume of data is continuously growing. In the educational area, metadata are considered to be helpful in such a process. We propose to enrich the description of educational resources by introducing several levels of description of concepts, and to make them machine- readable by using a formal language of ontology, OWL. Using both this ontology and the expressive power of an OWL query language to query pedagogical resources will improve the retrieval and interchange of educational resources.

Categories and Subject Descriptors
H.3.3 [**Information Search and Retrieval**]:

General Terms
Standardization, Languages

Keywords
Semantic Web, ontology, OWL, information retrieval

1. Introduction

Educational resources available on the Web are intended to be shared, accessed or reused. Because of the ambiguity of the natural language (synonymy, polysemy, homonymy, multilingualism) the answers are spoilt by noise. Actually, keywords of the query are matched with indices extracted from the Web pages, but neither the semantics nor the structure are taken into account by the search tools. Some solutions have been proposed in order to explain the semantics of the Web: we note the recommendation of metadata Dublin Core [1] and more specifically the LOM [2] for e-learning resources. The W3C proposed the RDF standard [3] which aim is to represent the knowledge about the available Web resources. Using ontologies [4] is a further step to encourage authors to clarify the domain and the content of the resources, so that search tools could improve the precision and recall and agents could infer some knowledge. The Web Ontology Language (OWL) [5] was carried by the W3C to formalize ontologies on the Web. In this paper, we propose first to explicit a part of the pedagogical ontology of our engineer school, Supélec. Subsequently, we present some examples of queries with OWL-QL [6], using the predefined ontology.

2. Creating several views of an educational ontology

The pedagogical ontology concerns both the organization of an engineer school: Supélec and the content of a teaching program.

2.1. Description of an educational ontology

We first present a part of a UML model of the teaching organization at Supélec.

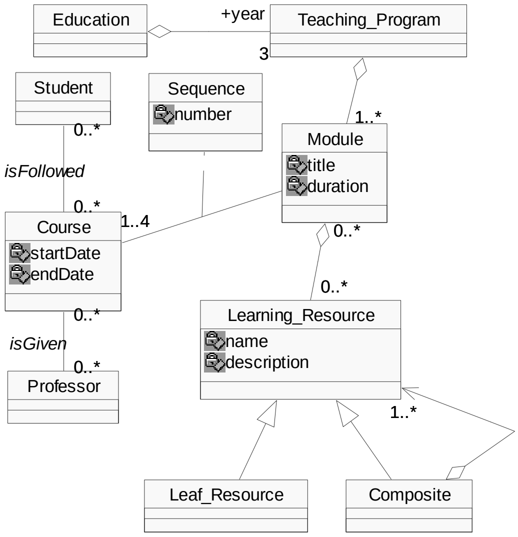

Figure 1. Education's organization

At Supélec, the education lasts three years. Each year is divided into four sequences and contains several teaching modules (each module corresponding to one course per sequence). A module contains learning resources which are either atomic or composite. In the LOM terminology, a learning object is considered as a learning resource, this equivalence can be expressed with an OWL restriction. The UML schema can be transformed into an RDF representation by the way of XPetal [7]. Because exact cardinalities cannot be expressed with RDF, we added an example of a cardinality constraint upon a property of the Education class. With OWL it is possible to specify that one member of Education has exactly three Teaching_Programs corresponding to year 1, 2 or 3. This is an extract of the OWL schema that we get:

```
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns:owl="http://www.w3.org/2002/07/owl#"
  <owl:Ontology rdf:about="file:/C:/BLD/Recherche/Articles/2003-
2004/onto1-supelec.owl "/>
  <owl:Class rdf:ID="Education">
<rdfs:subClassOf>
<owl:Restriction>
  <owl:onProperty rdf:resource="#contains />
  <owl:cardinality rdf:datatype=
"&xsd:nonNegativeInteger">3</owl:cardinality></owl:Restriction>
</rdfs:subClassOf></owl:Class>
<owl:ObjectProperty rdf:ID="contains">
<rdfs:domain rdf:resource="#Education">
<rdfs:range rdf:resource="#Teaching_Program">
</owl:ObjectProperty>
  <owl:Class rdf:ID="Teaching_Program"/>
  <owl:oneOf rdf:parseType="Collection">
   <Teaching_Program rdf:about="#year_1">
   <Teaching_Program rdf:about="#year_2">
   <Teaching_Program rdf:about="#year_3">
</owl:one of></owl:Class>
<owl:Class rdf:ID="Learning_Object" >
  <rdfs:subClassOf>
  <owl:Restriction>
  <owl:onProperty rdf:resource="#isComposedOf"/>
  <owl:allValuesFrom>
    <owl:Class>
    <owl:unionOf rdf:parseType="Collection">
    <owl:Class rdf:about="#Composite"/>
    <owl:Class rdf:about="#Leaf_Resource"/>
    </owl:unionOf>
    </owl:Class></owl:allValuesFrom>
    </owl:Restriction></rdfs:subClassOf>
</owl:Class>
```

The domain and scope of the second part of the pedagogical ontology are the learning resources participating in a teaching program, created by teachers or educational organizations. In order to preserve the semantics given by the LOM, we mention some definitions:

Learning Object: any entity that may be used for learning, education or training.

Category: a group of related data elements.

Data element: a data element for which the name, explanation, size, ordering, value space and datatype are defined in the LOM standard.

Now we present two other UML representations of a learning objects view and a LOM metadata view.

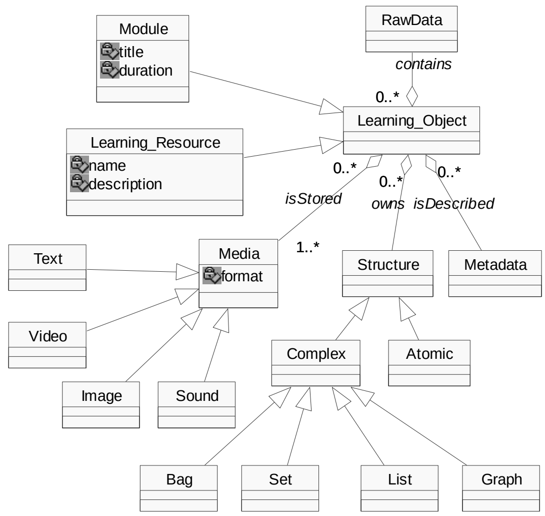

Figure 2. Model of Learning Objects

In figure 2, the Module and Learning resources are two types of Learning Objects in the terminology of LOM. A learning object is composed of raw data, media, structure and metadata. The media is text, sound, image or video. Each media type has a format (for example jpeg for an image, MP3 for a sound). The structure of a learning object is either atomic or complex (for example a definition, an example or a theorem is an atomic learning object whereas a module of software engineering is a complex one). Each learning object is described by a set of metadata which are detailed in figure 3. This representation reflects the view of LOM metadata with the concepts of categories, data elements and types of data element (the structure to represent the logical relationships between learning objects and the content to represent the content of a learning resource).This is an extract of the OWL representation of the learning object's view.

```
<owl:Class rdf:ID="Text">
  <owl:disjointWith>
    <owl:Class rdf:about="#Video"/>
  </owl:disjointWith>
  <rdfs:subClassOf>
    <owl:Class rdf:about="#Media"/>
  </rdfs:subClassOf>
 </owl:Class>
<owl:Class rdf:ID="Bag">
 <rdfs:subClassOf rdf:resource="#Complex"/> </owl:Class>
<owl:Class rdf:ID="Set">
 <rdfs:subClassOf rdf:resource="#Complex"/> </owl:Class>
<owl:Class rdf:ID="List">
 <rdfs:subClassOf rdf:resource="#Complex"/> </owl:Class>
<owl:Class rdf:ID="Graph">
 <rdfs:subClassOf rdf:resource="#Complex"/> </owl:Class>
</owl:Class>
<owl:class rdf:ID="Bag">
  <owl:disjointWith rdf:resource="Set"/>
  <owl:disjointWith rdf:resource="List"/>
  <owl:disjointWith rdf:resource="Graph"/>
</owl:Class>
```

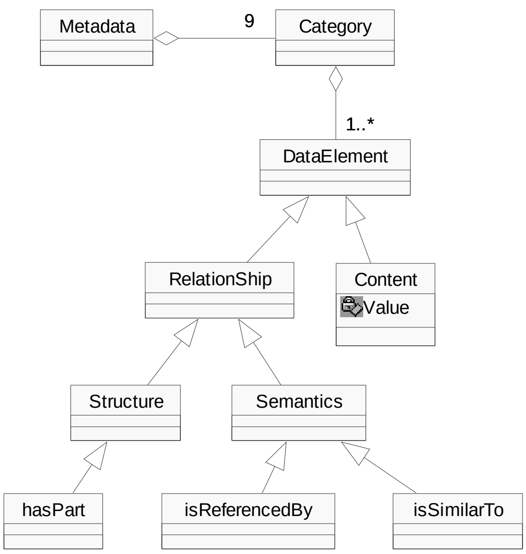

Figure 3. Model of LOM Metadata

A domain view (for example a thesaurus of the computer science) is illustrated by a hierarchy of terms, that guaranty there is no ambiguity in terms of understanding. The following extract of the classification of computer science built by ACM can be also translated into OWL:

D SOFTWARE
D.0 GENERAL
D.1 PROGRAMMING TECHNIQUES (E)
D.2 SOFTWARE ENGINEERING (K.6.3)
D.2.0 General (K.5.1)
D.2.1 Requirements/Specifications (D.3.1)
  Elicitation methods (e.g., rapid prototyping, interviews, JAD) (NEW)
  Languages
  Methodologies (e.g., object-oriented, structured) (REVISED)
  Tools
D.2.2 Design Tools and Techniques (REVISED)
D.2.3 Coding Tools and Techniques (REVISED)
  Object-oriented programming (NEW)
D.2.4 Software/Program Verification (F.3.1) (REVISED)
  Assertion checkers
  Class invariants (NEW)
D.2.5 Testing and Debugging
  Testing tools (e.g., data generators, coverage testing) (REVISED)
  Tracing

This hierarchy of terms may be represented in OWL with subclass and equivalent relations.

```
<owl:Class rdf:ID="D">
   <rdfs:label>Software </rdfs:label></owl:Class>
<owl:Class rdf:ID="D2">
   <rdfs:label>Software engineering </rdfs:label></owl:Class>
   <rdfs:subClassOf rdf:resource="#D"/> </owl:Class>
   <owl:equivalentClass rdf:resource="#K.6.3"/> </owl:Class>
</owl:Class>
```

Each of the view was translated and refined by the OWL formalism.

2.2. Description of learning resources with the LOM semantics

The preliminary task consisted in translating the model of the LOM into a schema in OWL. We did it with the Protégé 2000 editor [8] in figure 4. We considered the Learning Object as a class, the categories and data elements as the properties of the Learning Object, and we explained the constraints on the space value. The following task consisted in classifying the concepts of our pedagogical ontology, integrating the two parts of ontologies, and specifying the properties and constraints:

```
<rdf:RDF
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:lom="http://ltsc.ieee.org/wg12/"
<owl:Ontology rdf:about=" ">
<owl:imports rdf:resource="file:/C:/BLD/Recherche/Articles/2003-2004/onto1-supelec.owl "/>
```

In our example, the concepts introduced in section 2.1: education, teaching_program, module, and learning_resources are considered as learning objects. The Learning_Object class is divided into two subclasses: Atomic_Object and Composite_Object. To express the level of granularity of the different learning objects, we used the following data elements of the LOM: General.Structure with value space in {atomic, collection, networked, hierarchical, linear} and General.AggregationLevel with value space in {1,2,3,4}. Thanks to OWL, we can easily specify that an Atomic_Object must values General.Structure = atomic, General.AggregationLevel = 1, or that a teaching program has value General.AggregationLevel > 2.

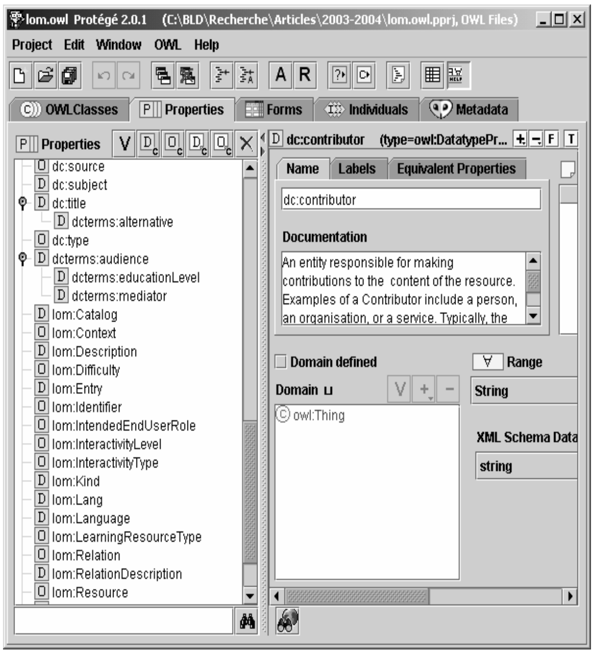

Figure 4. Edition of classes and properties

2.3. Description of the relationships between learning objects

Let's go further with the composition of learning objects which has been evoked in sections 2.1 and 2.2.
We define two categories of links among learning objects: the structural and the semantical ones. The structural links correspond to the logical structure of resources ("hasPart" and "sequence" links) whereas the semantical links correspond to the semantics of the associations among resources (besides the various relations defined in Dublin Core [1] we establish additional semantical links such as "summarization, reason, rephrase, negative, example" links). The structural links are particularly important because they participate in the reasoning mechanisms as we will see in the next section.

Figure 5. simplifies an example of the description of learning resources with two levels of representation: the schema level and the instance one. The schema level is described thanks to an ontology, the instance level is the knowledge base.

