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1 Executive Summary

The work of the cluster has progressed during the reporting period with the following outcomes:

- Two major Deliverables have been produced in this period.
- The Digital Repositories Report (D5.1.1) *An evaluation study on the development and implementation of community repositories to support research and learning and teaching* has been completed.
- The substantive Deliverable Report and demonstrator (D5.4.2) has been completed: *Demonstrator of mapping between the eLearning and AV content description standards*
- In Task 5.5, the CIDOC-CRM / FRBR Harmonisation work has produced a core ontology and complete textual definition and mapping specification.
- The *GraphOnto* tool has been extended further to provide ontology mapping functionality to define the combined FRBR-CIDOC CRM Model.
- Work has progressed on the mappings and modeling for the cultural heritage demonstrator based on the English Heritage archaeology vocabularies and thesauri.
- A total of 22 published papers and invited (high-profile) international conference presentations have been produced.

2 Introduction and Scope

This report aims to summarise and synthesise the progress during part of the third Joint Programme of Activities (JPA3) to date (February - September 2006) of the Knowledge Extraction and Semantic Interoperability (KESI) cluster.

Currently, the KESI cluster has the following goals for JPA3:

- To build links between the digital repository work and the digital library reference model developments.
- To work more closely with e-Learning and cultural heritage user communities in the design, testing, evaluation and enhancement of the prototype systems and to facilitate their integration with the Delos Digital Library.
- To extend the functionality of the *GraphOnto* tool and promote its application and use in other Delos research tasks as an exemplar of integration within the Network.
- To investigate and develop methods and a demonstrator for the integration of heterogeneous data types, models, upper level ontologies and domain specific KOS

Whilst providing current factual descriptions of the activity underway in each of the three Task areas in JPA3 (Information Repositories and Open Archives, e-Learning and Digital Libraries, Ontology-driven Interoperability), the report also aims to be reflective and critical in approach. Within the scope of the KESI cluster, it attempts to address some of the relevant emergent issues both in the European context and in the wider Digital Library (DL) environment but also within the Delos Network itself. These include dissemination and practical take-up of KESI work, promoting links between Delos activity and other global DL initiatives and facilitating intra- and inter-cluster integration.

The Report is structured with a section on each of the three Task areas followed by sections on Management, Dissemination and Outreach, Intra- and Inter-cluster integration, and finally, some Conclusions are presented. There is also an Executive Summary.

3 Information Repositories and Open Archives

This task T5.1 has been carried forward from JPA1. It has the objective of delivering a "Digital Repositories Forum" which will support discussion of particular topics which will contribute to an evaluative study on the development and implementation of community repositories to support research (institutional, national, e-prints, subject/disciplinary, species, scientific and other e-data) and learning & teaching (institutional, national learning objects and other materials). The Task Leader is UKOLN with partners including Southampton, Imperial, FORTH and TUC (See Partners section 10).

3.1 Main achievements

The Report (D5.1.1) "*An evaluation study on the development and implementation of community repositories to support research and learning and teaching*" associated with this Task, has been completed and is available in the Private Area of the Cluster Web site at http://delos-wp5.ukoln.ac.uk/. The Report has the following Table of Contents:

1 Introduction

1.1 Defining repositories

1.2 A typology of repositories

1.3 Ecology of repositories

2 Digital repositories and scholarly communications

2.1 Introduction

2.2 Building the infrastructure to support research and learning

2.3 The Open Access landscape: political, socio-legal and cultural issues

2.4 Institutional repositories: examining their role in the scholarly workflow

2.5 Data repositories: a case-study in crystallography

2.6 The native digital scholar: developing repository services for added value and knowledge extraction

3 e-learning repositories

3.1 Definitions: e-learning repositories and learning objects

3.2 Curation and rights management

3.3 Architectures of learning systems

4 Multimedia content and its relation to digital repositories

4.1 Multimedia content

4.2 Multimedia issues

4.3 Multimedia in common repository software

4.4 Exemplars of multimedia repositories

5 Subject access and semantic interoperability

5.1 Subject access and semantic interoperability in repositories

5.1.1 Introduction

5.1.2 Empirical finings regarding subject access in repositories

5.1.3 Semantic interoperability and knowledge organisation work

5.1.4 Recommendations

5.1.5 Existing national recommendations on good practice

5.1.6 Summary

5.2 CIDOC Conceptual Reference Model

5.2.1 The CIDOC CRM – engineering core information structures

5.2.2 The CRM – FRBR harmonization project

5.2.3 Conclusions and future work

6 Summary and recommendations

7 References

Appendix 1: Educational Digital Libraries (DLs) and Courseware Repositories

The Report describes a range of repository types and raises some fundamental questions in its Summary and Recommendations:

- How do repositories relate to digital libraries?
- How do institutional repositories relate to national data centres and to community subject-based repositories?

Specific areas are identified for further work such as a common approach to rights management in repositories, aspects of multimedia objects in repositories such as retrievability, versioning of digital objects in repositories and curation aspects of provenance and identifiers in relation to research and learning objects.

There is also a need to develop a framework for repositories which would encompass:

- Interfaces between repositories
- Data flow between repositories
- Integration of repositories into personal workflow.

This Report is timely, in that it builds on the growing body of work on digital repositories, much of which has been led by the Delos partners: the University of Southampton and UKOLN. A significant amount of funding is being invested in this area in the UK through various JISC initiatives. A new European DL proposal Digital Repository Infrastructure Vision for European Research (DRIVER)1, which aims to develop and deliver an infrastructure of networked repositories in Europe, has now begun and includes some KESI cluster partners.

There are synergies between wider Digital Repository (DR) developments and the Delos Reference Model (Task 8.2) and also with the supporting Standards Task in WP1. As part of relevant JISC-funded work, UKOLN is investigating Digital Repository Reference Models including the applicability of the OAIS Reference Model. More information is available on the DigiRep wiki2. OAIS is currently undergoing a full Review of the standard, and this also has direct relevance to the Digital Preservation work in WP6.

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[1] DRIVER Project http://www.driver-repository.eu/

[2] JISC Digital Repository (DigiRep) wiki at http://www.ukoln.ac.uk/repositories/digirep/index/JISC_Digital_Repository_Wiki

4 Interoperability of eLearning Applications with Digital Libraries

Task 5.4 is exploring the interoperability of eLearning applications and Digital Libraries looking particularly at data models, standards and workflows. The aim is to study the major standards for eLearning (e.g. SCORM) and audio-visual (A/V) content description (e.g. MPEG7 etc.), produce mappings and following this analysis, develop an integration framework or architecture and build a demonstrator based on this architecture. The Task leader is TUC with partners Ionian University and UKOLN.

4.1 Main achievements

During the current JPA Task T5.4 has sought to answer the following questions:

- What are the major architectural requirements and workflows for effectively supporting eLearning applications running on top of digital libraries?
- What are the major interoperability requirements for DL and eLearning standards?
- What are the management requirements and tools for audiovisual material and 3D object representations, which form the basis for many collections of learning resources?

The task is focussing on the design and implementation of appropriate tools which can be deployed across the wider DL practitioner community. Initial work has addressed developing models for an architectural framework and for workflow, producing mappings and transformations between relevant metadata standards, implementing the *GraphOnto* tool, implementing aspects of the architecture and documenting the issues in a series of reports.

A generic interoperability framework has been developed that could be also applied to other types of applications built on top of digital libraries, although this task focuses on eLearning applications. Moreover, a framework and an algorithm for supporting personalization has been developed that performs automatic creation of personalized learning experiences using reusable (audiovisual) learning objects, taking into account the learner profiles and a set of abstract training scenarios (pedagogical templates). From a technical point of view, all the framework parts have been organized into a service oriented architecture that has been implemented as a demonstrator (available on the WP5 site - http://delos-wp5.ukoln.ac.uk/).

The demonstrator has been built using the following technologies: Web services, JavaTM 2 Platform Standard Edition v1.5, Berkeley DB XML, Jena API, SPARQL RDF Query Language (Prud'hommeaux & Seaborne, 2005) and XQuery for querying the XML-based metadata descriptions of the digital objects stored in the digital library.

The demonstrator and all the work done in T5.4 regarding the interoperability of eLearning applications and Digital Libraries, the proposed framework and architecture are described in the *Deliverable 5.4.2 "Demonstrator of mapping between the eLearning and AV content description standards"* (available on the WP5 site - http://delos-wp5.ukoln.ac.uk/). Specifically, the deliverable presents the research problem that T5.4

tries to address and analyses the complex and multilevel problem of interoperability between digital libraries and (eLearning) applications (Chapter 3). Some technologies and notions related with this work and also some related work are presented next (Chapter 4) necessary for the reader in order to be able to understand the rest of this document. In the following chapter (Chapter 5) the semantic mapping between MPEG7 and SCORM is presented, the major metadata standards in the audiovisual and eLearning domains respectively, to conclude and prove that a mapping between two standards is not enough to solve the problem of interoperability between digital libraries and eLearning applications and that the problem is much more complex as described in Chapter 3. Finally, the interoperability framework and the architecture supporting also personalization and its implementation are presented in Chapter 6.

The interoperability framework and the architecture developed in this Task have been presented and published as a full paper in the IEEE International Conference on Advanced Learning Technologies (ICALT2006) held in July in the Netherlands (Arapi, Moumoutzis & Christodoulakis, 2006a) and also in ECDL 2005 held in September 2005 in Austria (Christodoulakis, Arapi, Moumoutzis, Patel, Kapidakis, Arahova & Bountouri, 2005).

Beyond the final formal deliverables (*D5.4.2*. and *D5.0.2*), a number of *Internal Deliverables* (**non formal**) have been written during the project covering the objectives of the task, achieving better collaboration between the partners, better organization and flexibility. These Reports are available in the private area of the cluster Web site at http://delos-wp5.ukoln.ac.uk/ (username: private, password: D3l0s-WP5):

- *Interoperability framework and architecture*: In this deliverable from TUC, an interoperability framework and a corresponding architecture is presented for the integration of eLearning applications on top of digital libraries.
- *Semantic mapping between SCORM and MPEG7 concepts*: the major eLearning and audiovisual standards are studied and a mapping between them is presented by IU and TUC. To illustrate the equivalence between the two models, an ontology has been developed and coded in OWL.
- *Investigation of content packaging options – Final model for the storage of audiovisual objects along with educational information Content packaging*: In this deliverable from UKOLN and TUC, the major content packaging schemes are studied and a framework for the storage of audiovisual objects along with educational information in the digital library part and also for their delivery to the eLearning applications according to the architecture was developed.
- *Personalization*: A study of existing models for the representation of Learner Profiles (e.g. IEEE LIP, PAPI and ELENA Project) has been completed by UKOLN and a Learner Information Model (LIM) was proposed.
- *Learning Styles*: In this deliverable produced by IU and TUC, several existing approaches of categorization of learning styles are studied.
- *Instructional ontology*: In this deliverable a workflow model for the construction of abstract training scenarios (learning designs) represented in an instructional ontology (OWL) is presented by TUC, according to the interoperability

framework proposed. This allows reusability of the learning designs and provision of real personalized learning experiences: learning objects are bound to the learning experience on run-time, according to the needs of the learner expressed in the learner profile.

- *A domain ontology for the Digital Libraries domain*: In this deliverable written by IU, an ontology for the digital libraries domain and its implementation in OWL (using GraphOnto) is presented which could be used among others in the interoperability architecture for experimentation purposes.

In addition, a successful research proposal was made based on the Task activities and the corresponding project (IST EU STREP LOGOS) is currently running (starting from February 2006).

Negotiations are being made with the Greek National Educational Radio-Television (ERT) and the Greek Planetarium to achieve a final agreement of using available audiovisual material for a DELOS earth sciences demonstrator for the provision of eLearning services to schools.

In addition to its primary objective (to create a framework for supporting interoperability with eLearning applications which are built on top of digital libraries), on-going work in this task explores interoperability with other applications that are built on top of digital libraries (e-science) and extends the GraphOnto tool to provide ontology mappings, which are needed in many interoperability applications. In particular, models for supporting semantic 3D information to be used in a variety of eScience applications have been derived and functionality requirements investigated. Two ontologies for 3D scenes, based on formal and *de facto* standards have been developed. They are available on DELOS WP3 testbeds and demonstrators site for downloading: http://astral.ced.tuc.gr/delos/. This work is described in a paper from TUC that has been accepted in the IEEE Virtual Reality international conference (Kalogerakis, Christodoulakis & Moumoutzis, 2006). This work is complementary to the work in the Task 3.8 “Description, matching and retrieval by content of 3D objects”, which does not consider semantic descriptions. This Task is also working to extend *GraphOnto*, which is an interactive ontology editor and ontology mappings tool for OWL. GraphOnto which has been developed by TUC, is used in several DELOS tasks (T3.6, T3.9, T3.10, T3.11, T5.4 and T5.5) and is offered through the DELOS demonstrators and testbeds Web site: http://astral.ced.tuc.gr/delos/ (Universities outside DELOS have also obtained it) (Polydoros, Tsinaraki & Christodoulakis, 2006). The tool is planned to be extended to provide full ontology mappings and query mappings. Wider use of the tool will clearly be advantageous to integration efforts across the DELOS network.

In the next sections, after describing in detail the research problem, which T5.4 tries to address, the main achievements of T5.4 are presented. Detailed information can be found in the *Deliverable 5.4.2 “Demonstrator of mapping between the eLearning and AV content description standards"*, which is available on the WP5 Cluster Web site at http://delos-wp5.ukoln.ac.uk/.

4.2 Research problem

A very important application of Digital Libraries (DL) is to support knowledge and learning purposes. However, DLs and their standards have been developed independently of eLearning applications and their standards. For that, interoperability issues between digital libraries and eLearning applications are risen (complex and multilevel problem). In order to enable the construction of eLearning applications that easily exploit DL contents it is crucial to bridge the interoperability gap between digital libraries and eLearning applications.

4.2.1 The multilevel problem of interoperability between digital libraries and (eLearning) applications

Digital Libraries are an important source for the provision of eLearning resources (McLean, 2004). However, digital library metadata standards and eLearning metadata standards have been developing independently, presenting interoperability issues between digital libraries and eLearning applications. This is a complex and multi-level problem, which can be seen as a stack of conceptual layers where each one is built on top of the previous one (left part of Figure 4.1): There are different data representations, objects, concepts, domains, contexts and metacontexts in the layer stack that should be efficiently managed in a standard way. Metadata models are languages that are used to represent the knowledge in a particular application area. Each metadata model is shown as a vertical bar on this stack to cover a specific region that represents the parts that the model tries to capture and describe in a standard way. If one places different metadata models besides this stack, he may identify gaps and intersection regions so that being apparent where the interoperability problems among these models occur. Interoperability problems exist also in the overlapping areas. But in these areas solving the problem of interoperability is easier and can be solved with standard methods (e.g. by means of mappings). The major problems arise in the areas with no overlaps between the two metadata standards. The right part of Figure 4.1 shows such a picture in the case of MPEG7 (MPEG7, 2001, 2003) and SCORM (SCORM, 2004), the major metadata standards in the audiovisual and eLearning domains respectively. It is apparent from this graphical presentation that MPEG7 and SCORM are not completely overlapping meaning that we need additional models to provide interoperability mechanisms between them.

