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A Cultural Heritage Repository as Source for Learning Materials

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Abstract

We discuss a system for the digital capture of museum artefacts which are accumulated into a multimedia repository comprising 3D models, images, video and sound clips as well as textual descriptions. A comprehensive set of metadata is recorded and stored alongside these various media with the aim of re-using and re-purposing them for multiple applications. We investigate issues relating to both internal and external interoperability to enable the creation of learning scenarios within the system itself as well as the export of primary multimedia objects into an independent, external Learning Content Management System for the creation of complex Learning Objects.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism; K.3.1 [Computers and Education]: Computer Uses in Education; H.2.8 [Database Management]: Database Applications

1. Introduction

The low-cost and widespread availability of hardware and digitisation equipment, coupled with the popularity of the Web, has prompted the recent inception of numerous digitisation projects and initiatives. Of particular note are those in the cultural heritage sector, such as EnrichUK [EUK] the gateway to a lottery-funded collection of 150 websites supported by the New Opportunities Fund. Another such example is North Carolina's Exploring Cultural Heritage Online (ECHO) initiative [NCECHO]. Such projects are aimed at improving the accessibility of rare, valuable and often fragile cultural treasures while at the same time conserving the original physical objects.

However, in spite of falling hardware prices, the cost in terms of time and effort involved in creating digital surrogates of cultural artefacts remains considerable. One way in which the use of large amounts of resources can be justified is by making digitised objects available for re-use and re-purposing in multiple applications. Development of multiple repositories of digital resources opens up the exciting prospect of being able to combine objects from differing collections to create novel, themed virtual exhibitions. Another major application envisaged in the Cultural Heritage sector is that of eLearning and Education. Museums hold vast amounts of resources, which can be used to create rich and rewarding learning experiences.

It is noticeable that the majority of large-scale digitisation initiatives are based on 2D image capture, aiming to build up repositories and archives of images of artefacts [EUK]. In this paper we discuss a system capable of 3D digital capture, management and visualisation of both 2D and 3D multimedia objects. The system has a database, which is used as a multimedia repository from which digital resources may be retrieved and used as content in creating many different types of applications.

Recently, we have been investigating the re-purposing of 3D digital museum artefacts for use in virtual and augmented reality learning contexts. Evidence in the education and learning domain suggests that interaction and exploration enforces learning objectives and improves knowledge retention [Moo89, FZ93]. One of the major prerequisites to re-using resources is that of interoperability; we have tested the interoperability of our system by exporting primary multimedia objects into an independent Learning Content Management System (LCMS).

2. Background and related work

Pedagogical issues have always been at the forefront of research and practice in the education domain, whether in formal contexts: such as Higher and Further education; schools; corporate or military instruction, or in more informal settings such as through personal development via online learning, reading or visiting a museum. Advances in information and communication technologies (ICT) are set to revolutionise the way in which learning and teaching is performed. Whilst educational professionals grapple with the impact of new technologies on their profession and how best to make use of them [ITTE03], work is already underway to develop the necessary infrastructures to support and enable the integration of ICT into common teaching practice.

Educational issues have been the underlying motivation for a huge amount of research being conducted in the discipline of Computer Science. Early work focused on aspects relating to on-line learning and teaching as well as computer assisted learning (CAL) systems and included investigation of instructional models and user interfaces. More recent research has been influenced by further advances in technology and the development of a networked information environment in which learning resources are distributed. For example, progress in the field of computer graphics in terms of virtual and augmented reality has led to the investigation of immersive experiences in learning and teaching [JMC*02, ZMK03, LMW*04], whilst in the UK the Information Environment (IE) is intended to create a managed environment for accessing quality-assured information resources on the Internet [ZGJ04]. Further, the advent of networked environments has brought about the exploration of more radical models for sharing resources using peer-to-peer technologies such as in Edutella [NWQ*02].