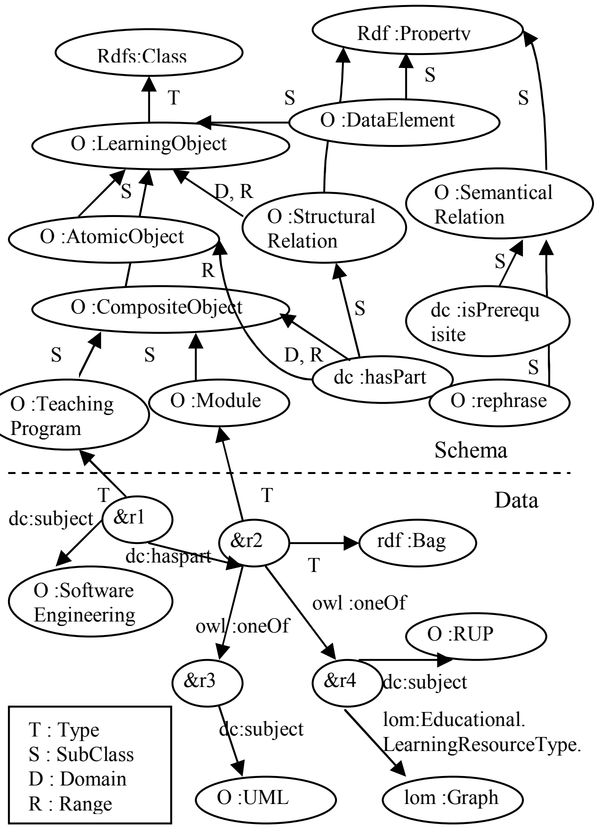

Figure 5. Schema and data example

3. Querying the pedagogical ontology

OWL-QL is a formal language and it is intended to be a candidate standard language for query-answering among semantic web computational agents. An OWL query contains a query pattern that specifies a collection of OWL sentences in which some URIrefs are considered to be variables. These answers provide bindings of URIrefs or literals to some of the variables in the query. For example, we could ask "Is there any course module whose the author is Mike?" The query can have the form: "(type ?c module) (author ?c mike)" where each query pattern is represented by a set of triples of the form (property subject object) and the variables are prefixed by the character "?". Inference mechanisms enable to deduce new information from some properties (symmetry, transitivity…).The OWL language allows us to specify property characteristics, which provide a powerful mechanism for reasoning about a property. The property can be exploited in the query part. For example consider the transitive property in OWL. If a property P is specified as transitive then for any x, y and z: P(x,y) and P(y,z) implies P(x,z). The structural relation "isPartOf" is transitive. This allows us to define simple query for asking about any learning object linked to a module by a direct or indirect "isPartOf " structural relation :

Q1 : (type ?x LearningObject) (type ?y module) (isPartOf ?x ?y)
From the example Figure 5., finding a graph resource illustrating a module or a course in software engineering is expressed with an OWL-QL like language as:
Q2: (type ?c Graph)(or (isPartOf ?c module) (isPartOf ?c course))
Finding all semantical links related to the &r1 resource:
Q3 : (type ?c SemanticalRelation) (rdf:Range ?c &r1)
As we illustrated in some of these examples, possibilities in expressing various powerful queries widen from schema and data queries, metadata, structural and semantic links, and reasoning forms.

4. Conclusion

In the building of a pedagogical ontology at Supélec, we distinguished two domains. The first one represented an education's organization. It has been enriched with the second ontology which represented a pedagogical content using standardized metadata (LOM). We showed the importance of the relations among learning objects to infer additional knowledge in the querying step. We use Protégé 2000 for our examples. We edited the entire LOM schema, the schema and instances of our pedagogical ontology. Protégé 2000 enabled us to detect and solve some inconsistencies in the classes and relations and therefore to validate our schema. It is possible to query some simple facts and to make some inferences. We gave some examples of queries in order to show the expressive power of a query language exploiting the benefit of the ontologies. OWL-QL syntax was chosen to show some examples of queries but we consider other query formalisms. We are currently implementing an OWL query language to test further our pedagogical ontology.

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Learner-centred Accessibility for Interoperable Web-based Educational Systems

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ABSTRACT

This paper describes the need for an information model and specifications that support a new strategy for delivering accessible computer-based resources to learners based on their specific needs and preferences in the circumstances in which they are operating. The strategy augments the universal accessibility of resources model to enable systems to focus on individual learners and their particular accessibility needs and preferences. A set of specifications known as the AccessForAll specifications is proposed.

Categories and Subject Descriptors

H.1.2 (**User/Machine Systems**): *Human factors, human information processing*

H.3.7 (**Digital Libraries**): *collection, dissemination, standards, user issues*

H.3.3 (**Information Search and Retrieval**): *retrieval models, selection process*

H.3.5 (**Online Information Services**): *data sharing, Web-based services*

General Terms

Management, Human Factors, Standardization.

Keywords

E-learning systems, accessibility, learner profiles, AccessForAll

1. INTRODUCTION

This paper describes the requirements, model and specifications for a new strategy for delivering accessible computer-based resources to learners based on their immediate specific needs and preferences. There are many reasons why learners have different needs and preferences with respect to their use of a computer, including because they have disabilities. Instead of classifying people by their disabilities, this new approach emphasizes the resulting needs in an information model for formal structured descriptions of them. It then provides a complementary formal, structured information model for describing the characteristics of resources required for the matching process. The aim is to make it easy to record this information and to have it in a form that will make it the most useful and interoperable.

This work builds on work being done primarily by the World Wide Web Consortium Web Accessibility Initiative (W3C/WAI) [1] to determine how to make resources as accessible as possible. The focus of the new work is how to make sure that accessibility is learner-centered and supportive of good educational practices. The distinguishing feature of the current work is that it provides an approach that assembles distributed content into accessible resources and so is not dependent upon the universal accessibility of the original resource.

The specifications for a common description language, while initiated in the educational community, are suitable for any user in any computer-mediated context. These contexts may include e-government, e-commerce, e-health and more. Their use in education will be enhanced if there are accessibility descriptions of resources available to be used in education even if that was not their initial purpose. The specifications can be used in a number of ways, including: to provide information about how to configure workstations or software applications, to configure the display and control of on-line resources, to search for and retrieve appropriate resources, to help evaluate the suitability of resources for a learner, and in the aggregation of resources.

An extra value of the specifications described will be in what is known as the network effects: the more people use the specifications, the more there will be opportunities for interchange of resources or resource components, and the more opportunities there are, the more accessibility there will be for learners.

2. OVERVIEW

Virtually any student, irrespective of any disability, can be enabled to effectively interact with a computer. Some students with disabilities require alternative access systems, usually referred to as "assistive technology," to enable them to do this and others need the way content is presented to them by the computer to be appropriate or they may need to interact with the computer using methods other than the conventional keyboard and mouse. There are well-established principles for how to promote accessibility in software design and electronic content [2]. These promote compatibility with assistive technology and ensure that different ways of interacting with the computer can be accommodated.

There are a number of approaches to making networked resources accessible, whether on the Internet or on an Intranet.

The first and most common approach is to create a single resource (Web site, Web application) that meets all the accessibility requirements. Such a resource is known as a universally accessible resource. While this approach would work well in many situations,, it is not often that the resource is fully 'universally accessible', especially if it contains interactive components. Worse, so-called universally accessible resources are so judged by conformance to W3C accessibility conformance and this approach is not infallible, as the guidelines are not 'perfect'. There are examples of when the guidelines can be followed without the resource actually being accessible as expected and there are many vagaries due to lack of attention to usability principles that also account for lack of satisfactory access [3]. Indeed, the resource may be accessible to everyone, but optimal for no one. Often, resource components that are very effective, entertaining or efficient for some but not all learners are rejected or not displayed. New technologies and techniques are often not used for fear that they will not meet the requirements.

The second approach used by a number of educational content providers is to create two versions of the resource: a media rich version and an "accessible version," which is stripped of all media that may cause accessibility problems. While this solves some of the problems with the first approach, it can also cause other problems. In some cases, the accessible version is not maintained as well as the default version, giving learners with disabilities an out-of-date, different view of the information. More often, students who perhaps need more assistance get less because they are using the impoverished version of the resource. The notion that learners with disabilities are a homogenous group that is well served by a single bland version of a resource is also flawed.

The third approach differs from the first two in a number of ways. Accessibility requirements are met not by a single resource but by a resource system. Rather than a single resource or a choice between two resource configurations, there can be as many configurations as there are learners. The ability of the computer mediated environment to transform the presentation, change the method of control, to disaggregate and re-aggregate resources and to supplement resources is capitalized upon to match resource presentation, organization, control and content to the needs of each individual learner. This is known as the AccessForAll approach.

For a network delivery system to match learner needs with the appropriate configuration of a resource, two kinds of descriptions are required: a description of the learner's preferences or needs and a description of the resource's relevant characteristics. These two descriptions are the subject of the AccessForAll specifications [4]. The Accessibility for Learner Information Profiles specification (AccLIP) is a specification for describing a learner's needs and preferences and the AccessForAll Meta-data specification (AccMD) is a corresponding specification for description of the resource.

The AccessForAll specifications were developed by IMS Global Learning Consortium; the Dublin Core Metadata Initiative Accessibility Working Group, and others.

2.1 Accessibility for people with disabilities

It is not the purpose of this paper to give an introduction to accessibility. The authors and numerous others have done that many times. In order to understand the rationale for this work, however, it is important to realize that virtually anyone, irrespective of disability can be enabled to use computers. They just require one sense (visual, aural, or tactile) that they can use to interpret the output from the computer and control input to the computer. Most people with disabilities are able to employ technical aids usually referred to as assistive technology. These include screen readers that can transform well-formatted text into synthesized speech; screen magnifiers that enlarge the display in a well-managed way; and alternative input devices that replace or augment the conventional keyboard and mouse. Other people require content on the computer to be presented to them in a particular way. For example, they may find text much easier to read if it is presented in a high contrast as yellow on black and in a particular font. Others will, of course, prefer alternative fonts and color schemes. Sometimes only a part of the content is not accessible to a learner and they require the same information to be presented in an alternative way. For example, a blind person may not be able to access video material but can benefit from an audio description of the same material or a deaf person can benefit from captions (sub-titles) that replace the dialogue. It should be stressed that not all such requirements arise from a disability but can also be because of the circumstances the computer is being used in. For example, when working in a large lecture theatre, a noisy environment, hands free, or on a small screen PDA.

2.2 The value of the accessibility agenda

There are many well-documented arguments for why web content and service providers in general, should be concerned about accessibility [5]. Major arguments are often cited; social responsibility, market-share, financial benefits and legal liability. By not dealing with accessibility issues a provider excludes a large number of people from using their site.

Recent research in the US for Microsoft has shown that 60% of the working community would benefit from accessible content. Of these, perhaps 10% have no access unless the content and services are fully accessible. The moral and market arguments are obvious. Those who do provide accessible resources will have exclusive access to a significant sector of the market. In Australia in 2004, a large publishing house re-built their website to make it fully accessible. They have reported that they now save $1,000,000 in transmission costs per year [6]. Finally, in many countries there is increasingly strict legislation requiring access for all citizens and in education, the standard is often quite demanding and the consequences of failing can be expensive anti-discrimination penalties.

In education, where the requirements are usually more demanding, many countries are now practicing what is sometimes called 'inclusive' education that aims to include and provide equally for all potential students. Lack of accessibility is a serious problem.

2.3 Describing Learner Needs and Preferences

The AccessForAll approach involves specifications for describing learner preferences and needs that define a functional description of how a learner prefers to have information presented, how they wish to control any function in the application and what supplementary or alternative content they wish to have available. This requirement for functional specifications is based on the philosophy that disability is a mismatch between a learner's needs and preferences and what they are presented with. It is an artifact of the relationship between a learner and an interface or application. Thus a learner who is blind does not have a disability in an audio environment but a learner who is using a computer without speakers or a headphone does.

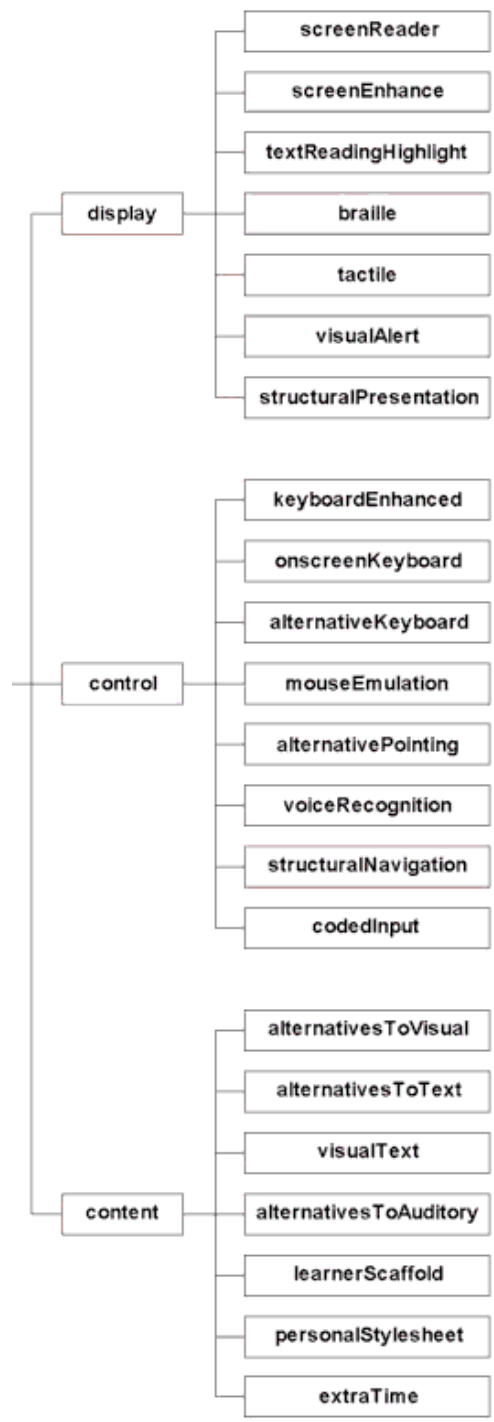
This description should be created by learners or by their assistants, usually with a simple preference wizard. It should be of needs and preferences that are essential to a learner's functioning as a consequence of their having a disability or it may be that the circumstances, devices, or other factors have led to the mismatch between them and the resources they wish to use. Each learner may need more than one description of needs and preferences or accessibility *profiles* to accommodate their changing needs within different contexts. A learner may have one profile for work and another for home if the bandwidth is different, for example. In addition, these profiles should be able to be changed to suit immediate needs and preferences, to accommodate changes in circumstances or context.