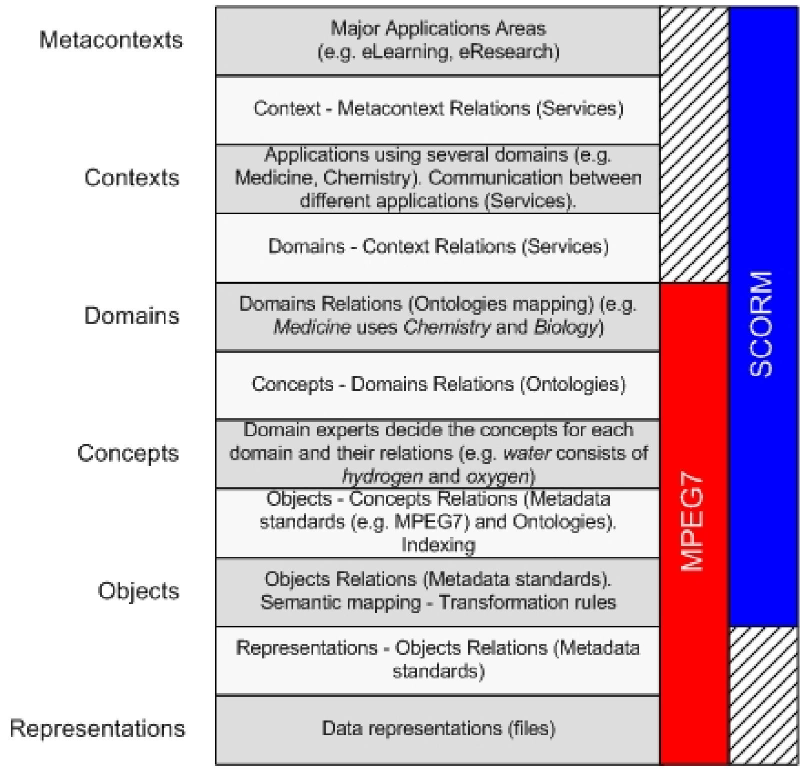

Figure 4.1 The multilevel problem of interoperability

For example, SCORM contains an educational part that cannot be mapped directly or indirectly, completely or partially to MPEG7 elements. That is because MPEG7 does not include information about possible educational use of audiovisual (A/V) objects because it is not an application-specific context metadata standard. However, educational information is very important in the case that MPEG7 (and generally an A/V digital library) is used for educational purposes. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions, which will form the basis for applications that provide the needed effective and efficient access to audiovisual content, which can not represented in SCORM.

Modifying the above standards (e.g. mixing parts of them) would be not a good and right idea, since they have been developed to satisfy the needs of different communities. It would be not right to add elements from an eLearning standard to MPEG7, since it is context-independent, or adding MPEG7 elements to SCORM, since learning resources in SCORM are not always audiovisual.

The above shortcomings are crucial in order to develop an integrated model that will allow for the unified description of audiovisual eLearning material i.e. unified metadata descriptions of audiovisual objects and their parts from an educational perspective. Neither MPEG7 nor SCORM could be used as they are to satisfy this critical need because of the shortcomings presented above. In order to overcome these shortcomings and fill in the gaps between SCORM and MPEG7 we have to use a higher level metadata model that is able to encapsulate both SCORM and MPEG7 in the context of a digital library. This model should be essentially a wrapper that will allow for the use of MPEG7 metadata of existing audiovisual objects and parts of them together with the necessary LOM metadata to specify the educational characteristics of these objects and their parts. A good candidate for this wrapper model is METS (METS, 2005), which is the first widely-accepted standard designed specifically for digital library metadata. METS is intended primarily as a flexible, but tightly structured, container for all metadata necessary to describe, navigate and maintain a digital object (*see Section 4.1.4 of the D5.4.2*).

The above considerations lead to a concrete framework and architecture that addresses the identified interoperability problems and offers a generic framework for the automatic creation of personalized learning experiences using reusable audiovisual learning objects.

Before presenting an interoperability framework and architecture addressing the interoperability problem between eLearning applications and audiovisual digital libraries we will refer to several technologies, notions and work related with this task.

4.3 Semantic mapping between MPEG7 and SCORM

After studied MPEG7 (MPEG7, 2001, 2003) and SCORM (SCORM, 2004) (*see Sections 4.1.3 and 4.1.2 of the D5.4.2*), the major metadata standards in the audiovisual and eLearning domains respectively, we realized a semantic mapping between these two models. Since SCORM makes use of the IMS Content Packaging (IMS CP) specification and a profile of the IEEE Learning Object Metadata standard (LOM) (IEEE LOM, 2002) we separate this mapping in two parts: a) mapping between MPEG7 and SCORM Learning Objects Metadata (LOM) and b) mapping between MPEG7 and SCORM IMS Content Packaging (IMS CP). The Tables of the semantic mapping exist in *Chapter 5 of the D5.4.2*.

After presenting the semantic mapping between MPEG7 and SCORM, it is also practically proven that a mapping between two metadata models is not always a panacea to support interoperability. As already mentioned before and shown in Figure 4.1 standards do not always overlap meaning that we need additional models to provide interoperability mechanisms among them.

For example, SCORM contains an educational part that cannot be mapped directly or indirectly, completely or partially to MPEG7 elements. That is because MPEG7 does not include information about possible educational use of audiovisual (A/V) objects because it is not an application-specific context metadata standard. However, educational information is very important in the case that MPEG7 (and generally an A/V digital library) is used for educational purposes. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions, which will form the basis for applications that provide the needed effective and efficient access to audiovisual content, which can not represented in SCORM. Modifying the above standards (e.g. mixing parts of them) would be not a good and right idea, since they have been developed to satisfy the needs of different communities. It would be not right to add in MPEG7 elements from an eLearning standard, since it is context-independent, or adding in SCORM MPEG7 elements, since learning resources are not always audiovisual.

The above shortcomings are crucial in order to develop an integrated model that will allow for the unified description of audiovisual eLearning material i.e. unified metadata descriptions of audiovisual objects and their parts from an educational perspective. Neither MPEG7 nor SCORM could be used as they are to satisfy this critical need because of the shortcomings presented above. In order to overcome these shortcomings and fill in the gaps between SCORM and MPEG7 (and generally between two metadata standards that are not completely overlapping) we have to use a higher level metadata model that is able to encapsulate both SCORM and MPEG7 in the context of a digital library. This model should be essentially a wrapper that will allow for the use of MPEG7 metadata of existing audiovisual objects and parts of them together with the necessary LOM metadata to specify the educational characteristics of these objects and their parts.

The above considerations lead to a concrete framework and an architecture that addresses the identified interoperability problems and moreover offers a generic framework for the automatic creation of personalized learning experiences using reusable audiovisual learning objects.

4.4 Interoperability framework and architecture

In this chapter we propose a framework and an architecture that has been implemented to support interoperability of eLearning applications with digital libraries. Moreover it supports the construction of personalized learning experiences according to the needs of different learners.

4.4.1 Interoperability framework

As previously mentioned the problem of interoperability between digital libraries and applications is a complex and multi-level one. Although in this task we focus on the interoperability problem between digital libraries and eLearning applications, the methodology proposed here for the description of digital objects that reside in a digital library, can be also applied to other contexts (e.g. eScience etc.).

A digital object can be described in many ways and delivered to many applications (upper part of Figure 4.2). Usually, digital objects have a source metadata description that is appropriately transformed to a target metadata description when this object should be delivered to an application. However, performing just a transformation between the source metadata scheme and the target metadata scheme is not always applicable (Arapi, Moumoutzis & Christodoulakis, 2006a). As shown in Figure 4.1, standards do not always completely overlap. In the non-overlapping areas the interoperability problem cannot simply solved using transformations.

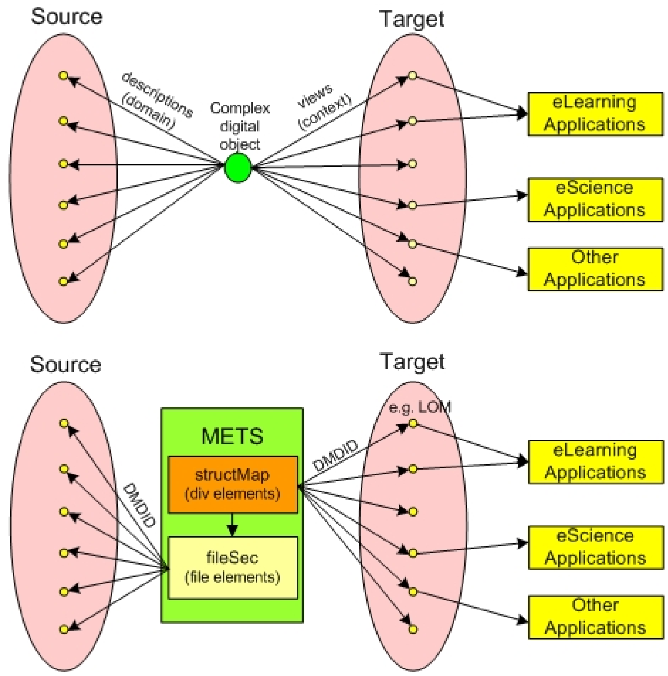

Figure 4.2 Supporting multiple-contexts views of a digital object using METS

For example, an audiovisual digital object that resides in a digital library and described with MPEG7 can be used in eLearning or eScience applications. However, the pure MPEG7 description does not say anything about the educational use (e.g. learning objectives) of the digital object nor contains any information usable to eScience applications. Performing just a transformation between the source metadata scheme and the target metadata scheme does not solve the problem. For example, a Learning Management System that searches for appropriate learning objects in a digital library should have access to descriptive metadata regarding the educational use of a digital object to select object in this context.

So, we need a way to incorporate in a digital object description both source metadata (domain) and target metadata (context). We should have multiple descriptions ((source metadata (domain), target metadata (context)) pairs) for a digital object showing possible views of the object. Context and domain information should reside in different levels, where context information is above domain information.

A flexible model that satisfies the above needs is METS (METS, 2005). As already mentioned, METS is the first widely-accepted standard designed specifically for digital library metadata. METS is intended primarily as a flexible, but tightly structured, container for all metadata necessary to describe, navigate and maintain a digital object, primarily the three types defined by the Digital Library Federation. For each digital object, three types of metadata are possible:

- **Descriptive metadata**: information relating to the intellectual contents of the object, akin to much of the content of a standard catalogue record: this enables the user of a digital library to find the object and assess its relevance.
- **Administrative metadata**: information necessary for the manager of the electronic collection to administer the object, including information on intellectual

property rights and technical information on the object and the files that comprise it.

- **Structural metadata**: information on how the individual components that make up the object relate to each other, including the order in which they should be presented to the user: for example, how the still image files that comprise a digitized version of a print volume should be ordered.

Each type of metadata is described in a separate section, which is linked to its counterparts by a comprehensive system of internal identifiers. The metadata itself may be held physically within the METS file, or may be held in external files and referenced from within the METS document: it may follow any preferred scheme, although a number of these are recommended specifically for use within METS.

Using METS we can create different views of a digital object pointing to both source metadata description and target metadata description (context) in different levels (Arapi, Moumoutzis & Christodoulakis, 2006a). The methodology is illustrated in the lower part of Figure 4.2. Using the DMDID attribute of the <div> elements of structMap section where the structure of the digital object is described we can point to an appropriate metadata scheme creating a context (view) of this object and its parts. For example, we can use LOM metadata (IEEE LOM, 2002) to describe the educational characteristics of each the object and its parts, so that being able for this object to be searched and retrieved (whole or parts of them) by eLearning applications (educational context) (Figure 4.3). In parallel, using the DMDID attribute of the <file> elements of fileSec section, where all files comprising this digital object are listed, we can point to a source metadata scheme that describes the low features or the semantics of this object (e.g. using MPEG7). This is useful when applications want to further filter the resulted objects according to its multimedia characteristics. For example, consider an intelligent system (as the PALEA component of the interoperability architecture described later in this document) that assembles and provides personalized learning experiences to learners using audiovisual content that is stored in a digital library. In the retrieval and selection process, information regarding the semantics or low features of audiovisual content can be taken into account beyond its educational characteristics.

For the purposes of this task we combine METS, MPEG7 and LOM to give to the audiovisual objects and their parts educational characteristics constructing this way audiovisual learning objects. Moreover, the same MPEG7 document can be referenced by many METS documents that include LOM descriptions, having this way multiple views (contexts) for the same audiovisual objects. This framework that is applied in the T5.4 is illustrated in the following figure:

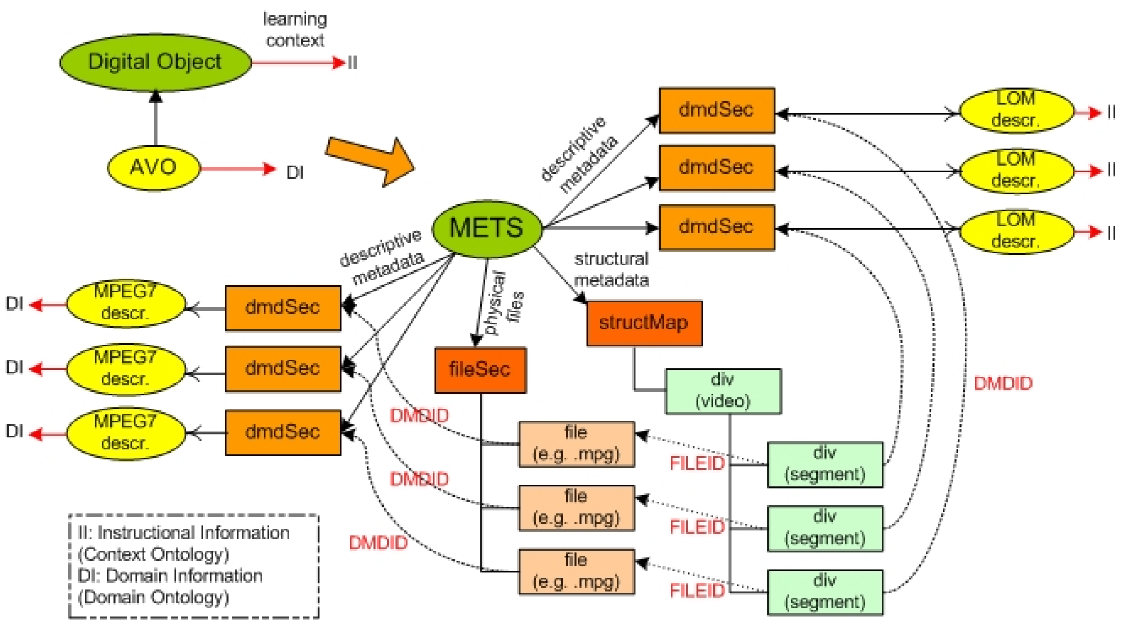

Figure 4.3 Combining METS, LOM and MPEG7 to build audiovisual learning objects

Domain and Context is separated in two levels. The DMDID attribute of the <file> element is used to reference the MPEG7 metadata (domain metadata) describing the audiovisual object referenced by FLocat element. In an upper level we put the Context Metadata (in our case educational metadata) using the DMDID attribute of the div element to reference LOM metadata. This way the video decomposition to segments is described through the METS document (as a complex object) and there is no need to be described in a MPEG7 document using for example the TemporalDecomposition element. An MPEG7 description is used for each segment to give semantics (Domain information) to this segment.