Within the areas of digital libraries and repositories, issues relating to accessibility, re-usability and interoperability are paramount in harnessing the potential of distributed resources – whether for educational or other applications. All of these aspects are under-pinned by the development of technical and metadata standards, which facilitate search, retrieval, evaluation and sharing of information resources.

Several unrelated and independent initiatives have been involved in the development of standards, theory and models for learning materials, three of the most prominent are the IMS Global Learning Consortium (IMS) [IMS], ADL Shareable Content Object Reference Model (SCORM) [ADL] and the Dublin Core Metadata Initiative (DCMI) [DC]; it is encouraging that standardisation efforts are now beginning to merge with the IEEE Learning Object Metadata (LOM) [LOM] acting as the basis on which to simplify discovery, management and exchange of learning resources over the Web [Duv04].

Re-usability, in particular, is of relevance to the development of learning materials, which are prime targets for multiple uses in differing educational contexts. For this reason, the concept of a *Learning Object (LO)* has emerged. According to the IEEE LOM standard, a LO is "*any entity, digital or non-digital, that may be used for learning, education or training*" [LOM]. This definition, however, allows a wide variety of granularities, which makes it difficult for LOs to interoperate. Duval et. al are attempting to resolve this problem by defining a global component architecture for LOs [Duv04, VD04, DH03].

The adoption of standards allows differing eLearning systems to define their LOs, so that they can be exchanged. This is particularly important in the cultural heritage sector, where contents can be distributed on the network and represented in different formats, making them difficult to find, access, present and maintain. The SCORM and the IMS aim to describe how learning objects can be packaged making them sharable and interoperable. The SCORM is a set of specifications for developing, packaging and delivering educational and training materials. SCORM's Content Aggregation Model defines how learning objects can be identified and described, aggregated into a course - or portion of a course - and moved between systems. It uses IMS Content Packaging [IMSCP] to assemble contents and IMS Metadata [IMSMD] to tag learning resources.

The concept of developing repositories of learning materials, which can be re-purposed for varying educational contexts, is not new [ND02]. Early issues relating to this area were investigated in the 4th Framework EU RTD project, ARIADNE (Alliance of Remote Instructional Authoring and Distribution Networks in Europe) [NDT*03] while the MERLOT (Multimedia Educational Resources for Learning and Online Teaching) website [MERLOT] provides content as well as comprehensive support for teachers and educators. There are also instances of subject specific repositories beginning to appear, one such example is CGEMS, the online Computer Graphics Educational Materials Source [FEJ04]. In addition, IMS has published the IMS Digital Repositories specification [IMSDR] to help enable the exchange of LOs.

Macedonia [Mac03] provides an overview of many ways in which museums are being revitalised through the use of digital technology, including virtual and augmented reality as well as by going mobile. Heritage professionals are beginning to better understand the opportunities that the Web is capable of providing for cultural resources, and are developing collaborative projects to investigate the use of digitised and indeed "born digital" works of art in the educational arena. For instance, Bennett et al. [BSP02] describe the Digital Cultural Heritage Community project, which aimed to develop an online database of digitised materials from museums and libraries for use by elementary school teachers.

3. Digitisation to visualisation

The ARCO (Augmented Representation of Cultural Objects) [ARCO] system is designed to provide museums with a set of tools and services to enable them to digitize, manage and present small to medium artefacts in virtual museum exhibitions. These requirements have defined the specification of the system architecture, which is illustrated in Figure 1. At a conceptual level, it comprises, content production, management and visualization.