2.4 Describing Resource Characteristics: The Content Model

The AccessForAll approach requires finer than usual details with respect to embedded objects and for the replacement of objects within resources where the originals are not suitable on a case-by-case basis. This is made possible by describing the resources in terms of their modalities – auditory, visual, tactile, and text. In addition, the separation between primary and equivalent resources is necessary to permit flexible dis-aggregation and re-aggregation to meet the individual needs.

Most resources consist of multiple objects combined into what are commonly known as pages. Sometimes this is done once and there is a static version available and sometimes it is done dynamically for the learner. What is unusual about the new accessibility approach is that the objects that

Figure 1: The AccessForAll profile criteria



comprise the version of the resource that is sent to the learner need not be located in the same place, that is, they may be distributed. In fact, the original composite resource may contain objects that need to be transformed, replaced or augmented; the equivalent objects used for replacing or augmenting may have been created in the original authoring process, or in response to some other learner's difficulties with the original resource.

Resources and objects within resources should be classified into two categories: primary and equivalent. Most resources are primary resources and require a simple set of statements: how transformable is this resource, what access modality is used (vision, hearing, text literacy or touch) and what is the location of any known equivalent alternative. The workload of the creator of the primary materials' metadata should be kept as light as possible. The accessibility characteristics of equivalent alternatives such as caption files or image description files also need to be described

2.5 The Process of Matching

2.5.1 Authors and Authoring Tools

The authoring requirements for the content creator using the AccessForAll approach are different and sometimes easier than in other approaches to creating accessible materials. Objects are treated in a more modular fashion, and universal accessibility is not expected of each object, just the combination of objects. The responsibility is, as always, with the author to provide as many accessible pieces as possible but mainly on the resource server to combine them appropriately for the learner. For this approach, there are the usual basic authoring principles, requiring that each part of the resource be created following the standards for accessibility, but when there is an object that may not be accessible, it can be described as inaccessible and the location of an alternative identified. This means that the author does not have full responsibility for creating accessible content and also that a second or later author can make an inaccessible resource or object accessible, by providing or identifying an equivalent alternative and contributing its accessibility profile.

The W3C/WAI guidelines offer specifications for accessible authoring tool [7]. Accessible authoring tools provide authors with guidance in the authoring process as well as making it possible for people with special needs and preferences to participate in the authoring process. Many of these assume little 'accessibility' expertise on the part of the author. Some tools are specifically for the production of content but others help in the process of making content accessible. Some of these tools are already able to help in the production of content profiles.

2.5.2 Cumulative and Collaborative Authoring

The AccessForAll approach supports cumulative and collaborative authoring by allowing new equivalent resources to be added to a collection independently of the original resource authors. Subject matter experts can create primary content, while organizations or educators with experience in alternative access strategies can create the equivalents. Over time, a resource collection can grow richer with alternatives and thereby provide more complete access.

2.5.3 Dynamic and Static Content Publishing

Where content is to be stored ready for presentation to learners, it may be in complete resource form or it may be held as objects that will be accumulated and presented within a template at the time of a request from a learner. Static content publishing, the former, requires the content to be in a universally accessible form, replete with all the alternatives that may be needed within the single resource. Dynamic publishing allows for the customization of the resource, with objects being selected as they are combined. This form of publishing is easier to adapt to the new approach. It is also a more common form of publishing for larger educational institutions.

2.5.4 Transforming, Supplementing and Replacing

The process of selection of objects for combination into resources according to learner profiles can take three forms: transforming, supplementing and replacing. When there is no visual ability, images need to be replaced by either audible or tactile equivalents. Where there is a need for intellectual support, a dictionary may be needed as a supplement to a resource or an object. Where transformation of objects occurs most frequently is with text. Well-formed text can be rendered visually, as characters, or a sign language, or aurally, perhaps by a screen reader, or transformed into a tactile form as Braille or simply changed in color, size and other display features.

2.5.5 Metadata interoperability

The AccessForAll descriptions of learner needs and resources for them are metadata. Metadata is information, usually structured, about an object, be it physical or digital. It can be thought of as similar to a library catalog record of a book. As with a catalog record, metadata does not have to be part of a resource, although it should be associated with it, and it does not have to be made at the same time as the resource or even by the resource's author or owner. A good general description of metadata is available in "Metadata Principles and Practicalities" [8].

Metadata is most commonly associated with the resource discovery process. In the case of AccessForAll metadata, resources and objects can be filtered according to needs and preferences identified in a learner's profile, or metadata. Thus, in the new strategy, the matching of metadata enables the matching of resources to needs and hence accessibility.

The difference between what is commonly done with metadata and what is described here is perhaps in the way in which the resource is often seen both as a composite resource and as a set of objects, as described above. A resource, whether a service or content of another kind, often has components that are in different modalities; such as a Web page with some text and a picture. The text, if properly formed, can be transformed into speech but the image will need to be replaced by text that can then be rendered as speech. This means that not only is it important to note that the resource as a whole has some text and an image, but it may also be necessary to have some detail about those items that together form the resource. Metadata is most useful if it confines its scope to the thing it is describing but those descriptions, if correctly written, can often be combined to provide a description of the whole. In the approach described in this paper, the objects that will eventually comprise the whole resource are most easily discovered and used if they have their own metadata, as well as if the composite has its own metadata. This is considered quite reasonable practice in the metadata world.

Two metadata sets, the IEEE LOM and the Dublin Core Metadata Set (described below) together account for a vast amount of metadata used in education worldwide. It is essential that interoperability be maintained among the different communities using metadata but also across sectors such as education, e-government, e-commerce, e-health and other activities that want to share resources. The approach described in this paper was explicitly developed to be compatible with both IEEE LOM and DCMI metadata.

- **IEEE LOM [9]**
  The IEEE LOM (Institute of Electrical and Electronics Engineers' Learning Object Metadata Standard) is a profile for learning object metadata. It contains a description of semantics, vocabulary, and extensions. An encoding of accessibility metadata that harmonizes with AccessForAll metadata and is suitable for use in an IEEE LOM Application is under construction by CEN-ISSS Learning Technologies Workshop [10].
- **Dublin Core Metadata Element Set [11]**
  The Simple Dublin Core Metadata Element Set is the ISO 15836 standard for core metadata. There is also a Qualified Dublin Core Metadata Element Set with additional terms and extensions. Dublin Core metadata is not domain specific. Dublin Core elements include a new special one for accessibility to be used for AccessForAll metadata.

2.5.6 Accessibility and eLearning systems

A key challenge in accessibility is the diversity of need; different people require different accommodations. Established approaches towards addressing this are to allow customization by the end learner (e.g. text size and color) and to offer alternative presentations of the same content where automatic customization is not possible (e.g. text description of diagrams or audio descriptions of video content).

Integrated eLearning systems potentially offer an efficient way of managing and even extending this. They can personalize the way the interface and the content are presented to the learner and further, which content is presented to the learner can be determined by the system on the basis of stored information about the individual learner and their preferences.

Such eLearning systems offer the educational institutions the opportunity to efficiently manage their requirement to meet the needs of their disabled students. If they implement student profiles and adopt the AccessForAll approach, the system will “know” how best to present content and interfaces to each individual learner. If they implement the approach for the metadata of the content stored in their repositories, then the system can automatically offer the learning content, and other information, in the most appropriate format to meet individual learner needs. Furthermore, disabled students and their faculty or advisors will be able to instigate automated searches of the content associated with any particular course or module, and determine if any of it presents particular accessibility problems for that student. With this information, they will be able to commission alternative formats of the same content or locate an alternative learning activity ahead of time if that is more appropriate.

2.6 The Information Models

A detailed description of use of cascading learner profiles and of the preferences and requirements that can be recorded in a learner’s profile is a necessary part of the AccessForAll specifications. The other specifications necessary for the AccessForAll approach are for the description of the accessibility characteristics of resources and components.

The specifications developed by the IMS/DCMI collaboration contain an information model that can be implemented in a variety of ways. A typical implementation at the time of writing is likely to be in eXtensible Markup Language (XML) and so there is an XML binding and schema to accompany the model. The metadata specification for describing content has specific data structures within it that directly map to the data structures in the specification for describing preferences for how content should be presented to the learner. Understanding the learner profile model, the AccLIP makes understanding the resource profile model, the AccMD, a lot easier as the latter is derived from the former.

2.6.1 The AccLIP Model

The AccLIP information model is for a detailed machine-readable description of a learner’s needs and preferences in the way they interact with the computer. This includes information about any accommodations the learner may need in the way that content is presented to them and display and control approaches they may adopt when using the computer.

The AccLIP model includes accommodations and approaches needed or adopted by learners with disabilities but is more general than that. There are no elements that enable a description of a learner’s disability by medical classification to be declared, nor should there be. The description is of the preferred human computer interaction approaches and preferred content characteristics needed to enable the envisaged automated functions of the system to be implemented. It is in line with the philosophical stance that moves away from a medical model of disability to a social one.

2.6.1.1 The AccMD Model

The AccMD model is for metadata that expresses a resource’s ability to match the needs and preferences of a learner’s AccLIP profile. It is intended to assist with resource discovery and also provides an interoperable framework that supports the substitution and augmentation of a resource or resource component with equivalent or supplementary components as required by the accessibility needs and preferences in a learner’s AccLIP profile. For example, a text caption could be added to a video when required by a learner with a hearing impairment or in a noisy environment.

In general, metadata can be used for two main accessibility related purposes: to record compliance to an accessibility specification or standard (e.g., for adherence to legislated procurement policies) or to enable the delivery of resources that meet a learner’s needs and preferences. The AccMD specification addresses the latter purpose. Metadata to assert compliance to an accessibility specification or standard is not within the scope of this specification. It may be useful, however, if it is in a form that allows it to be transformed and re-purposed as AccMD metadata.

2.6.1.2 Overview of the AccMD Information Model

The AccMD specification is defined in terms of two basic classes that are then further refined and detailed. A description is either of a <primary> resource or an <equivalent>. This mirrors a common practice in the accessibility world for an equivalent to be produced not by the original author of the resource but by someone else, that person or organization having expert knowledge of how to make that resource accessible in the specific context.

A resource could contain its own equivalents (such as an image with alternative text description) and therefore could have a primary **and** one or more equivalent resource descriptions.

A primary description is very simple and consists of a simple classification of the access modalities of the resource with terms selected from *hasVisual*, *hasAuditory*, *hasText* and *hasTactile*. For each modality a simple binary judgment can be made as to whether that access modality is required for the resource to be useful.

A primary resource description can also have links to EARL [12] statements recording machine-readable adaptability properties that describe the transformability and flexibility for interface control of the resource. EARL is the Evaluation And Report Language, a Resource Description Framework (RDF) language developed by W3C that can express the outputs of evaluation and repair processes in machine-readable form. Typically, EARL statements contain the results of evaluation processes operated or managed by tools that can execute tests, possibly with some human intervention and guidance. The AccMD specification references EARL statements, to describe the display transformability and control flexibility of a primary resource. Such EARL statements are metadata with the constraint that they make it clear when the statements were made and by whom.

A primary resource description can contain a pointer to an equivalent for the resource or for a part of it. Equivalent resource descriptions provide a mechanism whereby an alternative (i.e. replacement for) or supplementary for a resource or part of a resource can be provided. The distinction between these is made with a Boolean field "supplementary", the interpretation being that if this is false then it is an alternative.

An equivalent resource description will have a link to the object and part for which it is an equivalent. For the case where an object contains its own alternatives this will be a link to itself. An equivalent or supplementary object may need to be synchronized with the primary or other objects and so there may also be a synchronization file.

The final part of a resource description according to the AccMD specifications is data drawn from the range of values in AccLIP fields. For example, the <colorAvoidance> elements defined in the <alternativesToVisual> class match the <colorAvoidance> values defined in the AccLIP specification.

The AccMD specification [13] provides guidance on how to match accessibility metadata (i.e. a resource profile) to the properties defined in the AccLIP specification (i.e., a learner profile). It also defines the behavior applications should exhibit in some specific contexts; see the Best Practice Guide [14] for more information. While AccLIP and AccMD are designed to work together, there is no prescription about how they should be implemented beyond necessary behaviors that should be standardized for the sake of interoperability.

2.7 The Process of Matching Learners with Resources

Given metadata about the learner's needs and preferences and metadata about the accessibility characteristics of the resource or object, the process of matching the resource to the learner's needs and preferences can begin.

A typical diagram showing the behaviors of systems using the metadata specified in the AccessForAll model is below (Figure 2).

2.8 Pilot Projects

Three projects described briefly here illustrate the diversity of application where the approach offers real benefit to both the end-learners and the service providers.

2.8.1 TILE

The Inclusive Learning Exchange [15] (TILE) is a learning object repository developed by the Adaptive Technology Resource Centre at the University of Toronto that implements both AccMD and AccLIP. When authors (educators) use the TILE authoring tool to aggregate and publish learning objects, they are supported in creating and appropriately labeling transformable aggregate lessons (codified by the TILE system using AccMD). Learners of the system define their learner preferences, which are stored as IMS-AccLIP records. TILE then matches the stated preferences of the learner with the desired resource configuration by transforming or re-aggregating the lesson.