4.4.2 The ASIDE architecture: An Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications

The architecture presented here addresses the identified interoperability problems in a layered architecture where eLearning (and other) applications are built on top of digital libraries and utilize their content. The ASIDE architecture (Arapi, Moumoutzis & Christodoulakis, 2006a) offers a generic framework for the automatic creation of personalized learning experiences using reusable A/V learning objects. It is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification (IMS DRI, 2003). The IMS DRI specification (*see Section 4.3 of the D5.4.2*) provides recommendations for the interoperation of the most common repository functions enabling diverse components to communicate with one another: search/expose, submit/store, gather/expose and request/deliver. These functions should be implementable across services to enable them to present a common interface. IMS DRI splits services into three categories:

- Access services (resource utilizers): Services with which the end user interacts (e.g. LMS/LCMS, portal)
- Provision services (repositories): Services that make content available, and

- Intermediares: Services that reside between the above two (e.g. aggregators, brokers)

The DRI specification acknowledges a wide range of content formats and is applicable internationally to both learning object repositories, as well as to other traditional content sources, such as libraries and museum collections.

Figure 4.4 illustrates the architecture components, which are the following:

- The **Digital Library**, where digital objects are described using METS+LOM (eLearning context), and MPEG7 (A/V descriptions) building this way interoperable A/V learning objects, which can be transformed to SCORM and delivered to eLearning applications (METS/SCORM transformation component). Some important elements used in the LOM descriptions are: educational objectives expressed as {verb (Bloom's Taxonomy (Bloom & Krathwohl, 1965))+subject (term from a Domain Ontology)} using the classification part of LOM, context, typicalAgeRange and difficulty. Regarding the MPEG7 descriptions, the methodology described in (Tsinaraki, Polydoros & Christodoulakis, 2004) is used for extending MPEG7 with domain-specific knowledge descriptions expressed in OWL (OWL, 2004)(domain ontologies).
- **Ontologies** providing knowledge to the Personalized Learning Experiences Assembler (PALEA) described later for the automatic construction of personalized learning experiences:
    - **Domain Ontologies** that provide vocabularies about concepts within a domain and their relationships.
    - **Instructional Ontology** (see Section 4.4.2.1 below) that provides a model for the construction of abstract training scenarios. These are pedagogical approaches (instructional strategies/didactical templates), which can be applied to the construction of learning experiences.
- **Learning Designs** are abstract training scenarios in a certain domain built according to the model given in the instructional ontology.

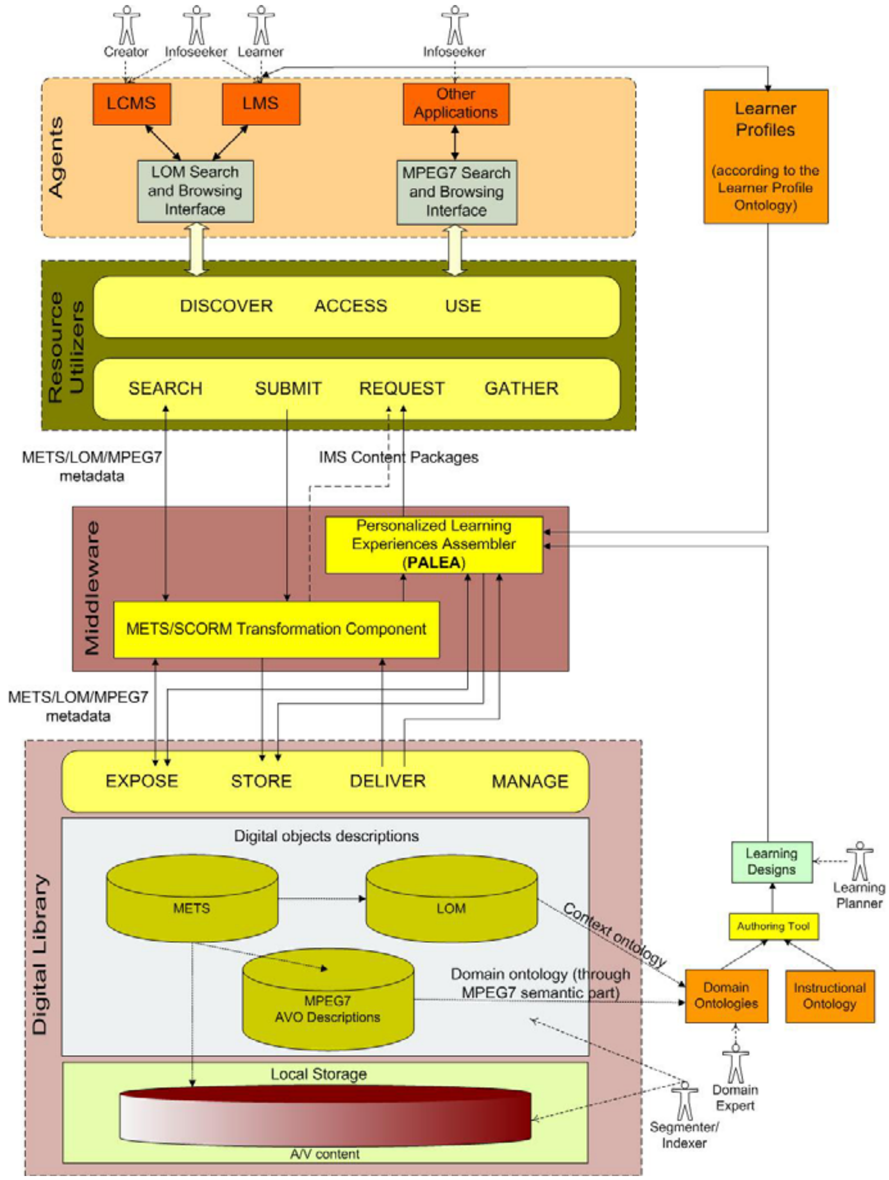

Figure 4.4 The interoperability architecture

- The **Middleware** consists of the following parts:
  - The **METS/SCORM transformation component**, which is responsible for the transformation of the METS descriptions pointing to LOM and MPEG7 descriptions to SCORM Content Packages (SCORM, 2004). This includes not only simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Moreover, the mime-type of the files is taken into account and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files).
  - The **Personalized Learning Experiences Assembler (PALEA)**, which, taking into account the knowledge provided by the Learning Designs (abstract training scenarios) and the Learner Profiles described later,

constructs the personalized learning experiences and delivers them in the form of IMS Content Packages. Before transforming the resulted learning experience to a SCORM package, it is stored as METS+LOM+MPEG7 description in the digital library according to the interoperability framework, being ready and available in an interoperable way for later requests. The dashed arrow in the left side of PALEA indicates that using this component is optional, and that digital library services can be directly accessed (e.g. a teacher wants to find appropriate learning objects to construct manually a learning experience).

- **Applications** (Software Agents in terms of IMS DRI, like Learning Content Management Systems, Learning Management Systems etc.) that discover, access and use the content of the A/V content of the digital library through appropriate services (resource utilizers). The generated personalized A/V learning experiences are delivered to the applications in the form of SCORM packages. Any SCORM-compliant system can recognize and "play" those packages.
- The **Learner Profiles** constructed using the vocabulary given in the **Learner Profile Ontology**, which represents a Learner Information Model (**LIM**) for the creation of learner profiles. Elements from IEEE PAPI (IEEE PAPI, 2002) and IMS LIP (IMS LIP, 2005) specifications have been also used in this model. Some important elements of this model are: learner goals, previous knowledge, educational level and learning style.

4.4.2.1 The instructional ontology

Nowadays, the need for eLearning systems supporting a rich set of pedagogical requirements has been identified as an important issue in the field of distance learning (Capuano et al., 2005). Several initiatives take place in order to meet this need. The most important of these initiatives seems to be IMS Learning Design (IMS LD, 2003) that provides a framework to depict pedagogies.

IMS Learning Design specification (IMS LD, 2003) is a development of the Educational Modelling Language (Hummel, Manderveld, Tattersall & Koper, 2004) (designed by the Open University of the Netherlands (OUNL) to enable flexible representation of the elements within online courses; not just the materials but also the order in which activities take place, the roles that people undertake, key criteria for progression, and the services needed for presentation to learners. The learning design specification does not detail how the course material itself is represented but rather how to package up the overall information into a structure that is modelled on a play, with acts, roles (actors) and resources.

The IMS Learning Design specification supports the use of a wide range of pedagogies in online learning. Rather than attempting to capture the specifics of many pedagogies, it does this by providing a generic and flexible language. This language is designed to enable many different pedagogies to be expressed. It allows different pedagogical approaches to be integrated into a single 'learning design' where different approaches may be appropriate for different types of learners. The approach has the advantage over alternatives in that only one set of learning design and runtime tools then need to be implemented in order to support the desired wide range of pedagogies.

The IMS Learning Design specifications (Figure 4.5) are structured in three levels. Level A includes activities, roles and environments. Activities (learning activities or support activities) can be grouped into activities structures and executed into specific environments. An environment is formed by learning objects and services provided to users during activity execution. Users are classified into roles (learners, teachers, tutors, etc.). Nowadays, learning objects are educational contents by which learners acquire knowledge and services are functionalities invoked during learning process in order to communicate with tutors or other learners. Level B adds properties (storing information about a single person or a group) and conditions (setting constraints upon the flow of activities) to the first level. Level C adds notifications (mechanism to handle messages passing between users) to the framework.

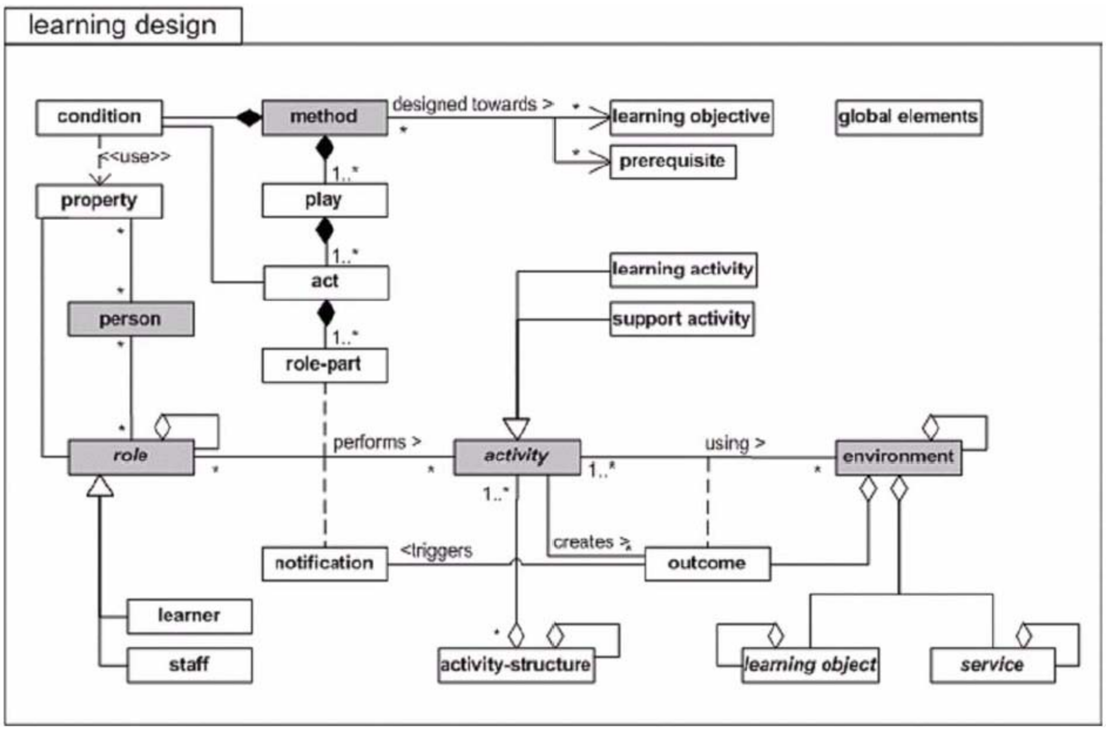

Figure 4.5 Conceptual model for overall IMS Learning Design (from IMS LD, 2003)

However, although IMS-LD provides a model to personalize the learning experience at run-time using properties and conditions at Level B, the instructional planner has to provide specific learning objects and services, so that learning objects and services are bound to the learning design scenario on design time. This prohibits the construction of "real" personalized learning experiences, where the appropriate learning object according to the learner profile are bound to the decided learning experience on run-time.

The model proposed in this work for the construction of abstract training scenarios and represented in an *instructional ontology* coded in OWL (Figure 4.6) has the important characteristic that learning objects are not bound in the training scenarios on design time.

Instead of that, the pedagogy is separated and independent from the content achieving this way reusability and interoperability of learning designs that can be used fron the systems as are, or parts of them for the construction of “real” personalized learning experiences. The term “real” is emphasized here, to indicate that to provide personalized learning experiences, the learner profile should not only affect the selection of a sequence or structure of activities comprising a training scenario that satisfy his/her learning needs (learning objectives, learning style, age, educational level etc.), but also the retrieval of learning objects that are appropriate for him/her. An intelligent component/system (as the Personalized Learning Experiences Assembler (PALEA) in the ASIDE architecture can match the knowledge given in the learner profiles and the learning designs in order to build firstly an appropriate activity structure or sequence for the specific learner (learning experience structure or training scenario) and afterwards selecting appropriate learning objects from a digital library for each node (activity) of this structure. This is possible, since the model proposed in the instructional ontology gives the opportunity to specify in each Activity the learning objects’ requirements, instead of binding the learning objects themselves, as IMS Learning Design (IMS LD, 2003) imposes. This ontology borrows some elements and ideas from the IMS Learning Design Specification and LOM and its purpose is to overcome the limitations that current eLearning standards and specifications impose. In the ASIDE architecture the final decided learning experiences along with the appropriate learning resources are finally packaged to a PIF file (SCORM package) and delivered to the eLearning applications.