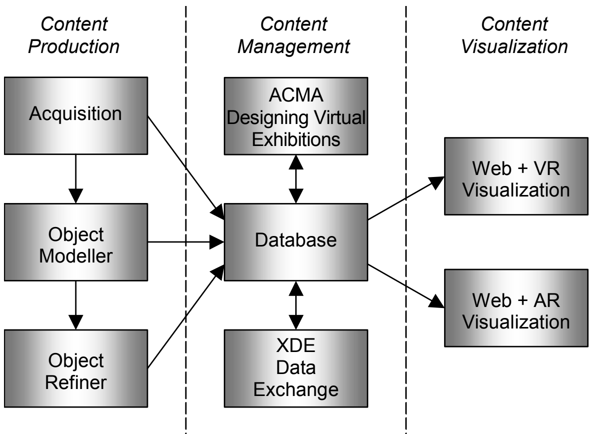

Figure 1: *ARCO system architecture*

3.1 Architecture

For the content production process ARCO provides its own solution composed of the Object Modeller (OM) used to capture and digitise museum artefacts and the Object Refiner (OR) based on the industry de-facto standard 3ds max 3D authoring tool [PWW*03]. The OM component is a 3D stereo photogrammetry based hardware and software system designed and implemented based on the principles of Image-based Modelling. The OR tool implements a simple artefact creation interface and a more complex interface for refining OM-generated virtual artefacts. Note that content production also includes acquiring other multimedia data such as images, movies, etc. for input to the content management process. Further, the system is compatible with the many other solutions available to a museum for digitisation and digital artefact creation ranging form using any number of 3D authoring packages to laser scanning and photogrammetry methods incorporating texture extraction.

Content management is achieved through a multimedia database management system based on Oracle 9i and the ARCO Content Management Application (ACMA). The database lies at the heart of the ARCO system in that it stores, manages and organises digital artefacts into collections for display in virtual museum exhibitions.

The final part of the ARCO architecture is the content visualization process. The end user is able to browse content stored in the ARCO repository either remotely over the Web, locally in a museum kiosk, or to interact with the virtual objects in an AR table-top environment [WWW*04].

3.2 Data model

The ARCO system is based on the data model illustrated in Figure 2. The model consists of several related entities. We define a class Cultural Object (CO) as an abstract representation of a physical artefact. There are two non-abstract entities, which are subclasses of the CO: the Acquired Object (AO) and the Refined Object (RO). The AO is a digitisation of the physical artefact used in the ARCO system whilst the RO is a refinement of an AO or another RO. There may be multiple RO created from a single AO or RO.

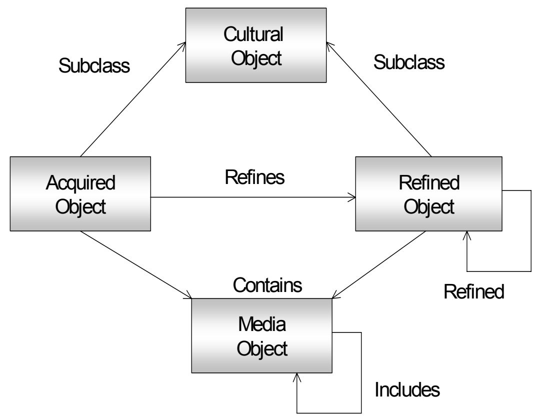

Figure 2: *ARCO data model*

A CO (i.e. AO or RO) may be composed of one or more Media Objects (MO). The MOs are representations of the CO in a particular medium represented by some MIME type. Examples of MOs are 3D Model, Simple Image, Panoramic Image, and Description—each with differing MIME types. A RO inherits MOs from the CO it refines, and may add new ones. For example, a museum curator may create an RO from an AO by adding a 3D Model or Description.

There are two main categories of MOs: simple and composite. Simple Media Objects correspond to media that can be represented in one data object—such as Description and Simple Image. Simple Media Objects contain the object data directly. Composite Media Objects do not contain the data directly, but instead are associated with a number of other MOs (either simple or composite). Composite Media Objects represent data objects with complex structure such as a VRML Model, Multi-resolution Image or Panoramic Image. The MOs that are children of a composite Media Object may have additional attributes that result from the parent-child MO relationship.

4. Interoperability issues

Issues relating to interoperability are crucial in the development of systems that aim to share data and information with other independent and heterogeneous systems. We identify two broad types of interoperability: syntactic interoperability and semantic interoperability. Syntactic interoperability is the technical ability of data from multiple and previously unknown or unplanned sources, to work together when combined. Semantic interoperability in addition involves the consistent use of metadata vocabularies and classifications to enable meaningful and seamless integration of information from independent systems.