2.8.2 Web-4-All

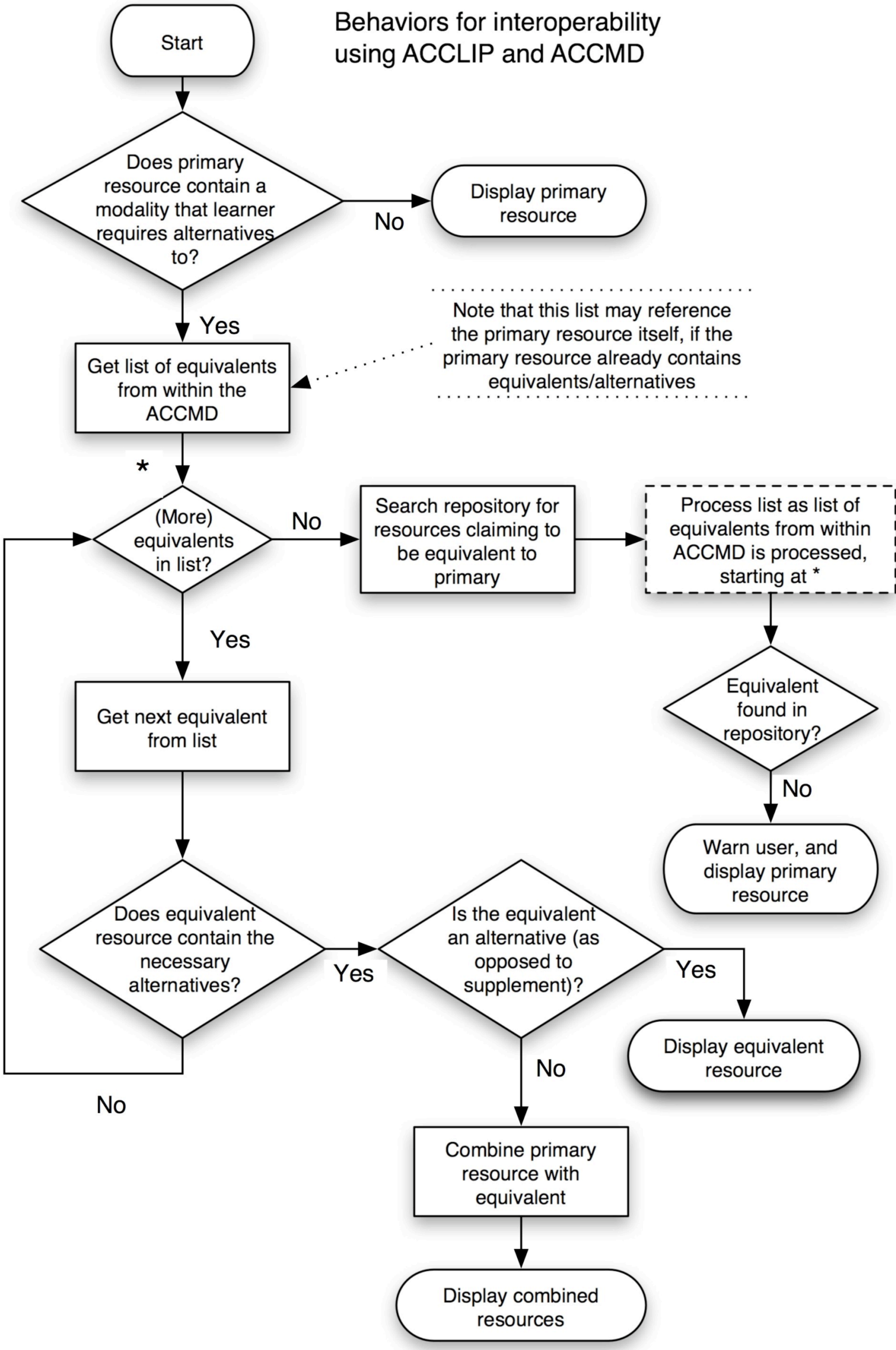
The Web-4-All [16] project is a collaboration between the Adaptive Technology Resource Centre at the University of Toronto and the Web Accessibility Office of Industry Canada to help meet the public Internet access needs of Canadians with disabilities and literacy issues. Web-4-All allows learners to quickly and automatically configure a public access computer using a learner preferences profile implemented with the AccLIP and stored on a smartcard that the learner keeps and can take from one public workstation to the next. When the smart card is read by the workstation, the Web4All software automatically configures the operating system, browser and necessary assistive technology according to the learner's AccLIP. These settings are returned to their default values and applications terminated once the card is removed in preparation for the next learner. This significantly reduces the technical support required for the public workstations, avoids conflict between the assistive technologies used by consecutive learners and allows the learner to begin using the workstation without lengthy manual reconfiguration. If the assistive technology requested by a learner is not available on a workstation, the program will launch and configure the closest approximation.

2.8.3 PEARL

The PEARL project (Practical Experimentation by Accessible Remote Learning [17]) was an early European Commission funded project led by the Open University, UK. It developed a technical framework teaching laboratories for science and engineering to be offered to students remotely. One motivations for this was to increase the participation of disabled students in these subjects by offering enhanced access to practical work. Hence accessibility was a priority for the project.

The project implemented a learner interface approach in which interfaces were generated "on the fly" from XML descriptions of all the interface elements and the type of interaction they supported. The project explored an extension to this approach where, as well as XML descriptions of the activity and its

Figure 2. Behaviours for AccessForAll interoperability.



control and display elements, the "interface generator" was presented as an XML description of the learner and how they preferred to use their computer. This learner description was based on the then current draft IMS LIP <accessForAll> elements. It was possible to optimize the interface for individual learners taking into account, as examples, assistive technology requirements or the fact that students might be working hands-free.

3. FUTURE WORK AND CONCLUSION

The AccessforAll specifications show how the AccessForAll strategy can be implemented. They are not prescriptive about the encoding that should be used. Significantly, they are not prescriptive about what constitutes accessibility. There are endless opportunities, given the model and strategy, to take further advantage of new technologies.

The Semantic Web offers one obvious technology that will be enabled by the AccesForAll approach. Already the AccessForAll specifications recommend using EARL so that the metadata will be as flexible and rich as possible. The range of other extensions includes opportunities for valuable cross-lingual exchanges to suit learner needs as well as cross-disciplinary changes of emphasis. Applications and Web services that transform resources or resource components to suit the needs of users with cognitive disabilities is a huge area that has hitherto not received the attention it deserves.

The authors wish to contribute to the valuable work being done by others and welcome involvement in their work.

4. ACKNOWLEDGMENTS

Our thanks to Anastasia Cheetham and David Weinkauf for their wonderful work on the information model and associated documentation that has made everyone's work so easy.

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Knowledge Level Design Support for Adaptive Learning Contents

- Ontological Consideration on Knowledge Level Structure of SCORM2004 Contents -

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ABSTRACT

This paper discusses learning contents design from the viewpoint of knowledge level and symbol level. The purpose of study is to develop a foundation for share and reuse of IESs on a global platform. SCORM2004 is becoming de facto standard so we choice it as the basis of the platform. On the platform we aim to build an environment for authors to clarify pedagogical meaning of learning contents based an ontology for IESs. This approach will allow us to share and reuse academic and technical expertise in the field of AIED research on common platform.

Categories and Subject Descriptors

K.3.1 [**Computing Milieux**]: Computer Uses in Education – *Computer-assisted instruction (CAI)*

General Terms

Design, Standardization

Keywords

Learning content design, Intelligent educational system, ontology, SCORM2004.

1. INTRODUCTION

In the research area of designing instructional systems, we have been aiming at a paradigm shift from "Story board representations of instructional material to more powerful knowledge based representation"[Murray 98]. Major benefit of the knowledge based representation is the realization of highly adaptive instruction with the integrated knowledge bases of learning domain, teaching strategies and learner models. However, building the knowledge bases still requires a significant cost. In order to bring about a solution for these issues, many efforts have been carried out in our IES community.

The thought of *Knowledge Level* by Newell [Newell 82] is seen to be value of designing intelligent systems. The Knowledge Level is a level of description of the knowledge of intelligent systems and the symbol level is one produces the intelligent behaviour based on the knowledge level description. If an intelligent system is high quality, the system is designed in a harmonious balance between the knowledge level and the symbol level.

Issues discussed in this paper are that what is support for structuring well-organized knowledge for intelligent educational systems and that what is adequacy of mechanisms for emerging intelligent behaviour based on the knowledge.

The authors think the keys to the issues are ontological engineering in terms of the former and scalability and interoperability, which are flowing from standards for e-learning, in terms of later.

This paper shows an advanced stage of our research activities on ontology-aware authoring tool [Hayashi 04] but the results are only in early stage. Based on the study, this paper discusses analysis of SCORM2004[ADL 04], which is a standard have gotten a lot of attention recently as next generation of foundation for e-Learning, from viewpoint of AI (Chap. 2), a way to connect knowledge level and symbol level (Chap. 3), and an SCORM2004 conformed ontology-aware authoring tool (Chap. 4).

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2. SCORM2004 as a symbol level for learning contents

2.1 Current state of designing learning contents conformed to SCORM2004

Currently, a typical learning content conformed to SCORM2004 has a tree structure reflected textbook structure. In such a content adaptive control is available by rules put on nodes representing chapter, section and so on.

Figure 1 shows an example of typical structure of SCORM2004-conformed learning contents. This content starts from "Pretest of brief of AI". If a learner passes the pretest, he/she will learn "the detail of AI". If not he/she will learn "brief of AI" before learning "the detail of AI".

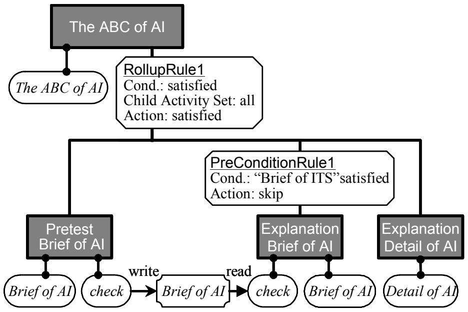

Figure 1. an example of typical structure of SCORM2004-conformed learning contents

This control is implemented by the sequencing rule (preConditionRule1).

When an activity is finished, tracking data in the activity is aggregated to its parent activity. For instance, "The ABC of AI" aggregates tracked data from all of "Pretest Brief of AI", "Explanation Brief of AI" and "Explanation Detail of AI" (That is because a parameter of RollupRule1 Child Activity Set is set "all"). So learning result of the entire content in recorded in "The ABC of AI".

These rules in SCORM2004 realize adaptive preorder page-turner structure easily. However, the focus of IES is not control that shows all of the contents or a part of them according the preordered structure but decision making of the next activity according to a learner's status.

2.2 Lessons learned from IES studies

IESs are educational support systems based on Artificial Intelligence technology [Wenger 87]. Typical thought of IESs is seen in the study of MENO-Tutor by Woolf [Woolf 84]. In MENO-Tutor knowledge of instructional control is described in an Augmented Transition Network (ATN). A node in the network indicates a teaching strategy or an action and is connected with other nodes that can be transit from itself. Depending on control rules referring to a learner model, instructional control is carried out by transition of the nodes. In this manner IESs have representation of its own structure of instructional knowledge. IES studies aim to generate learning sequences matching flexibility to each learner by sophisticating representation of knowledge and its learner model.

However there are some problems listing below.

I. Sharability and reusability are seriously low because a research oriented special purpose platforms are developed independently in each study. That has caused low productivity in practical aspect and few hoard of knowledge in research aspect.
II. Building an IES remains a costly work because of the complex knowledge representation and necessity of too much description of knowledge for a small learning content.

These problems stand in the way of research promotion and practical application of IESs. We suggest that the two following issues are important to solve the problems.

A. Organizing constructive concept of instructional control knowledge in IESs that allows IES designers to share their knowledge, that is, understanding others' description of knowledge easily and describing their own knowledge that the others can read easily.
B. Sharing IES platform to execute instructional control knowledge based on the constructive concept (ontology) in communities of researchers and practitioners.

2.3 Overlooking SCORM2004 from the viewpoint of AIED research

The Authors have developed an ontology-aware authoring tool called *i*Designer[Ikeda 97][Hayashi 04]. The study addresses the problems about making non-IES learning contents mentioned as I and II in the previous section with an approach A. Following up the previous study, this study aims to develop a high scalable user-friendly IES development environment with Sequence and Navigation specification in SCORM2004 as the basis of approach B. This section shows the authors' basic idea of SCORM2004 as a foundation of IES platforms.

An activity node in SCORM2004 is basically thought to represent learning experience learners have. An activity, that is to say, is "What to teach" from the view point of educational systems, and is "What to learn" from the viewpoint of learners. Each node represents "A material used in learning" (e.g. contents in described in a chapter, a section and a page). An activity tree represents "Structure of materials". On the other hand, in many cases, decision-making structures of IESs are "Which teaching action is better" from the system's view and "Which learning action is better" from learners'. A node represents an action and a structure represents decision-making of teaching actions, for example,. in ATN of MENO-TUTOR, "introduce", "tutor", "hack" and "complete" (Of course, if you embed "action" within "what to teach" in SCORM, it might looks like "Teaching action" in IES. But such an embedding must not be valid because it hides knowledge to select actions. This issue will be mentioned in chapter 3.)

If one wants to make a learning content to be highly adaptive to an individual learner, one must organize learning experiences with a central focus on knowledge-based decision-making structure of learning action. In this case, it is not so easy to reflect the structure to on an activity tree but not impossible. The solution is to find a way to convert selection of learning action into selection of activities in SCORM2004 and a way to convert selection structure of actions into activity tree.

This is matched with "Knowledge level and symbol level" that Newell proposed as the principle of artificial intelligent systems. Framework of description of IES knowledge is the source of intelligent behaviour of IESs and is equivalent to knowledge level. A platform that behaves intelligently based on the knowledge is equivalent to the symbol level.

The authors consider that studies of intelligent educational systems will be developed and turned into actual utilization if it is possible to build framework of knowledge level description of educational control knowledge based on SCORM2004 platform as high-scalable symbol level.