A *Training* is a collection of abstract training scenarios regarding one domain. The same subject can be teached in several ways (*TrainingMethods*) depending on the *LearningStyle* and the *EducationalLevel* of the Learner. There are several categorizations of Learning Styles (Konsolaki, Kapidakis & Arapi, 2006) and Educational Levels, thus these elements are flexible so that being able to point to values of different taxonomies. A *TrainingMethod* consists of a hierarchy of *ActivityStructures* built from *Activities* (elements taken from IMS LD). Since this model is RDF-based (OWL), existing *ActivitiesStructures* or paths of *ActivitiesStructures* can be reused in many Learning Designs. Each *Training*, *ActivityStructure* and *Activity* has a *LearningObjective*. Learning Objectives are treated here in a more formal way (as in SeLeNe project (Keenoy, Levene & Peterson, 2004)), than pure text descriptions. Thus, each *LearningObjective* has: (a) a *learning_objective_verb*, taken from a subset of the outcome-illustrating verbs which characterise each type of learning objectives specified by a committee of college and university examiners in 1956 (known as "Bloom's Taxonomy (Bloom & Krathwohl, 1965)). This subset has been selected for the description of Learning Objectives by the SeLeNe project. (b) a *learning_objective_topic* that indicates the topic that the learning objective is about, referenced as an entry in the RDF binding of a subject taxonomy or ontology (context ontology e.g. ACM Computing Taxonomy (ACM, 1998)), and (c) *learning_objective_annotation* that indicates additional textual description of the learning objective; for example, to specify areas within the topic at a greater level of detail than is catered for by the subject taxonomy (or ontology). The *LearningObjectType* class is used to describe the desired Learning Object characteristics (requirements) without binding specific objects with *Activities* on design time. If more than one entries are used per *Activity*, the interpretation is “OR”. Via the *related_with* property we can further restrict the preferred learning objects connecting them with *DomainConcepts* or individuals from a domain ontology.

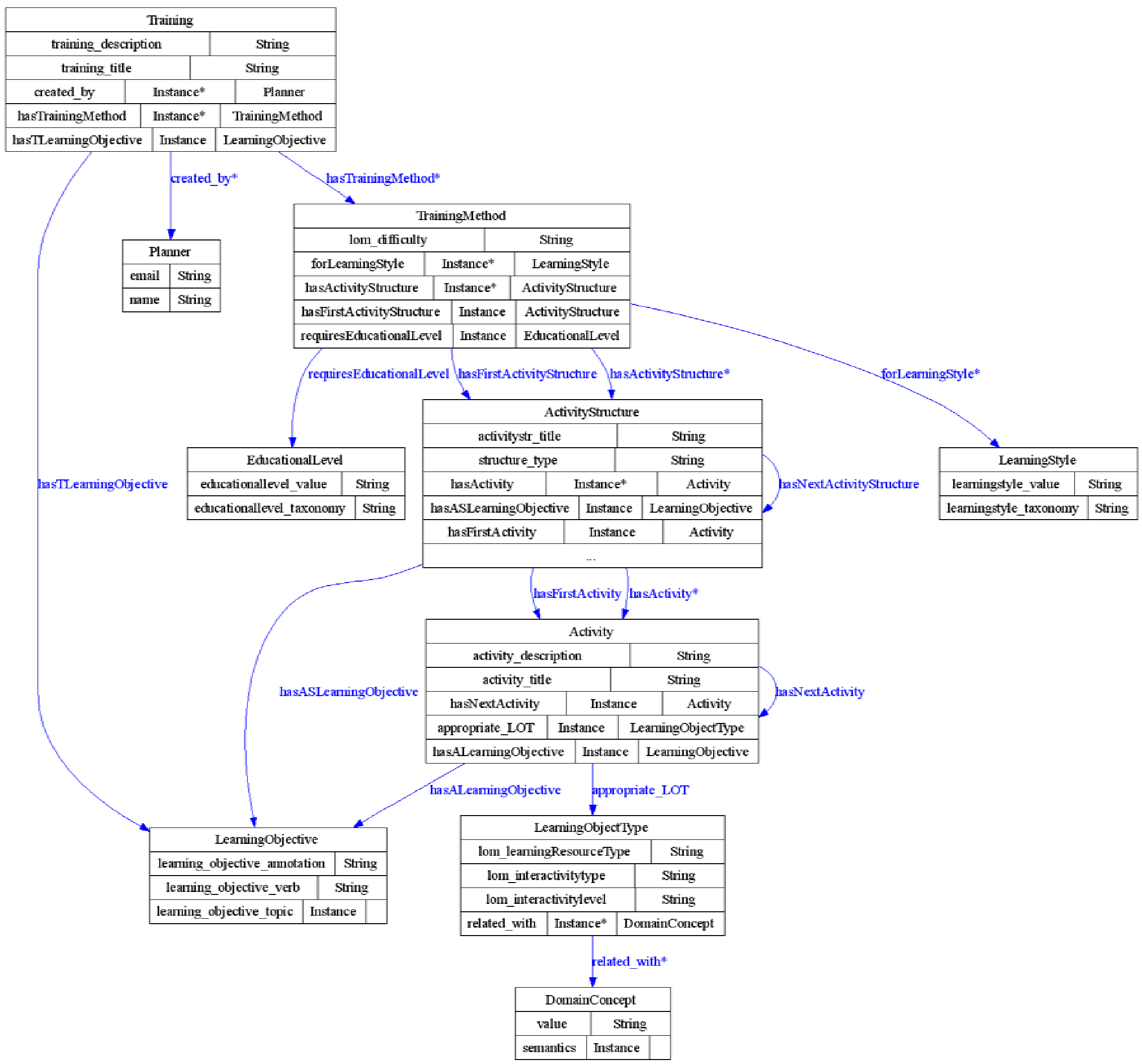

Figure 4.6 The instructional ontology

4.4.2.2 The Learning Designs

Learning Designs are abstract training scenarios in a certain domain built according to the model given in the instructional ontology. Here, we present an example of a simple Learning Design.

Training: PlayerActions

- *training_title*: Player Actions
- *created_by*: Mylonakis Manolis, Arapi Polyxeni
- *LearningObjective*: teach PlayerAction
    - **TrainingMethod**: PlayerActionsTM1
        - *LearningStyle*: GeneralToSpecific

- *EducationalLevel*: Primary
- *lom_difficulty*: medium
    - **ActivityStructure**: understandPlayerAction
      LearningObjective: understand PlayerAction
        - **Activity**: definePlayerAction
            - *LearningObjective*: define PlayerAction
            - *appropriate_LOT*:
                - *lom_learningResourceType*: video
                - *lom_interactivitytype*: Expositive
                - *lom_interactivitylevel*: very low
                    - *DomainConcept:*
                        - *value*: Morras
                        - *semantics*: http://.../socceragents#PlayerObject
        - **Activity**: describePlayerAction
            - *LearningObjective*: describe PlayerAction
            - *appropriate_LOT*:
                - *lom_learningResourceType*: video
                - *lom_interactivitytype*: Expositive
                - *lom_interactivitylevel*: very low
                    - *DomainConcept:*
                        - *value*: Marantona
                        - *semantics*: http://.../socceragents#PlayerObject
        - **Activity**: showPlayerAction
            - *LearningObjective*: show PlayerAction
            - *appropriate_LOT*:
                - *lom_learningResourceType*: video
                - *lom_interactivitytype*: Expositive
                - *lom_interactivitylevel*: very low
                    - *DomainConcept:*
                        - *value*: Marantona
                        - *semantics*: http://.../socceragents#PlayerObject
    - **ActivityStructure**: understandOut
        - **Activity**: defineOut
            - *LearningObjective*: define Out
            - *appropriate_LOT*:
                - *lom_learningResourceType*: video
                - *lom_interactivitytype*: Expositive
                - *lom_interactivitylevel*: very low
                    - *DomainConcept:*
                        - *value*: Morras

            - *semantics*: http://.../socceragents #PlayerObject
    - **Activity**: describeOut
        - *LearningObjective*: describe Out
        - *appropriate_LOT*:
            - *lom_learningResourceType*: video
            - *lom_interactivitytype*: Expositive
            - *lom_interactivitylevel*: very low
                - *DomainConcept:*
                    - *value*: Marantona
                    - *semantics*: http://.../socceragents #PlayerObject
    - **Activity**: showOut
        - *LearningObjective*: show Out
        - *appropriate_LOT*:
            - *lom_learningResourceType*: video
            - *lom_interactivitytype*: Expositive
            - *lom_interactivitylevel*: very low
                - *DomainConcept:*
                    - *value*: Marantona
                    - *semantics*: http://.../socceragents #PlayerObject

- **ActivityStructure**: understandClear
  LearningObjective: understand PlayerAction

    - **Activity**: showClear
        - *LearningObjective*: show Clear
        - *appropriate_LOT*:
            - *lom_learningResourceType*: video
            - *lom_interactivitytype*: Expositive
            - *lom_interactivitylevel*: very low
                - *DomainConcept:*
                    - *value*: Marantona
                    - *semantics*: http://.../socceragents #PlayerObject
    - **Activity**: showClear2
        - *LearningObjective*: show Clear
        - *appropriate_LOT*:
            - *lom_learningResourceType*: video
            - *lom_interactivitytype*: Expositive
            - *lom_interactivitylevel*: very low

- *DomainConcept:*
  - *value*: Ronaldo
  - *semantics*: http://.../socceragents #PlayerObject

- **TrainingMethod**: PlayerActionsTM2
  - *LearningStyle*: SpecificToGeneral
  - *EducationalLevel*: Primary
  - *lom_difficulty*: medium
    - **ActivityStructure**: understandClear
      - **Activity**: showClear

      …
      - **Activity**: showClear2

      …
      - **Activity**: describeClear

      …
      - **Activity**: defineClear
    - **ActivityStructure**: understandOut

      ....

4.4.2.3 The Middleware

4.4.2.3.1 The METS/SCORM transformation component

The METS/SCORM transformation component is responsible for the transformation of the METS descriptions pointing to LOM and MPEG7 descriptions to SCORM Content Packages (SCORM, 2004). This includes not only simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Moreover, the mime-type of the files is taken into account and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files). The mapping between METS and SCORM is presented in the following table:

Table 1 Mapping between METS and SCORM

METS	SCORM IMS Manifest
structMap	organizations/organization
structMap/@ID	organizations/@default
structMap/@ID	organizations/organization/@identifier
structMap/div/@LABEL	organization/title
structMap/div/@ID	organization/item/@identifier
div/@LABEL	organization/item/title
div/fptr/@FILEID	item/@identifierref

fileSec	resources
fileGrp	resources/resource
fileGrp /@ID	resources/resource/@identifier
file/FLocat/@xlink:href	resources/resource/@href
fileGrp/file	resources/resource/dependency
fileGrp/file/@ID	resources/resource/dependency/@identifierref
fileGrp/file/@ID	resources/resource/@identifier
fileGrp/file/FLocat/href	resources/resource/file/@href
If dmdSec/mdWrap/[@MDTYPE=LOM] dmdSec/mdWrap/xmlData	<adlcp:location>lomfiles/FG1.xml</adlcp:locat- ion> Creates an xml document with the LOM metadata for each resource.

4.4.2.3.2 The Personalized Learning Experiences Assembler (PALEA)

The **Personalized Learning Experiences Assembler (PALEA)** algorithm takes into account the knowledge provided by the Learning Designs (abstract training scenarios) and the Learner Profiles described later and constructs personalized learning experiences that are delivered next to eLearning applications in the form of SCORM Content Packages. Before transforming the resulted learning experience to a SCORM package, it is stored as METS+LOM+MPEG7 description in the digital library according to the interoperability framework, being ready and available in an interoperable way for later requests.

The algorithm of the PALEA is presented below and illustrated in Figure 4.7:

Input:

Learning Objectives Table: The Learner selects from his Learner Profile (or builds new) a set of Learning Objectives regarding a specific domain (e.g. soccer). The new Learning Objectives are added in the Learner's Profile and a status value is also given (this value express the satisfaction of a Learning Objective (float from 0.0 to 1.0)). A value of 1 means that this Learning Objective has been fully satisfied, while a value of 0 means that the Learning Objective has not been satisfied at all.

Learning Style: The Learner selects a Learning Style or the value from his Learner Profile is used.

Educational Level: The Learner selects an Educational Level or the value from his Learner Profile is used.

Difficulty: The Learner selects a difficulty level.

Planner (optional): The Learner selects a preferred planner (instructional designer), the person who develops learning designs.

Title (optional): The title of a Training, Activity Structure or Activity.