3. Building a bridge between a knowledge level and a symbol level

3.1 An activity tree as a decision-making tree for delivering learning object

Figure 2 indicates an example of decision-making model in knowledge level. The learning process described in the model is composed of a flow of learning. “Review”, the last part of the flow, will be done if a learner does not pass the exercise. The tree structure of “Review” represent that it is achieved either two types of alternative strategy.

As stated above, decision-making model describes a structure strategic decision-making of teaching action. Fig. 1 indicates a structure to select contents but fig. 2 indicates structure to select what to do. Clarifying knowledge to select action is the basis of IES and significant in the following two point.

A) The system can construct teaching sequences that fit for each learner’s understanding status, and
B) The system can assume a learner’s learning property through analysis of teaching action accepted by the learner.

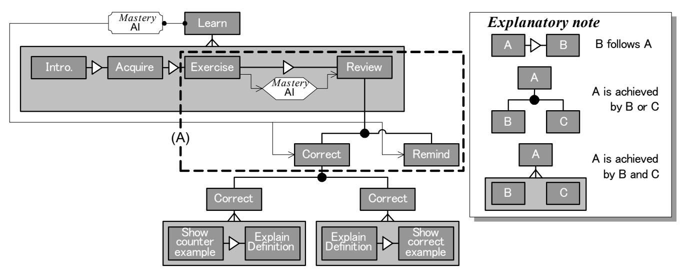

Figure2. an example of decision-making model in knowledge level

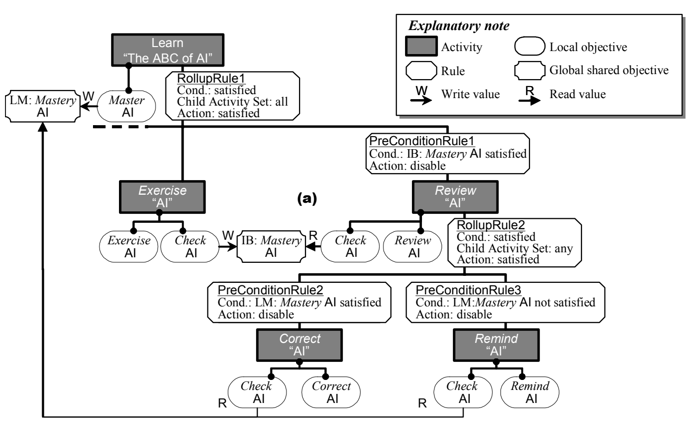

Figure 3 Symbol level model

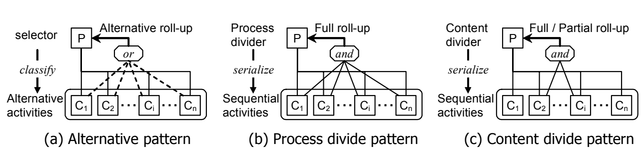

Figure 4. Patterns for designing an activity tree

Patterns of information collection represent connection upper objective and lower one in the decision-making structure. Two types of connection is defined; “And” and “Or”. In the structure shown in fig. 4 “Review AI” is achieved by any one of lower action; “*Correct* AI” and “*Remind* AI”. Hence result of “Review AI” is determined by the result of “*Correct* AI” or “*Remind* AI”. On the other hand, the entire content “Learn AI” consists of the flow of “*Introduction* AI”, “*Acquire* AI”, “*Exercise* AI” and “*Review* AI” so the result of “Learn AI” determined by all of the lower action. This aggregated result information is recorded in “LM: Mastery AI”. Therefore “LM: Mastery AI” represents not only the objective of the entire content but also the record of learner’s experience.

3.2 Symbol level model

Fig 3 shows the symbol level model converted from the knowledge level model shown in fig 2.

Decision-making structures are converted to structure of activity tree and sequencing rules. In fig 3 “*Exercise* AI” and “*Review* AI” are described as child activity of “Learn AI”. The condition that “*Review* AI” is made available is described as PreConditionRule1.

The information collection structures are converted to roll-up rules. “*Learn* AI” must aggregate information of all of child activity so the roll-up rule1 has value “all” in child activity set.

3.3 Patterns for designing an activity tree

In this section, we will organize decision-making structure and information collection structure and relate the patterns to SCORM2004 specification. This study proposes three kinds of basic decision-making and information collection patterns listing below.

(a) Alternative pattern: pattern for selecting only one activity,
(b) Process divide pattern: pattern for dividing a process, and
(c) Content divide pattern: pattern for dividing a contents

```
■Activity
  ■Introduce
    ■Take interest
    ■Pay attention
    ■…
  ■Remind
    ■Remind concept
    ■Remind example
    ■Remind relation
    ■…
  ■Understand
    ■Remind concept
    ■Remind example
    ■Remind relation
    ■…
  ■Dismiss
  ■Correct
  ■Check
  ■Evaluate
  ■…
```

Figure 5. Concept of activities (partial)

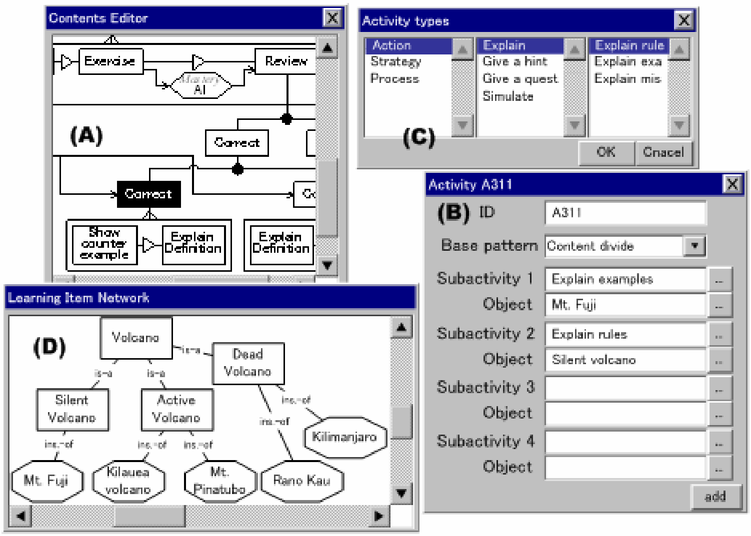

Figure 6. Interfaces of the authoring tool (imaginary)

These patterns are shown in fig.4. Each activity in the patterns are put into shape by the IES ontology (partially shown in fig. 5) which is developed our preliminary work in [Mizoguchi00][Hayashi 04]. Combination of these patterns allows designers to construct a flexible decision making model for variety of learning contents.

4. Toward a knowledge level authoring support

In this study we have been developing an IES authoring tool conformed SCORM2004 based on iDesigner [Hayashi 04]. Characteristics of the authoring tool are that it has not only ontology awareness [Ikeda 99] but also standard awareness for high scalability. The tool can convert author's design intention in knowledge level to the implementation in symbol level based on an ontology for learning contents, the patterns shown in fig. 4, and SCORM2004 specification.

Fig 6 indicates an image of the authoring tool. The main interface is the content editor (fig 6(A)). This shows a decision-making structure. Values of each node are set on window (B). While setting the values, authors can refer to items to be selected with windows (C) and (D).

5. Conclusion

This paper discussed learning content design with knowledge level representation on top of SCORM2004 platform as a symbol level architecture of IES decision-making structure. This approach will allow us to share and reuse academic and technical expertise in the field of AIED research on common platform. This will also contribute to develop SCORM into next generation standard specification for more adaptive and intelligent contents. Though many problems are left, for example organizing concepts related educational activities, accumulating principle or empirical knowledge of construction of activities, coordination between knowledge level and symbol level and so on, ontological engineering approach must be of assistance to do them.

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Ubiquitous Networking for GENES Society: e-Learning Tools and Digital Archives for Education with Significant Use of Cultural Heritage Contents

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ABSTRACT

Ubiquitous-networking is an active e-learning environment using the information communication technology (ICT) like cellular phones, personal computers, PDA and so on, where a learner can learn anytime, anywhere and any style. In this paper, We emphasize here that learners, and especially children should be able to use digitalized cultural heritage for education, as a "digital Cultural Genes". In order to backup "e-Japan strategy", we propose new creation tool

Categories and Subject Descriptors

K.3.1 **[Computer Uses in Education]** Computer-Managed Instruction

General Terms

Algorithms, Management, Human Factors, Standardization, Language.

Keywords

Digital archives, cultural heritage, ubiquitous networking, digital cultural genes, LOM, RDF, Semantic Web, XML, digital archivist

1. INTRODUCTION

Ubiquitous networking is an active e-learning environment using the information communication technology (ICT) like cellular phones, personal computers, PDA, electronic tag and so on, where a learner can learn anytime, anywhere and any style.

The Ministry of Education, Science, Sports and Culture (MEXT) founded National Information Center for Educational Resources (NICER) in August 2002.

NICER has the roles to arrange and manage all the information about education and learning in Japan on the Internet. In this paper, we propose new creation tool in order to backup e-Japan strategy.

Fig. 1 shows the relation between GENES (Gakujoken Network Studying group) and NICER.

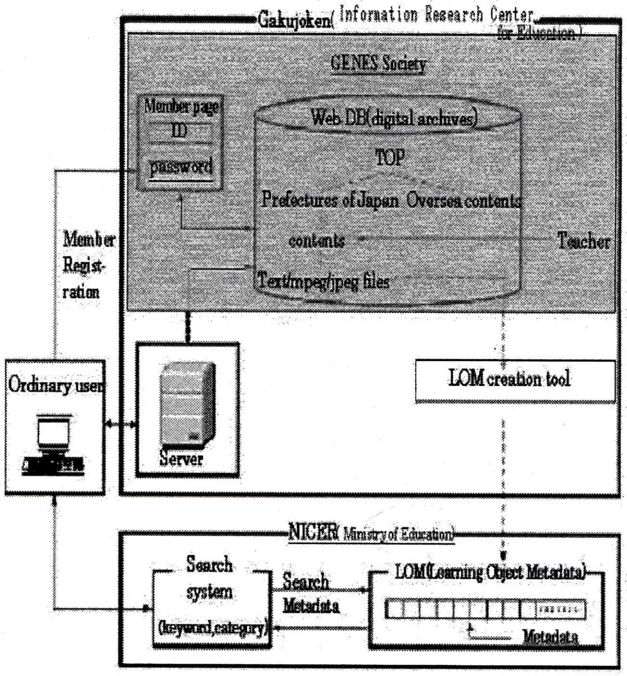


Fig.1 The relation between GENES and NICER

In this decade, authors have been coordinator of several Japanese Government ICT projects for policy preparation under the

Minister of Economy, Trade and Industry (METI) responsibility: Multimedia, Digital Archives, applications of ICT in Education.

GENES Project was launched in August 2001, in cooperation with Fujitsu and Ministry of Education[1]. GENES stands for Gakujoken network studying group. Gakujoken is the public organization managed by MEXT. The roles of Gakujoken is to collect and to offer the educational contents to learner.

2. OBJECTIVE OF GENES

The objective of GENES is to create the society where cultural heritage contents are created by teachers, as the knowledge base of digital archives for education. The roles and aims of GENES are to realize the e-bok like electric book that learners, especially children should be able to use digitalized cultural heritage for education, as a "Digital Cultural Genes". Today the profile of the project to realize GENES society is as follows:

-Cooperation with more than 1200 school teachers.

-More than 4,500 learning object metadata(LOM) for educational contents.

-More than 37,000 educational contents (motion picture, photos and texts) are combined in this digital archives. These educational contents contain the following specifications: a school grade, a subject and a unit, a coverage person, a coverage date, a coverage place, copyright, etc.

In the next step, we want to use the concept of Semantic Web, and digital archivist. We try to build the LOM RDF binding and defining LOM metadata by simple methods of knowledge representation, the Resource Description Framework, RDF[2].

Digital archivists are the professionals supporting the cultural activities in an information society. A digital archivist digitizes the cultural data which are needed in the future fields. Simultaneously, a digital archivist understands copyright and privacy, cultural art, protection and management, and so forth as the foundation of cultural activities.

3. KNOWLEDGE REPRESENTATION ON PAIRS OF "TACIT KNOWLEDGE" AND "EXPLICIT KNOWLEDGE"

Tacit knowledge[3] established through still/ motion pictures is a more suited approach for intuitively storing information to the human memory compared to explicit knowledge acquired through literary tools. Therefore it can be said that tacit knowledge is an optimum method for understanding the context (status) of oneself or another.

Advantages of implementing the new knowledge representation based on the combination of motion pictures and metadata are that it enables text-search within the realm of tacit knowledge derived from still/motion pictures.

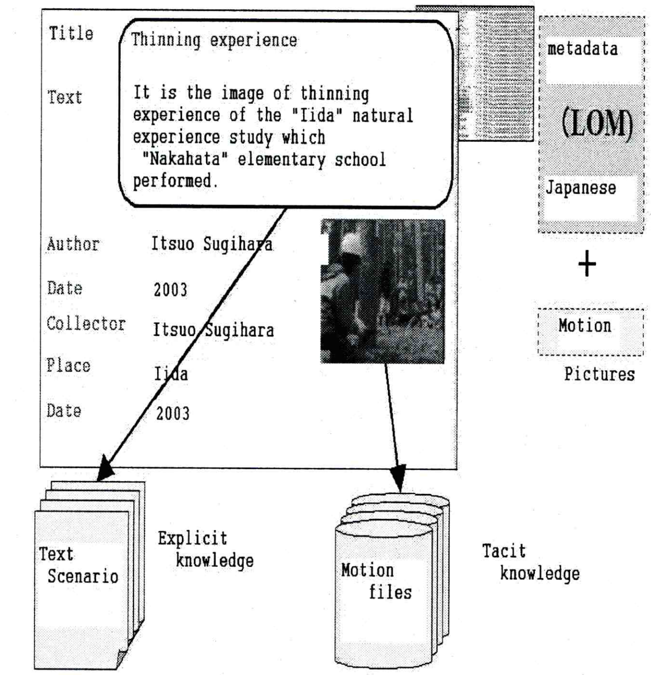


Fig.2 Knowledge representation on Pairs of "Tacit Knowledge" and "Explicit Knowledge"

3.1. Applying tacit knowledge to Web page Search Systems

Web pages targeted in this research consist of text scenarios of explicit knowledge and still/ motion digital image files of tacit knowledge. The explanation of the motion file is in the text scenario database.