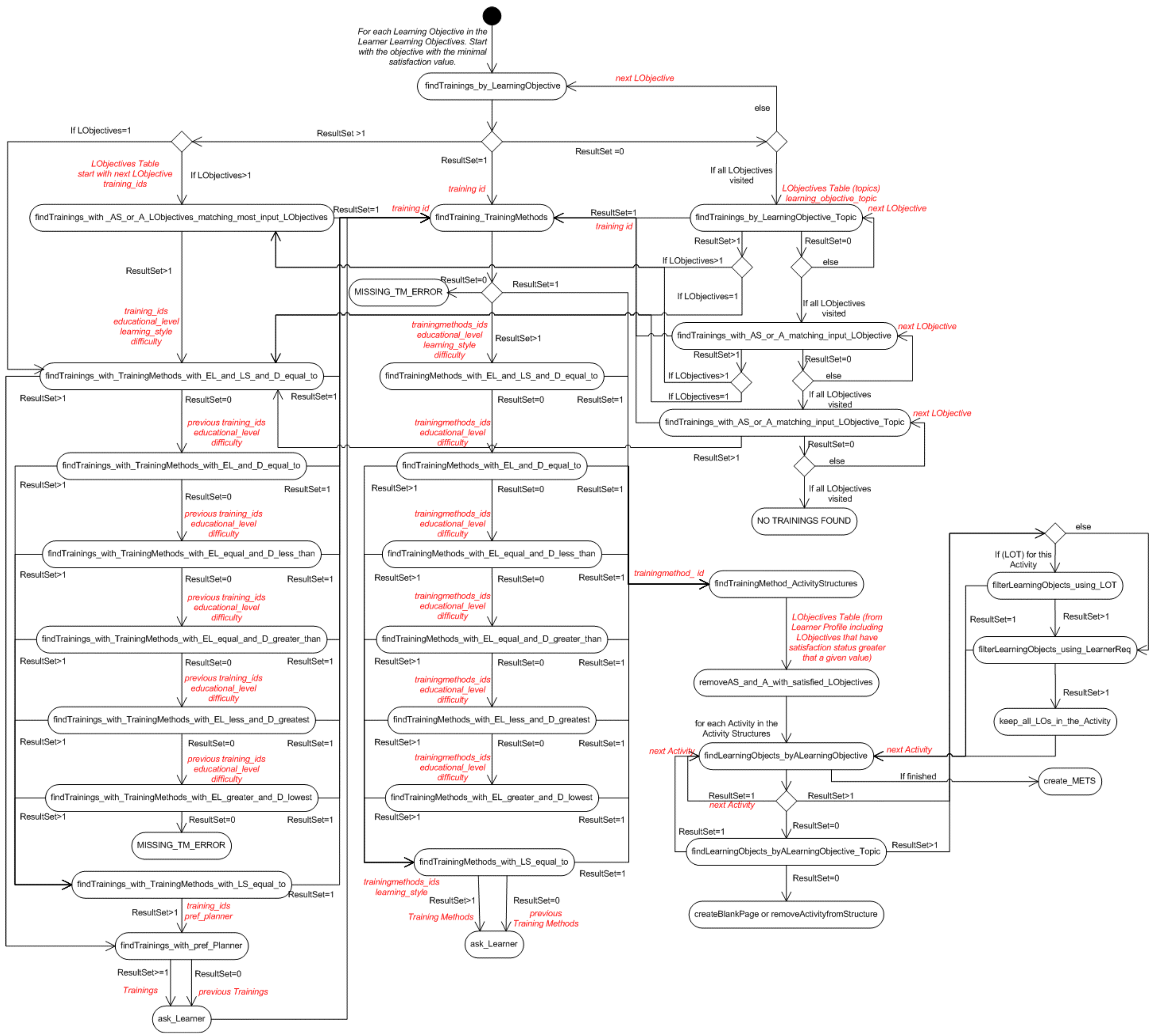

Figure 4.7 The Personalized Learning Experiences Assembler (PALEA) algorithm

The algorithm

1) Sort the Learning Objectives Table by the status value. Put the Learning Objective with the minimum satisfaction value (status) first.
2) Find Trainings that match the first Learning Objective in the sorted Learning Objective Table (*findTrainings_by_LearningObjective*).
   a. If ResultSet>1
      i. If size(Learning Objectives Table)>1 then go to **Step 3**
      ii. If size(Learning Objectives Table)=1 then go to **Step 4**
   b. If ResultSet=1 then go to **Step 12**
   c. If ResultSet=0
      i. If (All Learning Objectives in the Learning Objectives Table visited) go to **Step 20**
      ii. Else for the next Learning Objective in the sorted Learning Objective Table go to **Step 2**

3) From the Trainings that are given as input in this step select those that satisfy the most Learning Objectives given in the input Learning Objectives Table in all levels (ActivityStructures and Activities)(*findTrainings_with _AS_or_A_LObjectives_matching_most_input_LObjectives*).
   a. If ResultSet>1 (e.g. two "winner" Trainings that both satisfy the same maximum number of Learning Objectives) then go to **Step 4**
   b. If ResultSet=1 (only one Training remained after this procedure) then go to **Step 12**
   c. If ResultSet=0 (Is not possible!)

4) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level, Learning Style and difficulty matching those given in the input (*findTrainings_with_TrainingMethods_with_EL_and_LS_and_D_equal_to*).
   a. If ResultSet>1 then go to **Step 11**
   b. If ResultSet=1 then go to **Step 12**
   c. If ResultSet=0 then go to **Step 5**

5) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level and difficulty matching those given in the input (*findTrainings_with_TrainingMethods_with_EL_and_D_equal_to*).
   a. If ResultSet>1 then go to **Step 10**
   b. If ResultSet=1 then go to **Step 12**
   c. If ResultSet=0 then go to **Step 6**

6) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level matching those given in the input and difficulty less than and closer to that given in the input (*findTrainings_with_TrainingMethods_with_EL_equal_and_D_less_than*).
    a. If ResultSet>1 then go to **Step 10**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0 then go to **Step 7**

7) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level matching those given in the input and difficulty greater than and closer to that given in the input (*findTrainings_with_TrainingMethods_with_EL_equal_and_D_greater_than*).
    a. If ResultSet>1 then go to **Step 10**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0 then go to **Step 8**

8) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level less than and closer to that given in the input and the greatest difficulty (*findTrainings_with_TrainingMethods_with_EL_less_and_D_greatest*).
    a. If ResultSet>1 then go to **Step 10**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0 then go to **Step 9**

9) From the Trainings that are given as input in this step find those that have Training Methods with Educational Level greater than and closer to that given in the input and the lowest difficulty (*findTrainings_with_TrainingMethods_with_EL_greater_and_D_lowest*).
    a. If ResultSet>1 then go to **Step 10**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0 then produce a MISSING_TM_ERROR (Training has not TrainingMethods associated)

10) From the Trainings that are given as input in this step find those that have Training Methods with Learning Style matching those given in the input (*findTrainings_with_TrainingMethods_with_LS_equal_to*).
    a. If ResultSet>1 then go to **Step 11**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0 (Is not possible!)

11) From the Trainings that are given as input in this step find those that have been developed by the Planner given in the input (*findTrainings_with_pref_Planner*).

a. If ResultSet>1 or ResultSet=0 then ask Learner to choose Training (if ResultSet=0 use the Trainings from the previous step)
b. If ResultSet=1 then go to **Step 12**

12) Find the Training Methods of the current Training (*findTraining_TrainingMethods*).
    a. If ResultSet>1 then go to **Step 13**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 produce a MISSING_TM_ERROR (Training has not Training Methods associated)

13) From the Training Methods that are given as input in this step find those that have Educational Level, Learning Style and difficulty matching those given in the input (*findTrainingMethods_with_EL_and_LS_and_D_equal_to*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 then go to **Step 14**

14) From the Training Methods that are given as input in this step find those that have Educational Level and difficulty matching those given in the input (*findTrainingMethods_with_EL_and_D_equal_to*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 then go to **Step 15**

15) From the Training Methods that are given as input in this step find those that have Educational Level matching those given in the input and difficulty less than and closer to that given in the input (*findTrainingMethods_with_EL_equal_and_D_less_than*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 then go to **Step 16**

16) From the Training Methods that are given as input in this step find those that have Educational Level matching those given in the input and difficulty greater than and closer to that given in the input (*findTrainingMethods_with_EL_equal_and_D_greater_than*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 then go to **Step 17**

17) From the Training Methods that are given as input in this step find those that have Educational Level less than and closer to that given in the input and the greatest difficulty (*findTrainingMethods_with_EL_less_and_D_greatest*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 then go to **Step 18**

18) From the Training Methods that are given as input in this step find those that have EducationalLevel greater than and closer to that given in the input and the lowest difficulty (*findTrainingMethods_with_EL_greater_and_D_lowest*).
    a. If ResultSet>1 then go to **Step 19**
    b. If ResultSet=1 then go to **Step 23**
    c. If ResultSet=0 (Is not possible!)

19) From the Training Methods that are given as input in this step find those that have Learning Style matching those given in the input (*findTrainingMethods_with_LS_equal_to*).
    a. If ResultSet>1 or ResultSet=0 then ask Learner to choose Training Method according to the Learning Style (if ResultSet=0 use the Training Methods from the previous step)
    b. If ResultSet=1 then go to **Step 23**

20) Find Trainings that match the first Learning Objective Topic in the sorted Learning Objective Table (*findTrainings_by_LearningObjective_Topic*)
    a. If ResultSet>1
        i. If size(Learning Objectives Table)>1 then go to **Step 3**
        ii. If size(Learning Objectives Table)=1 then go to **Step 4**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0
        i. If (All Learning Objectives in the Learning Objectives Table visited) go to **Step 21**
        ii. Else for the next Learning Objective Topic in the sorted Learning Objective Table go to **Step 20**

21) Find Trainings that have Activity Structures or Activities with Learning Objectives that match the first Learning Objective in the sorted Learning Objective Table (*findTrainings_with_AS_or_A_matching_input_LObjective*)
    a. If ResultSet>1
        i. If size(Learning Objectives Table)>1 then go to **Step 3**
        ii. If size(Learning Objectives Table)=1 then go to **Step 4**
    b. If ResultSet=1 then go to **Step 12**
    c. If ResultSet=0

i. If (All Learning Objectives in the Learning Objectives Table visited) go to **Step 22**
ii. Else for the next Learning Objective in the sorted Learning Objective Table go to **Step 21**

22) Find Trainings that have Activity Structures or Activities with Learning Objectives that match the first Learning Objective Topic in the sorted Learning Objective Table *(findTrainings_with_AS_or_A_matching_input_LObjective_Topic*)
   a. If ResultSet>1 go to **Step 4**
   b. If ResultSet=1 then go to **Step 12**
   c. If ResultSet=0
      i. If (All Learning Objectives in the Learning Objectives Table visited) no Trainings found
      ii. Else for the next Learning Objective Topic in the sorted Learning Objective Table go to **Step 22**

23) Find the structure of the specific Training Method consisting of Activity Structures including Activities (*findTrainingMethod_ActivityStructures*) and go to **Step 24**.

24) Remove from this structure Activity Structures or Activities with Learning Objectives that have been satisfied in the past (previous knowledge). This information is extracted from the Learning Objectives that exist in the Learner's profile (not only those that are given in the input and initiate the algorithm). Specifically, all Learning Objectives that exist in the Learner's profile have a status value which shows the satisfaction level of a Learning Objective. The Learner can declare when a Learning Objective can be considered satisfied by defining a status threshold (e.g. 0.7), meaning that Learning Objectives that have status value greater than this threshold are considered as satisfied and the corresponding Activity Structures or Activities are removed from the structure (*removeAS_and_A_with_satisfied_LObjectives*). Go to **Step 25**.

25) For each Activity in the Activity Structures find Learning Objects from the Digital Library that have Learning Objective matching the current Activity's Learning Objective (*findLearningObjects_byALearningObjective*).
   a. If ResultSet=1 keep this Learning Object and continue to the next Activity (**Step 25**).
   b. If ResultSet>1
      i. If there is a LearningObjectType (learning object requirements) associated with this Activity go to **Step 27**
      ii. Else go to **Step 28**
   c. If ResultSet=0 go to **Step 26**

   When finished go to **Step 30.**

26) Find Learning Objects from the Digital Library that have Learning Objective matching the current Activity's Learning Objective Topic (*findLearningObjects_byALearningObjective_Topic*).
    a. If ResultSet=1 keep this Learning Object and continue to the next Activity (**Step 25**).
    b. If ResultSet>1
        i. If there is a LearningObjectType (learning object requirements) associated with this Activity go to **Step 27**
        ii. Else go to **Step 28**
    c. If ResultSet=0 remove this Activity from the structure and go to **Step 25** (next Activity).

27) Filter the set of learning objects according to the LearningObjectType (learning object requirements) associated with this Activity (*findLearningObjects_using_LOT*).
    a. If ResultSet=1 keep this Learning Object and continue to the next Activity (**Step 25**).
    b. If ResultSet>1 go to **Step 28**
    c. If ResultSet=0 (keep the previous set of Learning Objects and go to **Step 28**

28) Filter the set of learning objects according to some requirements of the Learner Profile (content provider, technical etc.) (*filterLearningObjects_using_LearnerReq*).
    a. If ResultSet=1 keep this Learning Object and continue to the next Activity (**Step 25**).
    b. If ResultSet>1 go to **Step 29**
    c. If ResultSet=0 (keep the previous set of Learning Objects and go to **Step 28**

29) Keep all learning objects found for this Activity (*keep_all_LOs_in_the_Activity*) and go to **Step 25**.

30) Create the METS document describing the final learning experience (*create_METS*) that could be thereafter transformed to a SCORM Content Package.

4.4.2.4 The Learner Profiles

With the huge range of digital educational resources becoming widely available and the opportunities afforded by the Internet and the Web, there is currently a trend towards the constructivist approach to eLearning (Burr, 1995). This approach puts the student at the centre of the learning process with the objective of tailoring educational resources to the individual learner's requirements and goals.

In addition, there is widespread recognition that learning is a life-long process and that learning technology systems need to track, manage and exchange information about their students. Learner information comes from three broad sources: personal information (address, telephone number etc.); preferences (operating system, network connection, desktop configuration, learning style etc.); and academic information (courses completed, grades etc.).

However, in order to match and tailor resources to an individual's requirements, it is also necessary to describe resources in an appropriate way, using for example the IEEE Learning Object Metadata (LOM) Standard (IEEE LOM, 2002).

Much of the work on personalisation of eLearning has been based on metadata about a user or learner. The techniques fall into two broad categories:

- **Adaptive hypermedia**: mostly related to adapting user interfaces, navigation, content selection and presentation according to the user's performance in a particular domain.
- **Filtering and recommendation**: based on interests, preferences, likes, dislikes and goals a user has. Resources are recommended according to features extracted from a description of the resource or according to its ratings by users with a similar profile.

Given the open and heterogeneous nature of the Web, there has been much emphasis on interoperability and reuse of educational resources. To this end, there have been two major attempts to standardize a learner profile, IEEE Personal and Private Information (PAPI) (IEEE PAPI, 2002) and the IMS Learner Information Package (LIP) (IMS LIP, 2005) (*see Section 4.4 of D5.4.2*).

According to Dolog & Nejdl (Dolog & Nejdl, 2003) these standards have been developed from different points of view. The PAPI standard reflects ideas from intelligent tutoring systems where the performance information is considered as the most important information about a learner. PAPI also stresses the importance of inter-personal relationships. On the other hand the LIP standard is based on the classical notion of a CV and inter-personal relationships are not considered.

One way forward is therefore to draw on both of the standards as a means of developing an adequate learner model, as in the ELENA Project (ELENA Project).

There is currently much work in progress in the area of personalisation and adaptation in eLearning systems, a considerable amount of this relates to the use of ontologies and semantic web technologies (Razmerita, Angehrn & Maedche, 2003; Dolog, Hemze, Nejdl & Sintek, 2004; Denaux, Dimitrova & Aroyo, 2004; Baldoni, Baroglio, Patti & Torasso, 2004). Some important projects are:

- **ELENA and Learner Projects**: One of the central design elements of the ELENA smart learning space is a dynamic learner profile, which includes a learning history, learner specific information and learning goals. The investigators of the ELENA (ELENA Project) and Learner (Dolog, 2005) Projects have developed a Learner Model based on both the LIP and PAPI, which could be leveraged for Task 5.4. In fact the Learner Project website makes available the relevant schemas which could be examined to see whether they meet the requirements of Task 5.4.
- **SeLeNe Project**: The Self E-Learning Networks Project (an EU FP5 Accompanying Measure, (IST-2001-39045) November 2002 to January 2004) has

developed a User Profile for SeLeNe users, which combines elements from existing learner profile schemes and adds extra elements where these schemes are insufficiently expressive to adequately support SeLeNe's personalisation requirements (Keenoy Levene & Peterson 2004). We adopt the SeLeNe model for the representation of Learning Objectives. Specifically, each Learning Objective can be represented by a verb (from Bloom's Taxonomy) and a subject (target (or context) ontology).