The benefits of this are that sharing methods utilizing web-page search systems will become available, for example the application of tacit knowledge through motion pictures to e-learning.

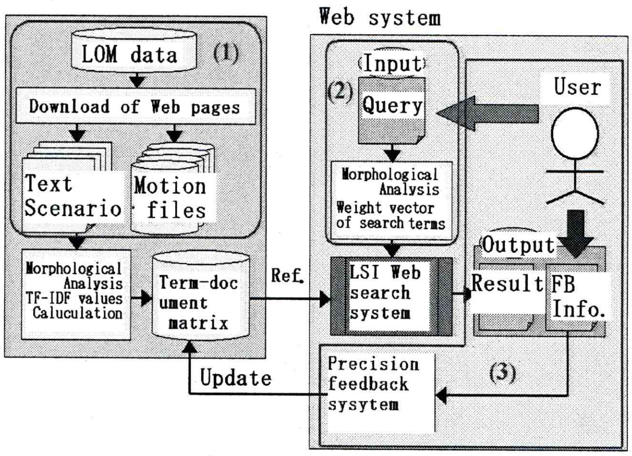


Fig.3 Web page Search Systems

Web pages similar to the imputed query will be searched within the database created by the text scenario of web pages, using Latent Semantic Indexing (LSI) [4) 5)] as a search method. Learning Object Metadata (LOM) which enables search for digital archives will serve as an interface for the actual search. This will enable the application of National Information Center for Educational Resources(NICER) to the search system.

In addition, this will help applying tacit knowledge from motion files to e-learning as well as conducting feedback searches.

Search criteria should be the sentences close to natural language. This will enhance universality and contribute to raising the system's utility value.

3.2. Establishing Term-Document Matrix

While necessary information such as ID numbers, titles, URLs will be extracted from the LOM data and stored as a file, index terms will be extracted from the text scenario downloaded from the targeted URL. The extraction will be conducted by morphological analysis and TF-IDF value calculations. Subsequently, an index term - document matrix will be established.

3.2.1 Morphological Analysis

Assuming that nouns well represent the characteristics of a web page, the target text will be morphologically analyzed in order to extract only the nouns included in it. Morphological analysis will be conducted using a Japanese language morphological analysis tool "chasen"[9)]. Numeric characters/ pronouns will be deleted as stop list.

3.2.2 TF-IDF Value Calculation

The weighted value of each noun (TF-IDF) will be obtained based on calculation of the value indicating the frequency of its appearance in each page (TF) and the value indicating the frequency of its appearance in all documents (IDF) . Nouns with a value exceeding a certain threshold value will be extracted as index terms.

3.2.3 Structuring the index term – document matrix

Each web page will be described as a document vector in the vector space dimensioned by the extracted search term, and its element will be the TF-IDF value. The search term – document matrix is a matrix representation of such document vector sets.

3.3 Web Search system by LSI Method

A web page with high similarity will be searched/ output by generating a weight vector of a search term in response to a query sentence in natural language and referring to the index term – document matrix using the LSI method.

3.3.1 Latent Semantic Indexing (LSI)

Latent Semantic Indexing will search base matrixes with ranks lower than the original index term – document matrix by conducting singular value decomposition against index term – document matrix and condensing dimensions with small singular values. This is a method to condense document vector dimensions by projecting each vector onto this base.

When an index term – document matrix is given as $m \times n$ matrix D, the singular value decomposition of D can be defined as follows:

$$D = U \Sigma V^T$$

U is a $m \times m$ orthogonal matrix ($UU^T = U^T U = I$), V is a $n \times n$ orthogonal matrix ($VV^T = V^T V = I$), Σ is a $m \times n$ matrix. When $rank(D) = r$, the number of singular values σ_i diagonally arranged in descending order will be r .

The projection onto U_k space can be considered in order to approximate a r -dimensioned document vector d to a k -dimensioned document vector $d^{(k)}$.

U_k is a $m \times k$ matrix composed only by the first k ($k < r$) left singular vectors of U .

$$d^{(k)} = U_k^T d$$

The index term – document matrix will be condensed to a lower dimension in this form.

The similarity is found by taking the cosine $sim(d, q)$ against a document vector d and query vector q in a vector space. The similarity $sim(d, q)$ can be calculated from U_k , Σ_k , V_k without seeking the index term – document matrix condensed to k dimension(D_k).

3.4 Precision feedback system

Users count the right answers from search results, and input this correct information to the Web search system. Then search ability of this system should be improved by Precision feedback system.

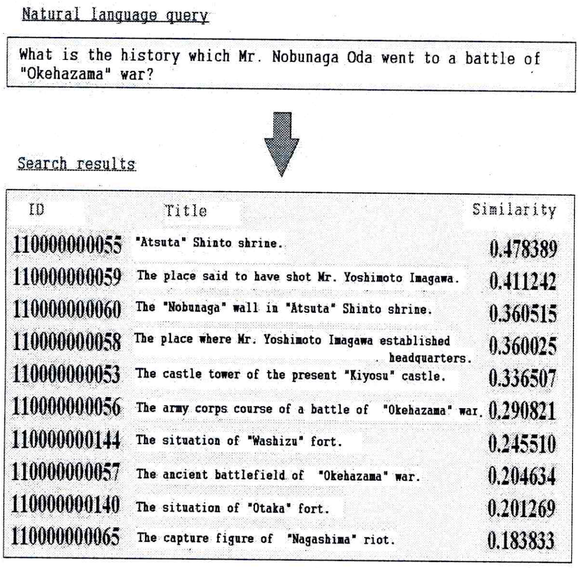
3.5 Evaluation of the Search System

The assessment of this Web search system will start by imputing natural language query and the number of dimensions/ results to display. The server will receive such data, calculate the similarity and display the search results.

The search results will display in descending order of similarity against the imputed data as shown in Fig.4.

It can be seen in Fig.4 that keyword search against the same evaluation subjects could not retrieve corresponding web pages.

Table 1 indicates that the search results are reasonable. However, as the current data volume 136 documents is not sufficient, it is desirable that the assessment of search precision be considered upon increased amount of data.



Natural language query

What is the history which Mr. Nobunaga Oda went to a battle of "Okehazama" war?

Search results

ID	Title	Similarity
110000000055	"Atsuta" Shinto shrine.	0.478389
110000000059	The place said to have shot Mr. Yoshimoto Imagawa.	0.411242
110000000060	The "Nobunaga" wall in "Atsuta" Shinto shrine.	0.360515
110000000058	The place where Mr. Yoshimoto Imagawa established headquarters.	0.360025
110000000053	The castle tower of the present "Kiyosu" castle.	0.336507
110000000056	The army corps course of a battle of "Okehazama" war.	0.290821
110000000144	The situation of "Washizu" fort.	0.245510
110000000057	The ancient battlefield of "Okehazama" war.	0.204634
110000000140	The situation of "Otaka" fort.	0.201269
110000000065	The capture figure of "Nagashima" riot.	0.183833

Fig.4 Search results of Web page Search Systems

Right	136Dim.	100Dim.	50Dim.
Query1	19	18	17
Query2	14	14	12
Query3	14	15	14
Query4	12	12	12
Query5	17	18	18
Average	15.2	15.6	14.6

Table1 Evaluation of search results

4. THE BULLETIN BOARD FOR UBIQUITOUS-NETWORKING CORRESPONDING MULTI-CAREER

The description method of the contents on the Mobile computing varies from 3 types of cellular phones, i-mode, EZWeb and J-SKY in Japan. As seen from a multi-career correspondence view, there are the following problems:

==

- Inefficiency of the individual contents creation for 3 types of cellular phones
- The extendibility to a new standard is low.
- URLs accessed by 3 types of cellular phones are different.

The anywhere anytime paradigm are realized by the extensible Markup Language (XML). First of all, all of the data written in the bulletin board and the data which can be displayed are saved in XML form. Then the screen data of the bulletin board created by XML are transformed automatically, using XSLT.

Fig.5 shows the automatic content transformation flows, corresponding to each cellular phone.

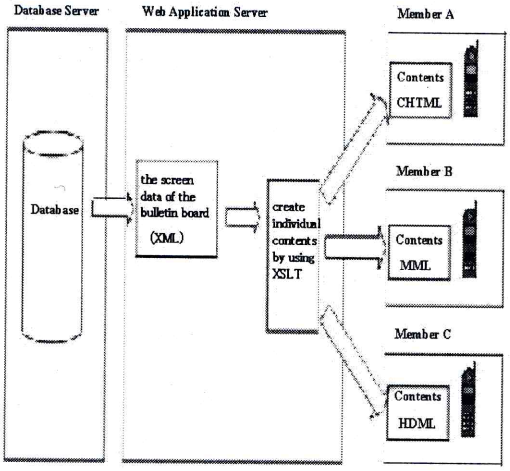


Fig. 5 Automatic content transformation flows

An administrator does not need to create individual contents for each cellular phones, and creation and management of contents become easy , as the Mobile computing of one-source multi-use styles.

Moreover, by adding XSLT, a correspondence new model can be easily added. It is easily extensible. Any user can access the same URL from any types of cellular phones, i-mode, J-SKY, or EZWeb.

5. CONCLUSION

We emphasize that learner, especially children should be able to use every digital Cultural Heritage for education, as a "Digital Cultural Genes". In This paper, we propose new creation tool in order to backup "e-Japan" strategy.

Anywhere anytime paradigm of Ubiquitous networking becomes more popular for learners to utilize the knowledge-base of digital archives for education made by GENES society.

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Web-based Learning in Remedial Course of Science and Technology

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ABSTRACT

We have been experimentally developing a web-based learning (e-learning) system for remedial courses of science and technology in higher education over last four years. We have improved several functions of the LMS and created more than 3000 contents, for practical use in educational institutions. In 2005, 12000 Japanese users including the learners in 80 secondary education institutions use our e-learning system. In the present paper, first, we report the outline of our project including the construction of system and the result of a case study in the remedial education. Second, we report a challenge to extend to an agent-based personal assistant application, aiming to effectively use educational resources in our e-learning system.

Categories and Subject Descriptors

K.3.1 [**Computer Uses in Education**]

General Terms

Design

Keywords

e-Learning, remedial education, agent

1. INTRODUCTION

Recently, the decline of basic learning abilities of students as regards science and technology has become a serious problem in Japan. A representative of this is a college student who cannot solve a fraction calculation. The Japanese government has begun supporting the efforts of elementary and secondary education institutions to promote basics of educational skills. Higher education institutions have also improved the elementary curriculum of science and have begun to introduce remedial education for mathematics and physics. To help the students acquire basic learning skills, higher education institutions may consider establishing additional curriculum employing small-class/group teaching techniques.

WWW2005, May 10–14, 2005, Chiba, Japan.
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On the basis of this social background, we have studied the use of web-based education as a means to enhance the teaching and learning effectiveness of fundamental course of mathematics and physics. We have been experimentally developing an e-learning system for mathematics since 1999 for recovering basic learning skills of students such as problem solving skills. [1] To provide practical solutions for students in educational institutions, we have developed our project in collaboration with teachers of junior high schools and high schools.[2] In 2005, 12000 users including the learners in 80 secondary education institutions use our e-learning system. More than 20 higher education institutions also use our system.

In this paper, we describe the e-learning system that is designed to support the self-learning process in remedial education for science and technology. In particular, we explain the construction of the system and the contents making to provide the practical use in educational institutions. In addition, we indicate the result of a case study and describe the effective learning style using e-learning. In the last part of this paper, we report a challenge to extend our e-learning system to an agent-based personal assistant application, aiming to effectively use large amount of educational resources in our e-learning system.

2. SYSTEM

2.1 Overview of the System

The implemented system is a WBT system that uses the function of problem solving, which consists of LMS and contents. Learners can study elementary courses of mathematics and physics, using the educational resources stored in this system.

Our study aims to realize the practical use of this system in educational institutions. The system developed in our study is characterized by:

- Educational resources consisting of multimedia materials, exercises and tests that are created in collaboration with teachers from secondary education institutions.
- Systematic maintenance of educational resources through the knowledge database to support knowledge acquisition of learners in remedial courses.

- Application of the knowledge database to the e-learning system through an instruction policy that aims at learning corrected and repeated problem solving in remedial education.

For the implementation on the server side, we use the Java Servlet Server and Tomcat which is a reference implementation of the Java Servlet. The Servlet server on the Linux OS manages the user session, answer check, and analysis of the users' learning history. PostgreSQL is used as the database server in which user data required for LMS are stored.

2.2 Contents

In mathematical education, expansion of logic is important and it is difficult to visualize its process. However, teachers in educational institutions, in their lectures, usually instruct on the logical steps, using images drawn on blackboards. In our study, this educational method is adopted in contents making. To promote the learners' interest and to encourage understanding, we design multimedia materials based on the blackboard image drawn by teachers during the actual lectures. Each material includes moving figures, expressions and characters. Users can read stories in the material at their own pace by clicking the control button and confirming expressions or figures step by step. The sequence of elements is based on the scenario designated by the actual teachers (experts) participating in our project. We prepared 1000 materials for mathematics and physics (science), which cover academic content from junior high school to the fundamental courses of universities. The series of multimedia materials adopted in our e-learning system is created in the SWF (Shock Wave Flash) format and viewed using a Flash plug in.