- **LSAL**: The Learning Systems Architecture Lab (LSAL) at Carnegie Mellon is also researching into customised learning using a web services approach (LSAL). Their customised learning prototype is used to present the right learning materials to the learner, on demand, using a model of role and competency-based content customisation.

Since our intention here is to support personalization there is a need to focus on the learner's goals and preferences. Of course, other elements could be also included in a learner profile but in this case they are not important. The Learner Profile Ontology which provides a Learner Information Model (LIM) for the construction of Learner Profiles is presented in Figure 4.8.

The basic elements of a Learner's Profile are her/his *LearnerGoals* and *Preferences*. A *LearnerGoal* is expressed in terms of *LearningObjectives* according to the format that is followed in the instructional ontology. A *LearnerGoal* has a *status* property which is a float number from 0.0 to 1.0 indicating the satisfaction level of the goal (e.g. a value of 0.0 shows that this goal has been not at all satisfied, while a value of 1.0 shows that this goal has been fully satisfied). From this information we can extract the previous knowledge of the Learner. The Learner can also define a priority for each *LearnerGoal.* The Learner can have several types of Preferences: *EducationalLevel* and *LearningStyle* matching with the corresponding elements of the instructional ontology, *Language, LearningProvider* (the author or organization making available the learning objects), *LearningPlanner* (the person that develops learning designs) and *Technical* preferences.

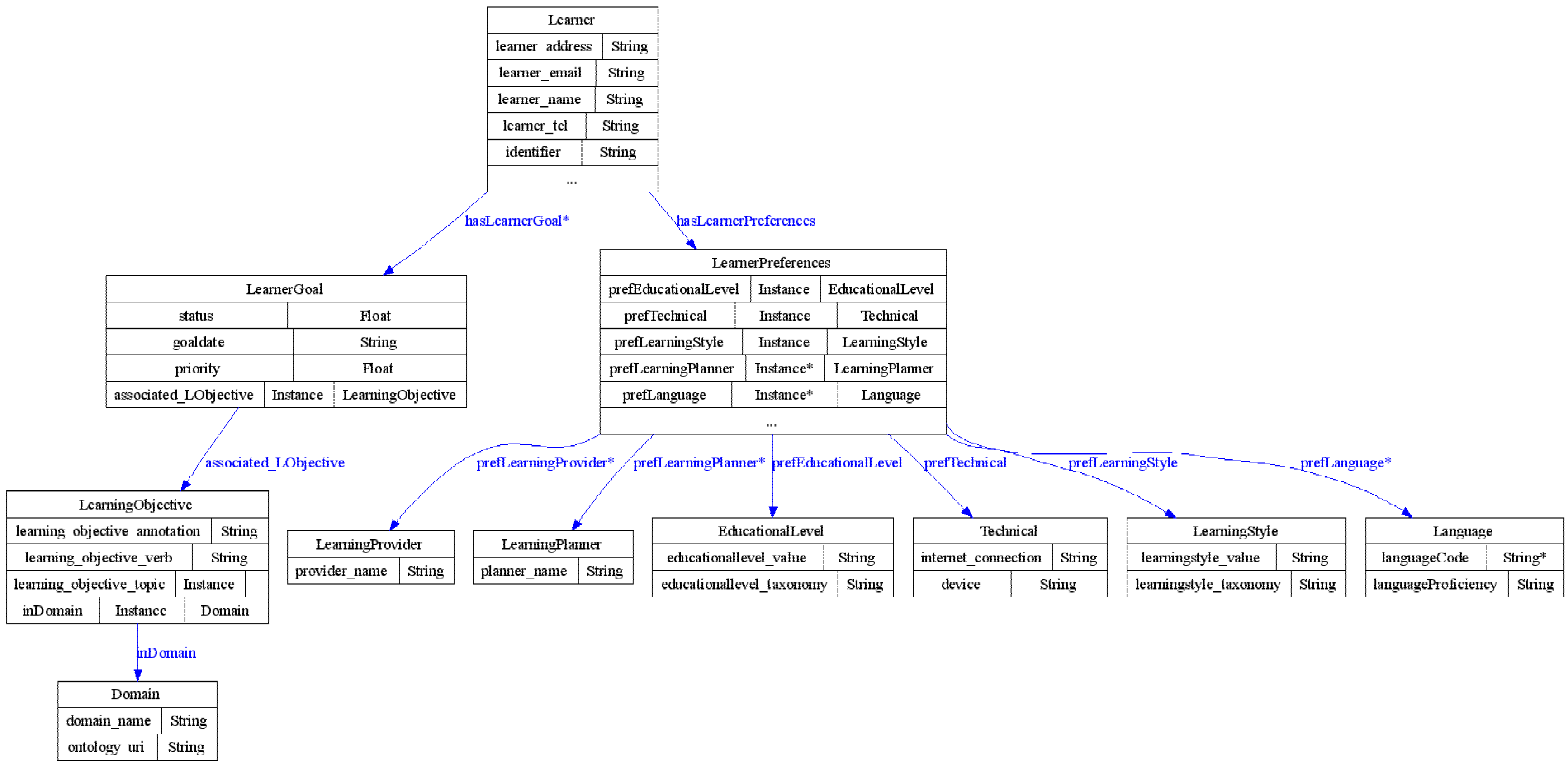

Figure 4.8 The Learner Profile Ontology

4.4.3 Demonstrator

The above interoperability architecture has been implemented using the following technologies: Web services, JavaTM 2 Platform Standard Edition v1.5, Berkeley DB XML, Jena API, SPARQL RDF Query Language (Prud'hommeaux & Seaborne, 2005) and XQuery for querying the XML-based metadata descriptions of the digital objects stored in the digital library.

Through an appropriate graphical user interface the user can do the following:

- Searching directly (without using the personalization component) the contents of the digital library using several educational criteria. After finding the appropriate content (s)he is able to transform it to a SCORM package in order to be accessible from eLearning applications.
- Creating a Learner Profile. The information stored in her/his learner profile can be also used when the user searches the contents of the digital library directly but it is fully exploited when the user requests a personalized learning experience adapted to her/his needs (see next).
- Requesting a personalized learning experience according to his Learner Profile giving also some additional criteria. Here, the Personalized Learning Experiences Assembler (PALEA) is used and the personalization algorithm is executed in order to prepare a learning experience for the user that fits to her/his learning needs. The resulted learning experience can be thereafter transformed to a SCORM package in order to be accessible from eLearning applications.

The SCORM packages that are generated from the METS/SCORM transformation component are tested twofold:

- Using an XML validator to check the validity of the output IMS manifest file according to the corresponding schema.
- Importing and playing the generated SCORM packages in the SCORM Sample Run-Time Environment provided by Advanced Distributed Learning (ADL) that developed SCORM.

Both methods show that the SCORM packages generated by the METS/SCORM transformation component were 100% SCORM conformant.

5 Ontology-driven interoperability

Task 5.5 builds upon earlier Delos work and in particular upon the *Semantic Interoperability in Digital Library Systems* Report (D5.3.1) http://delos-wp5.ukoln.ac.uk/project-outcomes/ produced during JPA1. It is concerned with the interoperability of data models and core ontologies which underpin the development of diverse digital library systems. The Task investigates and develops methods for the integration of heterogeneous data types, models, upper level ontologies and domain specific knowledge organisation systems. The main objectives are:

- To achieve harmonisation of core ontologies FRBR and FRAR model from IFLA (International Federation of Library Associations) with the CIDOC Conceptual Reference Model (CRM) from ICOM (International Council of Museums).
- To produce mappings of the CRM core ontology to the metadata schema of TEI and Dublin Core.
- To develop and evaluate a demonstrator for a case study on the mapping of a Knowledge Organisation System (KOS) to a core ontology.

The lead partner is FORTH with Athens University of Economics & Business, Glamorgan, Imperial College, Ionian University, Lund, MTA Sztaki, NTNU, and TUC.

The potential impact of this Task both within Delos and across the wider community is considerable. There are three major aspects: metadata integration in key application areas, metadata integration in general, and core ontology harmonization.

The task is integrating the core ontology (ISO21127) describing the data structure semantics of museum / cultural heritage documentation with the one describing the future semantics of general library metadata (FRBR). The main purpose of FRBR is to be able to describe and access information by the complex derivation chains from original conceptions to the final information objects, such as translations, adaptations etc.. The combined core ontology will allow for high precision schema integration of museums, libraries and archives ("MLA") information. The widely accepted Dublin Core Metadata Initiative has considerable limitations in its scope and level of granularity. The limits of applicability of the CRM for metadata integration in general have not yet been encountered (smaller extensions notwithstanding). It has the potential to become a core ontology for Digital Library metadata in general. This is demonstrated by the CRM Core metadata element set, which are compatible with Dublin Core, but implement the key element of the CIDOC CRM and the ABC Model: explicit *event representation*.

The demonstrator will show the solution to a generic problem of metadata and schema integration in a particular case study using cultural heritage data. The more usual approaches to metadata interoperability, such as metadata registries and application profiles, work only with nearly homogeneous materials, but fails for more heterogeneous and complementary material. The problem will become more acute when future digital libraries will include all kinds of scientific data and multimedia material and the "simpler" approaches will reach their limits. Potential beneficiaries of this work include all library and digital library developers who want to integrate highly heterogeneous resources, such as the TEL, MICHAEL and BRICKS Projects.

The methodology of harmonizing core ontologies has been developed in the previous DELOS Project, with the harmonization of ABC and CRM. The problems and method have already been published[3]. Task 5.5 is carrying out the task of harmonizing/merging the CIDOC CRM and FRBR through a series of meetings with invited experts and also students participating as part of their professional development.

5.1 Main achievements

In agreement with the work plan, during the reporting period, the following has been achieved in Task 5.5.

Harmonization FRBR-CIDOC CRM:

Two working meetings led by FORTH have been held for the elaboration of a common ontology for FRBR and CIDOC CRM:

a) Imperial College London, UK, March 27-29, 2006

b) University of Trondheim, Norway, June 26-30, 2006

These meetings build on the three earlier sessions held at various European locations in 2005.

Besides DELOS partners, these meetings were attended by leading experts from IFLA, CIDOC and TEI:

Patrick LeBoeuf, Bibliotheque nationale de France (BNF), Service de normalisation documentaire (Standardization Department). Chair of the IFLA Working Group on the FRBR Review. (Funded by DELOS).

Maja Žumer, University of Ljubljana, Library Science and FRBR expert. (Funded by DELOS).

Christian-Emil Ore**,** University of Oslo, Chair of CIDOC, member of the TEI Working Group on ontologies.

Stephen Stead, Consultant, Vice Chair of CIDOC.

Allen Renear, Graduate School of Library and Information Science at the University of Illinois, member of the Advisory Board of TEI.

In these meetings, the conceptualization behind FRBR (in the following "$FRBR_{ER}$") was analyzed as an ontology called "$FRBR_{OO}$", which specializes and extends the CIDOC CRM (ISO21127) in a compatible form. Minor changes in the CRM has been taken into account to assist the harmonization. It comprises all the intended meanings of the entities and relationships defined in $FRBR_{ER}$ and justifies the attributes and relationships by explicit modeling of the respective processes. This is verified by a mapping specification expressing $FRBR_{ER}$ in terms of $FRBR_{OO.}$ The model deals with the following general notions:

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[3] Martin Doerr, J. Hunter , Carl Lagoze, "Towards a Core Ontology for Information Integration", 2003, In *Journal of Digital information*, volume 4 issue 1, April 2003

a) Substance and Conception of a Work.

b) Reuse, continuation and aggregation of Work.

c) Realization of a work in a symbolic form, i.e., the connection of intellectual and material creation in the authoring process.

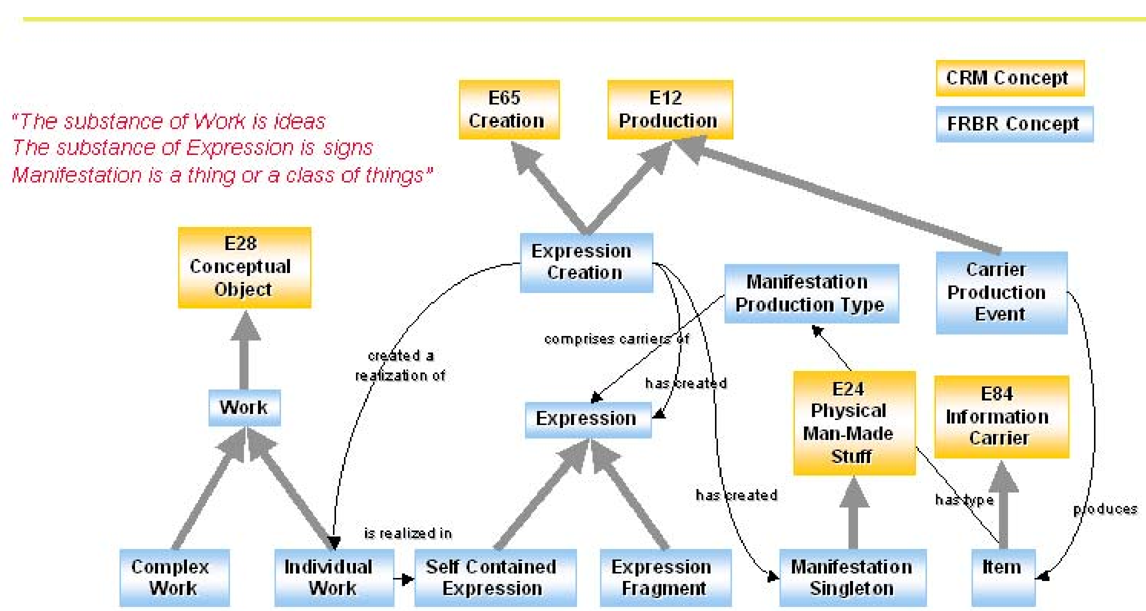
d) The substance of an Expression

e) The publishing process and the contribution and product of the publisher.

f) A detailed model of the equivalence of electronic and material publishing.

In particular point c), e) and f) must be regarded as innovative and a substantial progress in the modeling of intellectual creation processes. The model now comprises 33 classes and 47 properties. It follows strictly the methodology used for ISO21127. It could be formulated without particular difficulties as a specialization of the CIDOC CRM classes. Considerable effort was needed to detect and resolve inconsistencies or fuzzy concepts in $FRBR_{ER}$. See Figures 5 and 6. There have also been enough discussions to clarify concepts in the transition from the old to the new bibliographic practice which is underlying $FRBR_{ER}$, and should have an impact on the organization of Digital Libraries.

Figure 5. CIDOC CRM-FRBR harmonization. (From Martin Doerr, FORTH).



The following outcomes of this work have been published (http://cidoc.ics.forth.gr/frbr_inro.html):

a) $FRBR_{OO}$ has been formulated and validated together with the CRM in the Knowledge Representation Languages TELOS and OWL.

b) A complete textual definition, with a scholarly introduction, description of its purpose and modeling methodology, and explicit scope notes and examples for each class and property with title "FRBR object-oriented definition Version 0.6.7", by: International Working Group on FRBR and CIDOC CRM Harmonisation, editors: Patrick LeBoeuf, Martin Doerr, August 2006.

c) Another edition of the above text, augmented by the definition of all CIDOC CRM concepts referred to in $FRBR_{OO}$, and the complete mapping specification from $FRBR_{ER}$ to $FRBR_{OO}$.

d) A graphical representation of the complete $FRBR_{OO}$ model.

e) Detailed reports of all meetings with the justifications for all decisions taken.

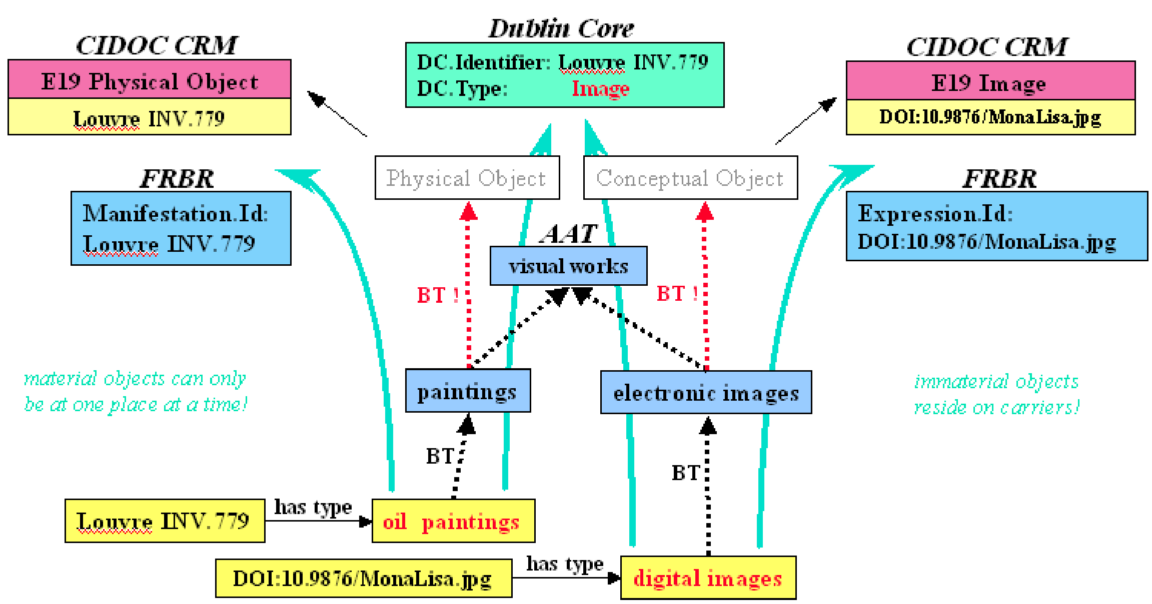
Work on CRM Harmonization will continue in three directions:

a) Definition of the equivalence of textual authoring and publishing processes with Performing Arts for the purpose of cultural-historical documentation.

b) Augmenting $FRBR_{OO}$ by the concepts underlying FRAR, the "Functional Requirements for Authority Records". FRBR and FRAR together are the complete formulation of current library conceptualization.

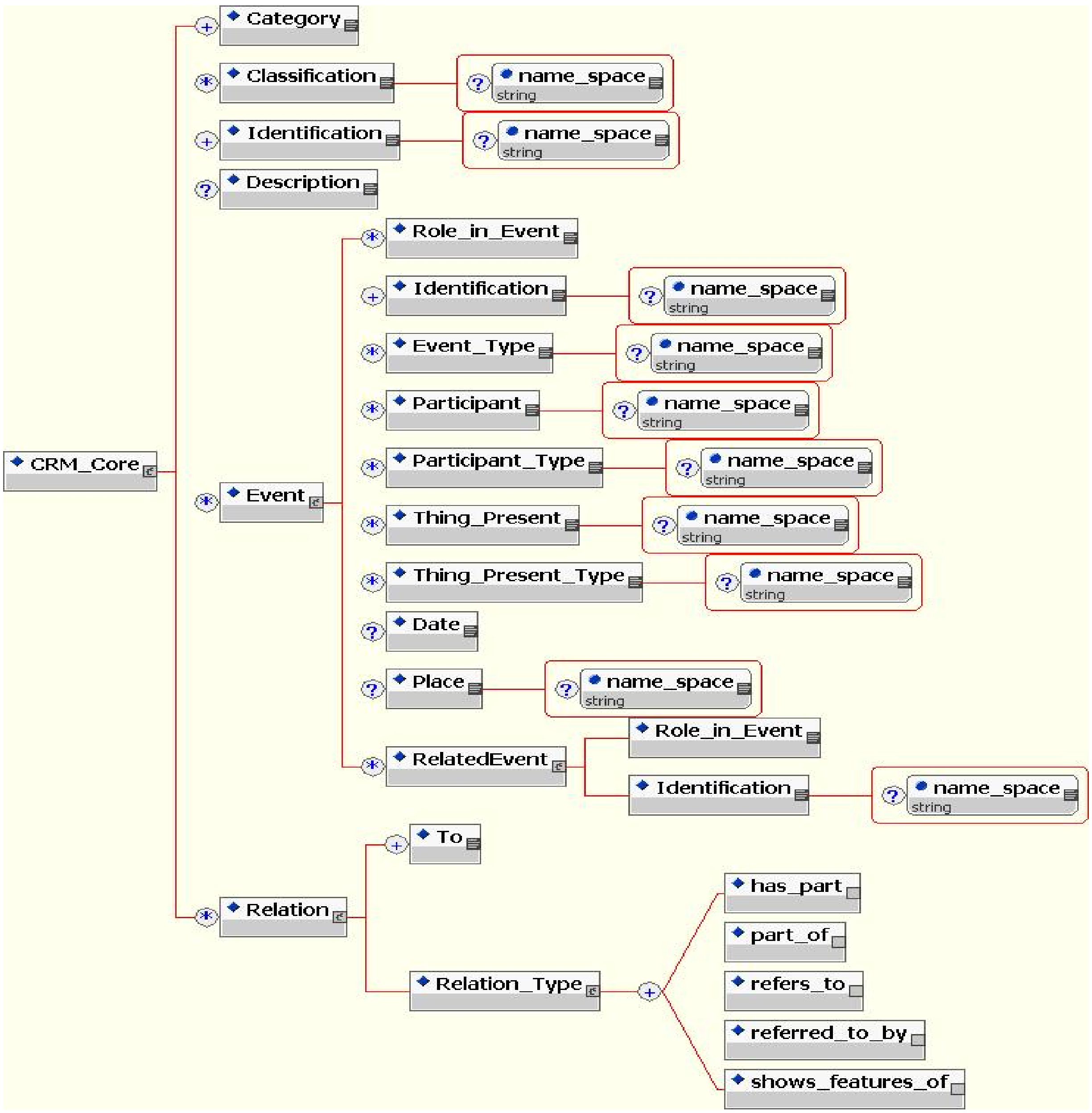
c) Identification of the semantic overlap of CRM- $FRBR_{OO}$ with TEI standards, and definition of a common harmonization work plan.

Figure 6. Resolving schema heterogeneity. (From Martin Doerr, FORTH).



The combined core ontology CRM- $FRBR_{OO}$ goes into considerable detail. As such it is suited as a global model in "local as view" (LAV) information integration strategy for a wide range of detailed data structures in use. In order to support the users that can only afford very simple metadata, but nevertheless intends to benefit from the information integration capacity of the combined model, the CRM Core metadata element set (http://cidoc.ics.forth.gr/working_editions_cidoc.html) has been defined by ICS-FORTH. See Figure 7. It is Dublin Core compatible, marginally more complex, but makes use of the full power of explicit event representation. For extensive documentation purposes, a comprehensive documentation format for cultural objects in the form of a CRM-compatible XML DTD has been defined by ICS-FORTH.

Figure 7. CRM Core metadata element set. (From Martin Doerr, FORTH).



Work supporting mappings from and to the CRM core ontology:

The combined FRBR-CIDOC CRM model has been formally defined in OWL and TELOS. TUC/MUSIC contributes to the task by providing, extending and supporting the use of the GraphOnto software component (http://astral.ced.tuc.gr/delos/cls_resource_description.jsp?id=10404). GraphOnto is a complete form-based application for manipulating graphically OWL-DL ontologies. Manipulation of ontologies includes: a) the importing of core ontologies (basic ontologies consisting of the minimal concepts required to understand the other concepts or representing an entire model), b) parsing of domain ontologies (ontologies tied to a specific domain) stored in an OWL-format file, c) editing of Domain ontologies, d) creation of new domain ontologies, and e) definition of metadata (OWL individuals) compliant to ontologies. All ontologies managed by the application support the full syntax of OWL-DL (one of OWL species), which provides maximum expressiveness contrary to OWL-Lite and guarantees computational completeness and decidability of reasoning systems contrary to OWL-Full. GraphOnto is a user-friendly application that covers the needs of both naive and expert users. Since ontologies may describe extremely complex concepts, GraphOnto provides mechanisms for information hiding, so that naive users and the metadata creators can concentrate only in the concepts they intend to use during their work. On the other hand, by supporting all the OWL-DL expressiveness it provides the Ontology experts and creators with powerful and easy to use functionality.

GraphOnto, has been extended in the context of Task 5.5 to provide ontology mapping functionality in order to be used in the definition of the combined FRBR-CIDOC CRM model in OWL. In particular, it supports the editing of multiple ontologies and mapping between elements of opened Ontologies is supported using the OWL constructs:

1. Mapping between Classes by specifying equivalence, disjointness or hierarchical relationships.
2. Mapping between Properties by specifying equivalence or hierarchical relationships.
3. Mapping between Individuals by specifying identity (sameAs) or difference (differentFrom).

The first version of the extended GraphOnto has been available from September 2005 and has been used by other partners of the task. Continuous support was provided by TUC and enhancements were made based on the partner's feedback.

The Ionian University (IU) has evaluated the GraphOnto tool in co-operation with TUC to test the ontology uploading, creation and edit functions and experimentation with CRM. The research team has studied the CRM and has developed a demonstrator based on a description of an excavation in Corfu, with the usage of the GraphOnto tool. Further, IU has produced mappings of DC-types to CRM to a subset of EAD elements (version 2.0) : the <EADheader> as well some basic compound elements included in the <archdesc> element such as the <did>, <dsc>, <bioghist> and <scopecontent>. Work is continuing to refine these mappings which will be published in the coming months.

SZTAKI has investigated new methods for collaborative support of the ontology mapping process. SZTAKI also experiments with query facilities in the scenario of multiple mapped ontologies. The CORES registry operated by SZTAKI contains more than 30 metadata schemas (element sets, application profiles, etc.) which can be browsed and searched in a connected way. This registry was connected with an OAI service provider with 500.000 records. The connection enables automatic adaptation of the service provider to schema changes. Furthermore, SZTAKI implemented a web-based search interface which is capable to construct and execute queries combining the use of several metadata schemas.

Case study and demonstrator:

A case study for deriving an elaborate data structure and a core data structure for describing cultural objects from the CIDOC CRM core ontology will be available at month 42. These are the first steps to demonstrate in practical examples the utility of mapping to common core ontologies, and of merging core ontologies from related domains. The case study scoping work has been led by the University of Glamorgan through leverage of the ongoing English Heritage (EH) Revelation project and their application/extension of the CRM core schema to EH archaeology (CRM-EH).

In order for effective search across different databases and associated controlled vocabularies or thesauri, a mapping from domain ontologies (thesauri) to an overarching common schema, ie the CRM, is needed. It was decided to investigate the environmental archaeological domain as a test case, building on an English Heritage (EH) existing extension of the CRM to their needs. This specialisation of the CRM schema had only existed previously on paper. Working in Protégé and in collaboration with EH, Glamorgan augmented the standard CIDOC CRM 3.4.9 release with the environmental archaeology section of the EH extended model. This can now be exported in various formats. EH have done a preliminary (satisfactory) assessment of the extended model. A report has been produced for EH, so that they are enabled to continue the work in their own right. Additionally, mappings have been made from the CRM-EH to the new EH Environmental Archaeology Thesaurus (EAT) and the (Archaeology Data Service's) Environmental Archaeology Bibliography (EAB) database.

A meeting between Glamorgan and Lund took place in London February 22, 2006 to plan further details of the demonstrator. The University of Lund has implemented a demonstrator illustrating how the mappings can improve search of the EAB (employing additional mappings to uncontrolled database fields).

A presentation on the work was made at the Semantic Interoperability Workshop mentioned – <http://cidoc.ics.forth.gr/workshops/london_workshop/Tudhope.ppt>.

A research grant has recently been awarded to Glamorgan, by the UK AHRC Research Council, for a 3-year project exploring this general area: AHRC Grant (AH/D001528/1): Semantic Tools for Archaeological Resources (STAR Project). Principal Investigator, 3 years, 2007-2010, £222,139.

6 Management, Dissemination and Outreach

UKOLN is continuing to act as cluster co-ordinator. DSTC, University of Queensland, Australia (Dr Jane Hunter) has formally joined the cluster.

The cluster has operated effectively and had one face-to-face meeting in London on 21st February 2006 with a second meeting scheduled for 22nd September in Alicante. In parallel work on the JPA3 tasks has been pursued through separate Task meetings and more details are given below.

Two CRM-FRBR Harmonization Workshops have taken place as described in Section 5.1.

The Cluster Co-ordinator attended Scientific Board Meetings in Luxembourg and Alicante and most fortnightly telcons, and the Project Review in Luxembourg in 2006.

The cluster Web site http://delos-wp5.ukoln.ac.uk/

has been maintained and updated with information relating to the new tasks. A private area has been set up for the sharing of draft documents, presentation slides and other work items. All items for dissemination have been linked to the cluster pages and deliverables made available.

A Workshop was held on 30th March 2006 at the Internet Institute, Imperial College, London with title: "*Semantic Interoperability for e-Research in the Sciences, Arts and Humanities*", with an international line-up of speakers (see http://cidoc.ics.forth.gr/workshops.html).

A further associated Workshop entitled "*Exploring the limits of global models for integration and use of historical and scientific information*" is planned for October 23-24th at ICS-FORTH in Heraklion, Crete and the Keynote speaker will be Nicola Guarino, ISTC-CNR, Laboratory for Applied Ontology, Trento.