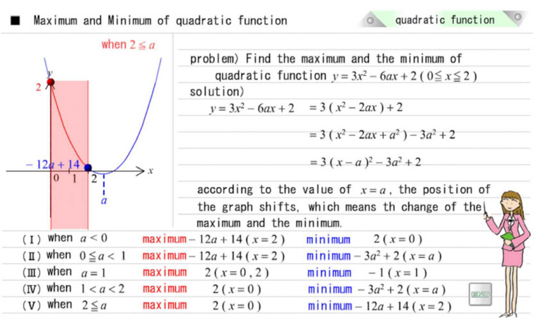

Figure 1: Sample image of multimedia materials.

Figure. 1 represents the mathematics material and indicates a problem and solution for calculating the maximum and minimum of a quadratic function with a variable. When a user clicks the control button on the material, explanations that use characters and mathematical expressions appear. Mathematical expressions, in particular, gradually appear, in the actual order that a teacher writes them in on a blackboard.

Exercises are also created using the Flash format. Each exercise consists of three frames; problem description, hint information, and answer box. The problem description frame allows users to create a problem using characters, mathematical expressions, and graphics. The hint information frame allows users to create hints at three levels, which appear step by step, according to the users' requests. A sample image of the exercise is shown in Figure. 2. The numbers 1, 2, and 3 in the figure correspond with the hints that appear step by step.

In our project, we prepared 1000 exercises for the fundamental courses and 1000 exercises for the standard courses of mathematics and physics (science), which cover academic contents from junior high school to the fundamental courses of universities. Furthermore, we prepared tests for learners to correct their own exercises in the section. There are 10 problems per section in each test. The test format is the same as that of the exercises, except for the hint information frame.

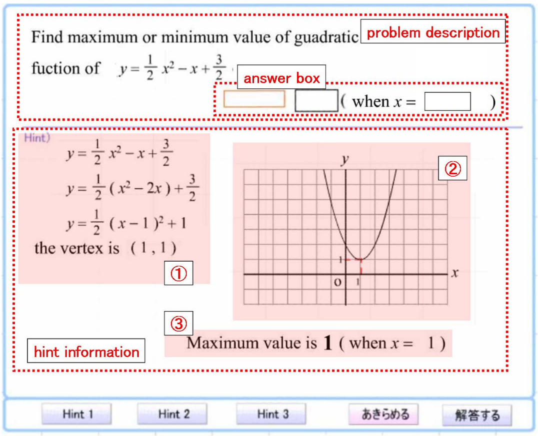

Figure 2: Image of exercises.

2.3 Knowledge Database

In remedial education, acquiring basic knowledge through training is one of the most important factors. In the present study, using original IDs, we reviewed and classified mathematics knowledge related to our materials and exercises. We categorized knowledge in order to support the learners educated through remedial study and defined 160 categories of knowledge. We rearranged the knowledge in the knowledge database whose data frame consisted of the name of the knowledge, its identification (knowledge ID), and its contexts.

Our final goal is to develop an effective e-learning system to support the knowledge acquisition of learners, using this knowledge database. Using the relation between the knowledge database and the exercises, we can provide appropriate materials for learners who attempt to solve a problem but do not understand its meaning. Learners can also identify their lack of knowledge through the knowledge names obtained on the basis of an analysis of the users' learning history.

2.4 LMS

It becomes particular important for the educational institutions to understand the learners' learning process in a time series. Therefore, our system provides three statuses of right, wrong, and hint information in time series, such as one day, one week, and one month. The user interface of the time series through graphics is shown in Figure. 3. Teachers can select a date from the calendar and view a learner's status through the graphics and table. This function is mainly used when teachers perform individual instruction as support for the learners' homework.

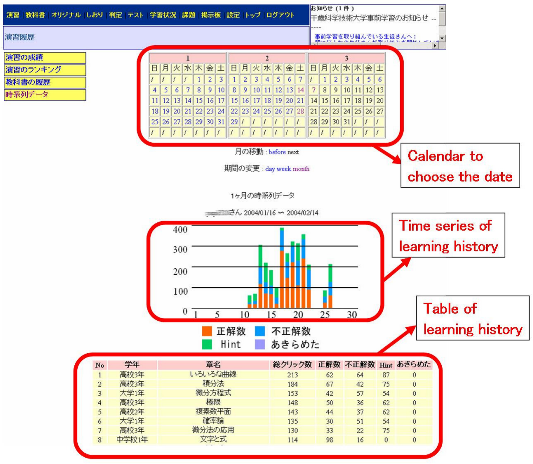

Figure 3: Time series of learners' history.

Table 1: Sample messages provided through the assignment system.

You should practice solving problems repeatedly.
You may solve questions correctly.
You should solve problems correctly without getting hints and making mistakes.
You make a lot of mistakes.
You refer to too many hints.
You should refer to textbooks positively.
You can solve problems. Referring to textbooks is good approach.
You can achieve the assignment. It's perfect.

The main targets for our system are learners doing homework and exercises related to subjects or lectures. To support these learning processes, we implemented the assignment function that teachers could designate previously for their lectures' homework or exercise. Through the interface of LMS, teachers can select not only names of students participating in the class but also types of exercises required in the assignment. Furthermore, in our study, we prepared typical instructional messages for learners in the database, that were provided automatically when the duration of assignment expired. These messages are determined in advance on basis of teachers' instructional policy, and the choice of messages is determined by if-then rules based on learners' click information for the assignment. The sample messages provided from the assignment function are shown in Tab. 1.

3. CASE STUDY

We investigated effectiveness of e-learning through its utilization in the actual lectures of a university. In the present paper, we present the results of a case study performed in a remedial course of mathematics at Chitose Instiute of Science and Technology (CIST). There were 120 learners and investigated terms were spring and autumn of 2002. On the basis of these results, learners at lower results could participate in the remedial course.

We divided this remedial class into two classes referred to as classes A and B. In class A, the same style as the exercise class was employed; a teacher chooses the subjects related to

Table 2: Comparison of both classes; without using e-learning (class A) and with e-learning (class B).

self-check	1st test	2st	3st	4st	5st
Month	4	5	6	7	8
Average (classA)	0.0	0.0	0.0	0.0	0.0
Average (classB)	-6.5	7.1	15.0	10.7	1.8

the mathematics lecture and provides several exercises to the learners. The homework is handed to learners on paper at the end of every remedial class and the results are returned two weeks later. In class B, the e-learning system is applied to the remedial class and learners can spontaneously study the subjects through the e-learning system. Homework is also assigned through the e-learning system, and the results are checked through the LMS by the learners.

We investigated the results of tests administered four times in the spring term. The comparison between classes A and B is presented in Table 2. Note that the results of class A are set to 0 in comparison with that of class B. Each set of data is an average of the learners' numbers. The "self-check" data in the table presents the results of the self-check test, which indicates that learners of class A have more skills than those of class B, before the beginning of the remedial course. The other four set of data indicate the results of examinations held after the start of the lecture and exercise in the spring term, which indicates that the results of class B always acquires more skills than those of class A.

To consider the skill of the teachers in the lecture and exercise class, we exchanged the teachers of the two remedial classes in the autumn term. The e-learning system was then applied to class A. Consequently, the averaged score of class A was always higher than that of class B. A series of results indicates that the utilization of the e-learning system in the remedial class is effective for an increase in basic learning ability.

The reason for this effectiveness is simple. The characteristics of using the e-learning system are;

- The learner's choice of subjects soon after the face-to-face lecture.
- Homework that is accompanied by answer check in real time.
- Development of individual instruction according to the information of LMS based on the time series of the learners' learning history.

4. EXTENSION

A series of our e-learning project has a feature of blended learning through web-based education. Actually, to recover basic skills or knowledge acquisitions of learners in the remedial class, we adopt not only the e-learning system but also teaching assistants to support the class.

Then, we started a new challenge to extend our e-learning system to a personal assistant application that imitated roles of teaching assistants in the blended learning and planned to instruct, using these educational resources.

To implement a series of adaptive personal assistant system, we utilized multi agent platform of JADE(Java Agent Development Framework).[3] Basic concept of the agent platform is as follows. The agent platform can be accessed from the server-side application. Under the initialized platform, each agent is activated and every request among agents is launched through multithreading. The agent works with serialized objects that are encapsulated as content of the ACL messages. Recently, implementation of adaptive Web application using multi agent framework with JADE becomes widely reported in researchers. As for adaptive e-Learning, several types of architectures are modelled and constructed.[4] In addition, practical development of the system assuming course management is also reported. [5]

In the present case, we defined four types of agents referred to as Adapter agent, User agent, Inference agent, and Subject agent. The User agent and Inference agent correspond with modules of a personal assistant agent. This personal assistant agent is designed to invoke to each learner and to be active only when the learner is in on-line status. The Subject agent is a single agent to share information among all personal assistant agents. The Adapter agent is a wrapper agent to listen to all messages as event from server-side. It is instantiated inside application-context on server-side and runs as session bean but it is started on the JADE platform by the server-side component. The agent architecture in our study is shown in Figure. 4.

From the autumn in 2004, we started to employ the agent-based system in the exercise time of remedial course using the assignment functions mentioned in sec.2.4. To operate the system in the practical use, we adopted distributed environment using network agent framework where the User agent and the Inference agent were separately coordinated in the physical environment. The averaged on-line users in the remedial class were 160. The message type and the instructional policy were designated to match the exercise course using assignment function. The Subject agent was also designated to manage the subject related to the context of the assignment. In this educational situation, a learner could usually obtain his/her personal learning degree for problem solving, but could sometimes get information of his/her degree among other learners in the class. For instance, when the learning degree of the learner was not good, agents recommended him/her to solve problems using hint information and related materials. However, if the Inference agent judged that total learning situation in the class was not good and his/her learner was in worse situation, agents recommended the learner to change the learning course. We show the user interface displayed by agents in Figure. 5.

5. SUMMARY

In the present paper, we reported the implementation of our e-learning system and effectiveness through the case study. Furthermore, we reported a challenge for extension to the personal assistant system through instructional messages, using multi agent framework. In consequence, we confirmed that agents collaborated and provided the adaptive messages to our legacy e-learning system, corresponding with the learning degree of on-line learners. In the future work, our educational resources should extensively apply to the adaptive system further more and consider the practical use of adaptive e-Learning system through a case study.

6. ACKNOWLEDGMENTS

Our project is selected as Good Practice of Learning (GP) in Japan and supported by Ministry of Education, Culture, Sports, Science and Technology, Japan.

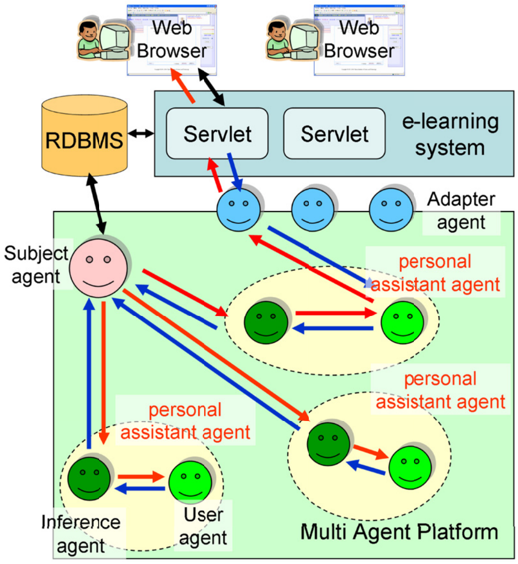

Figure 4: Agent architecture.

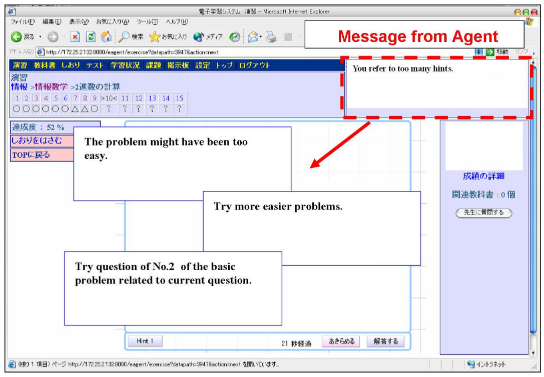

Figure 5: Examples of messages from agents.

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Intelligent Agent for e-Tourism: Personalization Travel Support Agent using Reinforcement Learning

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ABSTRACT

Web personalization and one to one marketing have been introduced as strategy and marketing tools. By using historical and present information of customers, organizations can learn, predict customer's behaviors and develop products to fit potential customers. In this study, a Personalization Travel Support System is introduced to manage traveling information for user. It provides the information that matches the users' interests. This system applies the Reinforcement Learning to analyze, learn customer behaviors and recommend products to meet customer interests. There are two learning approaches using in this study. First, Personalization Learner by Group Properties is learning from all users in one group to find the group interests of travel information by using given data on user ages and genders. Second, Personalization Learner by User Behavior: user profile, user behaviors and trip features will be analyzed to find the unique interest of each web user. The results from this study reveal that it is possible to develop Personalization Travel Support System. Using weighted trip features improve effectiveness and increase the accuracy of the personalized engine. Precision, Recall and Harmonic Mean of the learned system are higher than the original one. This study offers useful information regarding the areas of personalization of web support system.

Keywords: Personalization, Reinforcement Learning, intelligent agent, recommendation algorithm

1. INTRODUCTION

At present information technology (IT) plays an important role in working environments, many organizations use IT as a tool in making their business run smoother and competing faster in the market. In many industries, the Internet and WWW have significant roles in business processes. Online business is more competitive than traditional one since there are plenty of low cost online stores offering products and services on the Internet. Further, customer royalty for online business is low comparing to traditional market so that it is challenging for a company to attract new and keep customers in e-Commerce. Traditional marketing is not always successful on the Internet, and thus more specific online system such as one-to-one marketing should be helpful. In order to be more competitive on the Internet marketing, it is compulsory to offer customers with products or services which match for each customer [1]. During the past few years online massive marketing by using a push technology and informative websites always containing a great deal of information have been introduced to users. The existing search engines do not allow users to find the relevant information easily. Due to these challenging, web personalization and one to one marketing have been introduced to the e-commerce business, including tourist sector, retail, banking and finance, and entertainments [7].

In this study Personalization Travel Support System is introduced to arrange traveling information for users. This system applies the Reinforcement Learning to analyze the customer behaviors and studying customer interests.

WWW 2005, May 10--14, 2005, Chiba, Japan.

2. RELATED WORKS

Joachims et al. (1997) developed Web Watcher Program that analyzed user's interactions with specific websites. In this program, a Reinforcement Learning theory was adopted. The purpose is to offer the most suitable information to user by showing links in HTML.

The WAIR system [3] proposed information filtering techniques, by using reinforcement learning program. The system learnt the user' interests by observing his or her behaviors while interacting with the system. Then personalized information was provided to target users. Comparing with the other techniques, it was found that Reinforcement learning technique was the most efficient in information retrieval.

Yuan introduced the comparison shopping system [6] which supported the personalization system. Comparison shopping feature keeps the record of users, analyzes users' behavior, manage the record and gives the reward to the products based on those records. This method is called Temporal Difference Reinforcement Learning, which is one of the effective Reinforcement Learning process.

3. DESIGN OF PERSONALIZATION TRAVEL SUPPORT ENGINE

The characteristic of reinforcement learning [5] is a trial-and-error feature. A reward will be given when the answer to a question is correct, while the penalty will be awarded when there is an error. This goal-oriented approach is to explore personal interests by maximizing the reward to the item which user concerns and awarding the penalty to the items that user does not concern.

Environment (state): A trip list which users can select

Agent: An agent records data from user behaviors on clicking and reading on the web sites. Then it analyzes users' interests, and gives rewards and/or penalties.

Action: Filtering the travel list according to the agent's analysis.

Reward: Assign a value for the state that a user selects to perform.

Then, the engine offers a trip information to determine the user's interest and records the interactions and behaviors from the last surfing including clicking characteristics in browsing travel information.

Personalization Travel Support Engine Structure

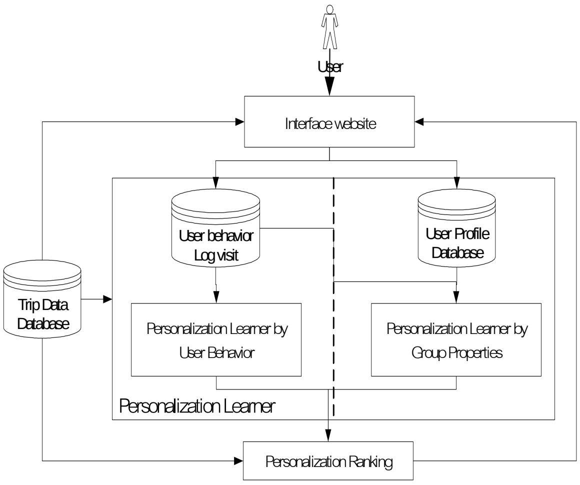

Figure 1. Personalization Travel Support System Structure

In this part, users can surf and view any websites. PTS records the information that the web users always visit, analyzes the user behaviors from each visit. Then system offers the trip information that matches the user's unique requirements.

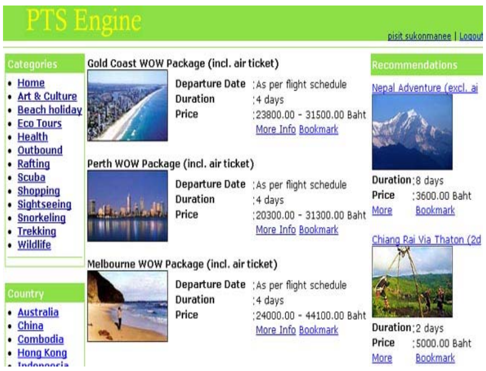

Figure 2. web site provides travel information

The Personalization Travel Support System Structure includes the followings:

1. Personalization Learner is the process of learning and analyzing of website usage behavior to understand user's interest.
2. Personalization Ranking. Its function is to rank the trip information for the web users. The work process is based on the initial weight of learning and the user's interests on each trip.
3. User Profile Database. This is the database of web users, which is operated for travel management. Depending on the user's behaviors, the database will be processed in mapping the trip list to the user's requirements. Profile database is categorized into two types: User's properties data and User's behavior.

Personalization Learner

To perceive individual user's interests, one has to study user's behaviors by means of the information from the Interface Web Site that records two categories of data.

1. Web user profile includes user name, age, and sex.

2. Traveling Information includes identification number, duration, categories, trip lowest price, trip highest price and destination country.

There are two learning approaches using in this study: personalization learner by group properties and by user behavior.

Personalization Learner by Group Properties: System learns from all users in one group to find the group interests of travel information by using given data on user ages and genders.

Personalization Learner by User Behavior: Recorded data is analyzed with user behaviors and the travel information in order to find the unique interest of each web user. Reinforcement learning algorithm, called Q Learning is applied at this stage.

Q Learning is used to maximize a reward to the item on the list which is clicked and award a penalty to the item that is not clicked, as shown in Eq. (1).

$$\hat{Q}(s_t, a_t) \leftarrow \alpha \left[r + \gamma \max_{a_{t+1}} \hat{Q}(s_{t+1}, a_{t+1}) \right] \quad (1)$$

Whereas max Q is defined as:

1 if user clicks the provided trip information

-1/n if user doesn't click the trip information on the web site, where n is total number of trips per page

1/p trips information on the database which are not recommended by the system, where p is the total number of trips in the system

given α is the learning rate valued at 0.2, and it is the discount rate valued at 0.8

Trip features

Trip features associate to user interests in tourist programs, they are as follows: (1) Trip Duration (Qt) is numbers of days offering by each trip. (2) Trip Categories (Qc) is type of trip including shopping, eco tour, scuba diving and trekking. (3) Trip Lowest Price (Qmp) is the lowest prices for trip expenses. (4) Trip Highest Price (Qxp) is the lowest prices for trip expenses. and (5) Trip Destination (Qd) is the country of visitation.

Personalization Ranking

The display area for Personalization Ranking was divided into two parts. Part one is the main box. When a user explores a website to find any travel information, the engine will rank the trip by using reinforcement theory and given data from group properties, fundamental data that the all user registers such as ages and genders and historical data when visiting the websites.

Part two is the Recommend Box. When a user explores a website to find any travel information, the engine will display trip information randomly at the first visit. After that it will display travel information which has been analysed, and learned from historical user transactions, and trip database. The travel information which is top five ranking will be offered on the web page.

The ranking score is evaluated from the equation:

Qr = WtQt+WxpQxp+WmpQmp+WcQc+WdQd

The first approach is learning by user behavior. The Qt, Qxp, Qmp, Qc and Qd are calculated by using input data from user transactions on surfing PTS web sites and Q learning equation. Wt, Wxp, Wmp, Wc, and Wd are weights of each feature obtained from learning. After that the total score (Qr) is the summation of Qt, Qxp, Qmp, Qc and Qd multiply their corresponded weights. Next Qr score from each trip is ranked in descending order. The five maximum Qr scores are selected and recommended for trips to the users on PTS web sites.

For the second approach is learning by group property or clustering users by ages and sex. The ranking of trip provided to users is depended on user profile and user behaviors or web surfing transactions. In this approach users are clustered into group by using age and gender. Then, the value of interesting trip in each group is calculated by using user behavior or transaction on PTS web site. The process of trip ranking in this approach is the same as the above paragraph. The recommended trips are shown in Figure 3. Area number 1 which is in the middle of web page is the main box. Area number 2 which is in the right hand sight is the recommended box.

Figure 3. Travel information provided after learning.

4. EXPERIMENTAL RESULTS

This experiment describes the prototype of the personalization support engine which is implemented for recording, and analysing the user interactions and behaviors. Then this engine presents and recommends interesting trips to user. User profile includes user name, age and gender. The trip list includes Categories (art and culture, diving, shopping, ….and eco tour), Country (Thailand, Nepal, China), Duration (3, 4, 5 days), Minimal Price (400 bahts), and Maximal Price (10000 bahts).

The prototype of the PTS engine implemented in this study include approximately 100 trips. In each transaction, PTS automatically provides five trips in Recommend Box and 10 trips in Main box. In this experiment, there is 115 participants includes 73 males and 35 females. They are undergraduate students in one Thai university.

Table 2. The ranking values of trip calculated by using user transactions as input data of Q-learning equation.

Rank	Trip Name	Qt	Qmp	Qxp	Qc	Qd	Qr
1	Thai Gulf-Koh Tao-Koh Nang Yuan-Chumphon	0.410	0.100	0.522	0.001	0.410	1.421
2	Rafting Kheg River-Kang Song Waterfall-Pitsanulok	0.001	0.410	0.522	0.100	0.410	1.398
3	Mo Koh Surin	0.190	0.100	0.522	0.100	0.410	1.300
4	Discovery Pattaya Package (3D2N)	0.001	0.410	0.522	0.001	0.410	1.299
5	Wonderful Thai: Similan Island	0.190	0.100	0.522	0.001	0.410	1.201
6	Mae Sot Package 3 days 2 nights	0.001	0.100	0.522	0.001	0.410	1.001
7	Loei Package 3 days 2 nights	0.001	0.100	0.522	0.001	0.410	1.001
8	Kanchanaburi Night Safari Tour 2 days	0.001	0.100	0.522	0.001	0.410	1.001
9	Kanchanaburi Good Health 2days	0.001	0.100	0.522	0.001	0.410	1.001
10	Rafting Hin Peang, Winery, Water fall	0.001	0.001	0.522	0.100	0.410	0.990

Table 2 shows PTS analysis for one user. After learning from user transactions by using Q learning, value of trip features are as follows. The first rank ID 43: Thai Gulf-Koh Tao-Koh Nang Yuan-Chumphon which its Duration 4 days is 0.410, Minimal Price 4,500 bahts is 0.100, Maximal Price 4,500 bahts is 0.522, Categories: Beach Holiday is 0.001 and Country: Thailand is 0.410. Total value is 1.421. This trip will be recommended to user firstly.

Users have accessed PST at least two times, given the time different from the first and second access is at least 24 hours. Weights of five features have been calculated from user behaviors and trip profile on PST. Results show that trip destination feature has maximum weight (0.27). The second largest is trip minimum price weight (0.23). The third one is trip maximum price weight (0.19). The fourth is trip category weight (0.19). Lastly, trip duration weight is about 0.14. Then all feature weights have been assembled in the following equation.

$$Qr = 0.14Qt + 0.19Qxp + 0.23Qmp + 0.17Qc + 0.27Qd$$

Evaluation of System Effectiveness

The purpose of this evaluation is to test the performance of the personalization support engine. In this study, we used precision recall and harmonic mean to estimate the system effectiveness. Precision is the ratio of interested trips over the total number of recommended trips. Precision is calculated by dividing the number of trips that users click on the personalization engine by the number of recommended trips. While, recall is the ratio of trip interested users over the total number of clicked trips. Recall is calculated by dividing number of recommended trips by number of clicked trips in user's transaction. Finally, *F1* is also used to represent the effects of combining precision and recall via the harmonic mean (*F1*) function. *F1* is calculated from the product of two multiplied by precision and recall then divided by the sum of precision and recall. *F1* assumes a high value only when precision and recall are both high.

Table 3. Average precision and recall of click recommended trips by user before and after system learning

	Unlearn	After learning
Precision	0.34	0.50
Recall	0.50	0.65
F1	0.40	0.57

Accordingly, Table 3 depicts the effectiveness of the engine by comparing precision, recall and *F1* values evaluated from user click stream before and after learning. The precision is 0.34 for the unlearned system (first access). After twenty four hours the system has been leaned by using Q learning, then users access PTS for the second time. The precision for the second access has been increased to 0.50 (about 47.06%). This pattern is the same for recall (0.50 for first access and 0.65 for second access) and harmonic mean values (0.40 for first access and 0.57 for second access). Thus, the growth rate for both precision and recall increase about 47% and 30%, respectively.

As well, Srikumar (2004) studied on personalized product selection of user behaviors on the Internet. System performance has been evaluated by using recall which is about 0.64. The recall for Srikumar's system is close to PTS's which is about 0.65. Unfortunately, the former study used only one dimension measurement, recall. So it can not conclude that among the two studies which personalisation systems has better performance in terms of both precisions and recalls.

5. CONCLUSIONS

In this study, the personalized support system that recommends trips for tourists based on user behaviors and group properties has been proposed. The system starts learning from user profile, trip database and user historical transactions in accessing PTS web sites. The learning process is using a Q-learning equation which is based on the reinforcement theory. The main concept of the system is that users can surf on the PTS web site to find out interesting trips. Then the top five trips are suggested for users after all candidate trips are ranked in terms of multiple criteria, these trips may be dynamically changed according to user behavior on PTS sites. Results show that both precision and recall of the system had been improved after the system had learned from user transactions and databases. With recommended trips based on significant data of user surfing and profile, it has the potential to increase the success rate of product promotion, and user acceptance.

Focusing on user's interest gives the satisfied results since the information offered to the users is based on historical data and statistical analysis. The advantages of Reinforcement Learning Algorithm is due to its simplicity, quickness and easy to implement. Since there is no need to find the best travel list but it provides the most appropriate information at the current time. Comparing to the traditional manual system which takes longer time and needs a lot of user supports.

This prototype can be applied to business intelligent agent for an e-Commerce. This agent can recommend interesting trips to target users by personalized marketing for new trip or product promotions. Enterprises can use this personalized or one to one marketing to increase numbers of sales and services growth through this channel.

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The ELENA research project follows the vision of creating Smart Spaces for Learning™. A Smart Spaces for Learning™ connects knowledge repositories and on-line market places for the purpose of enriching an institution's learning offerings. Personalization techniques and support for goal-oriented learning management yield in highly effective learning environments.

http://www.knowledgemarkets.at/

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