A NKOS Workshop will be held at ECDL 2006: Networked Knowledge Organization Systems and Services The 5th European Networked Knowledge Organization Systems (NKOS) Workshop at the 10th ECDL Conference, Alicante, Spain. http://www.ukoln.ac.uk/nkos/nkos2006/

6.1 Publications and Presentations

Other papers and presentations

Polyxeni Arapi, Nektarios Moumoutzis, Stavros Christodoulakis. ASIDE: An Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications, 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), July 2006, Kerkrade, The Netherlands

Blocks D., Cunliffe D. Tudhope D. 2006 (in press). A reference model for user-system interaction in thesaurus-based searching. Journal of the American Society for Information Science and Technology. Wiley.

Stavros Christodoulakis, Polyxeni Arapi, Nektarios Moumoutzis, Manolis Mylonakis, Manjula Patel, Sarantos Kapidakis, Christos Papatheodorou, Antonia Arahova, Barbara Vagiati, Haroula Konsolaki. Interoperability of eLearning Applications with Digital Libraries, Poster on the 10th European Conference on Research and

Advanced Technology for Digital Libraries (ECDL 2006), September 2006, Alicante, Spain.

Martin Doerr, Centre for Cultural Informatics, Foundation for Research and Technology, Crete (FORTH). Presentation Waking from a Dogmatic Slumber: A Different View of Knowledge Management for Digital Libraries Semantic Interoperability for e-Research Workshop March 2006, Internet Institute, Imperial College, London.

Golub, K., Ardö, A., Mladenic, D., Grobelnik, M. 2006. Comparing and Combining Two Approaches to Automated Subject Classification of Text. In J. Gonzalo et al. (Eds.): ECDL 2006, LNCS 4172, Spain. P. 467-470.

Golub, K. 2006. Automated subject classification of textual Web pages, based on a controlled vocabulary: challenges and recommendations. New review of hypermedia and multimedia, Special issue on knowledge organization systems and services, June 2006, 12(1). P. 11-27. DOI: 10.1080/13614560600774313.

Golub, K. 2006. Controlled-vocabulary based approach to automated subject classification of textual Web pages in the field of engineering. LIDA PhD Forum 2006.

Golub, K. 2006. Subject-based information organization: KnowLib's findings. LIVA project meeting, Lund, 5 April 2006.

Golub, K. 2006. Using Controlled Vocabularies in Automated Subject Classification of Textual Web Pages, in the Context of Browsing: PhD proposal. IEEE TCDL Bulletin, vol. 2, issue 2.

Rachel Heery, UKOLN, University of Bath and Andy Powell, Eduserv Foundation, Digital Repositories Roadmap: looking forward. April 2006 URL: <http://www.ukoln.ac.uk/repositories/publications/roadmap-200604/ > (Permalink)

Kalogerakis, V., Christodoulakis, S., Moumoutzis, N.: Coupling Ontologies with Graphics Content for Knowledge Driven Visualization. IEEE Virtual Reality International Conference, March 2006, Virginia, USA . Presentation: [Powerpoint]

Lyon, L.
Digital repositories as research infrastructure: a UK perspective.
European Infrastructure for Repositories of Scientific Information, Brussels, 8-9 June 2006
Presentation: [HTML] [Powerpoint] (Permalink)

Lyon, L. Digital Libraries and e-Research: new horizons, new challenges?
8th International Bielefeld Conference, Bielefeld, Germany, February 2006
Presentation: [Powerpoint] [HTML]

Henry Rzepa, Dept. of Chemistry, Imperial College London. Presentation Semantic Interoperability in Chemistry Semantic Interoperability for e-Research Workshop March 2006, Internet Institute, Imperial College, London.

Patrick Sinclair, Dept of Computing (Intelligence, Agents and Multimedia Group), University of Southampton. Presentation CRM Core: Multimedia Interoperability for Cultural Heritage? Semantic Interoperability for e-Research Workshop March 2006, Internet Institute, Imperial College, London.

Faletar Tanackovic, S., Golub, K., and Levine, E. Libraries in the Digital Age 2006: Report from the field. Information Today, July 2006. P. 28.

Doug Tudhope, School of Computing, University of Glamorgan. Presentation *Mapping Domain Thesauri to the CIDOC CRM for Semantic Interoperability of Data Archives* Semantic Interoperability for e-Research Workshop March 2006, Internet Institute, Imperial College, London.

Tudhope D., Binding C., Blocks D., Cunliffe D. 2006. Query expansion via conceptual distance in thesaurus indexed collections. Journal of Documentation, 62 (4), 509-533. Emerald.

Tudhope D., Nielsen M. 2006. Introduction to Special Issue on Knowledge Organization Systems and Services. New Review of Hypermedia and Multimedia, 12(1), 3-9. Taylor & Francis.

Tudhope D., Binding C. 2005. Towards Terminology Services: experiences with a pilot web service thesaurus browser. Proceedings of the International Conference on Dublin Core and Metadata Applications, (DC 2005), 269-273. A slightly revised version selected for publication in ASIS&T *Bulletin 32(5), 6-9, 2006*.

Tudhope D. forthcoming. A tentative typology of KOS: towards a KOS of KOS? NKOS workshop presentation, ECDL 2006, Alicante.

Tudhope D., Koch T., Heery R. 2006.Terminology Services and Technology: JISC State of-the-art review.

KOS issue in NRHM 2006 - The New Review of Hypermedia and Multimedia 2006 (1). Special Issue Call for Papers on: Knowledge Organization Systems and Services. Guest Editors: Douglas Tudhope, University of Glamorgan, UK (dstudhope@glam.ac.uk), Marianne Lykke Nielsen, Royal School of Library and Information Science, Denmark (mln@db.dk).

7 Integration: intra-cluster and inter-cluster

There are links to digital library architectures and reference models work (WP1) when considering the role of federated repositories as content providers in service oriented architectures and frameworks. The synergies between wider Digital Repository (DR) developments and the Delos Reference Model (Task 8.2) and also with the supporting Standards Task in WP1 will be described in the Deliverable D1.4.0. OAIS as a Repository Reference Model has direct relevance to the Digital Preservation work in WP6.

Tasks 5.4 and 5.5 are both concerned with metadata and semantic interoperability. Both Tasks are using *GraphOnto*, the interactive ontology editor and ontology mappings tool for OWL. *GraphOnto* developed by TUC, is used in several DELOS tasks (T3.6, T3.9, T3.10, T3.11, T5.4 and T5.5) The tool has been extended to provide full ontology mappings and query mappings. It is intended that this service will be available in the Delos Digital Library System prototype.

8 Conclusions

The activities of the cluster have progressed well with two major deliverables being completed in this period.

In Task 5.1 Information Repositories and Open Archives (from JPA1), the Report Deliverable D5.1.1 *An evaluation study on the development and implementation of community repositories to support research and learning and teaching* has been completed.

Task 5.4 which focuses on e-Learning Applications and Digital Libraries has produced a substantive Deliverable Report and demonstrator (D5.4.2) *Demonstrator of mapping between the eLearning and AV content description standards.*

Task 5.5 Ontology-driven Interoperability has continued to progress the CIDOC-CRM / FRBR Harmonisation work, which has produced a core ontology and draft detailed model; mappings from CRM to Dublin Core and some preparatory modelling for the cultural heritage demonstrator. Work has progressed on the mappings and modeling for the cultural heritage demonstrator based on the English Heritage archaeology vocabularies and thesauri.

Both Tasks 5.4 and 5.5 have used the *GraphOnto* tool which has been extended further in both cases to provide ontology mapping functionality in OWL.

Dissemination activity has continued. A total of 22 published papers and invited (high-profile) international conference presentations have been produced.

Additional Workshops have been held in the broad thematic area of semantic interoperability to promote the activities of the KESI cluster more widely.

9 Partners

This section gives some general information about KESI cluster partners.

9.1 Athens University of Economics and Business

9.2 ETH, Swiss Federal Institute of Technology, Zurich (Switzerland)

http://www.ethz.ch/index_EN

9.3 FORTH, Crete (Greece)

http://www.forth.gr/

FORTH is leading the CIDOC CRM SIG development team and has initialized together with BNF the dialogue with FRBR. It has led the Harmonization of CIDOC CRM and ABC Harmony under the previous DELOS Project. FORTH is contributing to WP5, Task 3 Semantic Interoperability and WP2, Task 2. FORTH develops RDF Technology. FORTH develops advanced cultural information systems and digital library system components.

9.4 Imperial College, London

Imperial College is leading the Newton Project. In the first five years of its existence, the Newton Project has produced the first ever comprehensive catalogue of Newton's non-'scientific' papers and has placed online nearly 50 per cent of the two and a half million words he devoted to the subject of theology, as well as a large selection of his personal and scientific papers. At the beginning of 2004, a closely linked sister project in the US received funding to begin similar work on the alchemical papers. Contact person is: Dolores Iorizzo worked for many years on the *Commentaria in Aristotelem Graeca* Project at King's College, London. She has held lectureships in Philosophy and Medical Ethics at King's College, London and Imperial College, London. She has also worked extensively as a Project Coordinator for global development economics projects. Her main area of research is in the transmission of Aristotelian and Stoic philosophical and medical theories into the Early Modern period. Now she is member of the Newton Project Staff.

9.5 Ionian University

IU participates in Cluster 2 dealing with semantic interoperability and information integration - the 3 faculty and 4 PhD students have recently written (with TUC) a state of the art review (activity 2, Task 2.2) on semantic interoperability. Participates in Cluster 7 (DL Evaluation) where it deals with interaction and DL services evaluation. IU has developed and maintains Cluster 7's website (http://dlib.ionio.gr/wp7) and discussion forum (http://dlib.ionio.gr/delosforum).

9.6 MTA Sztaki DSD

MTA SZTAKI DSD: -

Participation in all of previous DELOS projects

Development of DL reference model (previous Delos NoE)

Implementation of the MetaLibrary service for DL evaluation and testbed collection. Participated in CORES EU project, operating public registry for metadata schemas.

Implementation of a national OAI-based harvester and service provider.

Participating in INFRAWEBS project for implementing a framework for Semantic Web Services

9.7 Netlab Knowledge Technologies Group, Lund University (Sweden)

Knowledge Discovery and Digital Library Research Group (KnowLib), Lund University (Sweden)

http://www.it.lth.se/knowlib/

Research focuses on networked knowledge organization. KnowLib research group continues work in automated classification and focused Web-crawling (FP6 ALVIS, http://combine.it.lth.se/), develops intelligent DL components, eg DELOS harvesting/search, and News. Active in international NKOS efforts. Integration efforts in DELOS include active participation in Cluster 5, and developing components for the DELOS Web-server.

9.8 NTNU

NTNU has experience from FRBR related projects and has current activities on the implementation of a datamodel for FRBR and the application of FRBR in a large scale library catalogue. NTNU is WP7 participant and will coordinate a proposed metadata evaluation JPA with high relevance to this project proposals.

9.9 School of Electronics and Computer Science, University of Southampton (UK)

http://www.ecs.soton.ac.uk/

9.10 School of Informatics, University of Edinburgh (UK)

http://www.inf.ed.ac.uk/

9.11 Technical University of Crete (Greece)

http://www.music.tuc.gr/Research/Projects.htm

The activities of TUC include research, development, training and technology transfer in the area of multimedia information systems. The staff's research interests include Multimedia Information Systems, Very Large Data Bases, Multimedia Communication Systems, Collaborative Environments, Information Retrieval, Human-Computer Interaction, Electronic Commerce, Tourism and Cultural Systems and Applications.

For this reason the laboratory maintains strong links with other universities, research institutes and high technology companies, all over the world, and actively participates (or has participated) in numerous EU research and development projects (IST, ESPRIT, ACTS, Leonardo Da Vinci, RACE, AIM, DELTA, LINGUA, INCO, STRIDE, SPA etc.).

A second activity is to train graduate and undergraduate students of the Technical University of Crete in advanced technology related to the area of Information Systems. Many members of TUC are also associated with the Technical University of Crete and university students have easy access to the advanced research facilities of TUC and to the experience of its personnel.

A third area of TUC activities consists of technology transfer and collaboration with leading Greek and European companies. TUC has already established strong links with the leading Greek forces in the area of communications and computer technology. These links are maintained through joint participation in EU and National (competitive) projects.

9.12 UKOLN, University of Bath (UK)

http://www.ukoln.ac.uk/

UKOLN is a centre of expertise in digital information management, providing advice and services to the library, information, education and cultural heritage communities by:

- Influencing policy and informing practice
- Promoting community-building and consensus-making by actively raising awareness
- Advancing knowledge through research and development
- Building innovative systems and services based on Web technologies
- Acting as an agent for knowledge transfer

Research activity includes work on digital curation, institutional repositories, terminologies, metadata, schemas and registries. Development activity focuses on service-oriented architectures, development of innovative software demonstrators, and advice on digital library standards and protocols. Guidance is also given in areas of policy relating to semantic interoperability, collection level descriptions, bibliographic management, accessibility and Web use.

9.13 University of Athens

The Information Systems and Data Bases Division of the Department of Informatics has broad and intense activity in most areas of information systems and data base systems involving 10 faculty members. Of particular relevance to DELOS is research in formal and methodological aspects of conceptual modeling, information integration and interoperability, faceted ontologies, term composition, model mapping, semantic similarity, sense disambiguation, concept extraction, temporal aspects of document ranking, question answering systems and NLP techniques for IR, and semantically extended web services. A DL working group has been formed by 4 faculty members of the Division. Close collaboration with FORTH. Until the beginning of 2004 Constantopoulos has led the Information Systems Lab of FORTH and its participation in DELOS 1 and in preparing for DELOS 2.

9.14 University of Glamorgan

The Hypermedia Research Unit has a track record in hypermedia and knowledge organisation systems, projects including semantic hypermedia and spatial ontologies, with three PhDs awarded in this area. The EPSRC-funded FACET project investigated the automatic expansion of faceted search queries, using the semantic relationships inherent in a thesaurus. The project was in collaboration with the J. Paul Getty Trust, who provided the Art and Architecture Thesaurus (AAT) - the primary thesaurus used in the project, and the UK National Museum of Science and Industry (NMSI). An extract of the NMSI Collections Database acted as a test-bed for the project. The EPSRC's final assessment rated the project as 'Outstanding' in Communication of Research Outputs and Cost Effectiveness ('Tending to Outstanding' overall). A case study of the project was featured in a recent thematic issue of the EC project DigiCult, a technology watch for cultural and scientific heritage.

9.15 UNIMI, University of Milan (Italy)

http://www.unimi.it/engl/

http://dakwe.dico.unimi.it/

Our research activities cross the areas of Artificial Intelligence, Database Systems, and Mobile Computing. Reasoning techniques and well-founded logical approaches are applied to data and knowledge management. A theoretical line of research investigates time related aspects in data and knowledge management. A more applicative line of research investigates the application of knowledge-based techniques to different problems in mobile computing.

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