Our aim in the ARCO system is to facilitate re-use of digitised museum artefacts in a variety of applications; we therefore do not specifically address the use of educational vocabularies for semantic interoperability, but rather concentrate on syntactic interoperability for information exchange.

4.1 Internal and external interoperability

A key element of the ARCO system is the use of XML technologies to enable interoperability between ARCO components and external systems and applications. For this purpose we have implemented an XML schema called the XML Data Exchange (XDE) format. An XDE instance is composed of: a multimedia data archive containing cultural objects, media objects, metadata and presentation information; and an XML file that defines how the archive is structured. The structure could for example be as simple as a single cultural object data or a more complex virtual museum exhibition.

Extensive use of XML enables close integration of all ARCO components into a coherent suite, at the same time providing communication mechanisms that make the ARCO system both internally and externally open. This means that it is possible to replace any of the system components with a new version or even a new tool as long as the same XML interface is provided. Also, it is possible to exchange data with external systems and applications.

In addition to the use of XML to provide syntactic interoperability, openness and external interoperability are enhanced by the use of standards, especially in the heterogeneous environment of the Web. ARCO makes use of several different standards: Internet (HTML, HTTP); 3D graphics (VRML/X3D); W3C Recommendations (XML, XML Schemas) and metadata standards and best practice (Dublin Core [DC], SPECTRUM [SPEC]).

4.2 Best practice in the cultural heritage sector

Cultural Heritage institutions such as museums have amassed a huge range of valuable experience in the management of heritage resources. We have taken the view that ARCO should draw on, incorporate and build on extant museum best practice as far as possible in order to maintain compatibility (and interoperability) with existing museum systems.

A number of organisations and initiatives have attempted to address the wide-ranging requirements of the cultural heritage sector. Amongst these, some of the most notable are: the Consortium for the Computer Interchange of Museum Information (CIMI); the mda (formerly the Museum Documentation Association); the Art Museum Image Consortium (AMICO); the International Committee for Documentation (CIDOC), the European Museum's Information Institute (EMII), the Research Libraries Group (RLG) and the Visual Resources Association (VRA).

One of the most important standards in this area is SPECTRUM [SPEC], which is co-ordinated by the mda. SPECTRUM comprises procedures for documenting objects and the processes that they undergo. It also identifies and describes the information that needs to be maintained to support those procedures. The intention is that the standard should contain all those functions that are common to most museums. A particular institution would then choose and use those procedures that are most relevant to its own requirements. The advantage of adhering to SPECTRUM is that data exchange between heritage organisations becomes much easier.

Although the Dublin Core Metadata Initiative (DCMI) does not deal specifically with museum archives, the Dublin Core Metadata Element Set (DCMES) [DC] is pertinent for resource discovery across domains and hence of great relevance to any system proposing information retrieval over the Internet. It is becoming of increasing importance to issues of interoperability and information exchange [OAIP].

4.3 Learning Objects

As explained earlier in section 2, a LO is any digital resource that can be used to support learning objectives. They are designed and created in small chunks for the purpose of maximizing the number of learning situations in which LOs can be utilized. LOs therefore provide the salient focus of attention in creating re-usable learning materials.

A major issue is that authoring, deployment and re-purposing are significantly affected by the granularity of LOs so that there is in effect a trade-off such that smaller LOs are more easily re-usable, but the added-value they provide is lower, whilst larger LOs are less easily re-usable, but their added-value is higher.

To maximize the versatility of multimedia objects in the ARCO system, they do not have any added-value in terms of educational contexts or educational metadata. They are primary resources which may be assembled into LOs and correspond with the LTSC notion of "assets", which are self-contained media objects.

As opposed to the media objects, cultural objects and their collections, such as virtual exhibitions, provide apparent added-value in the educational context. Such an approach offers maximum flexibility allowing selection of data at differing levels of abstraction and complexity.

5. ARCO repository of cultural artefacts

The use of repositories for the accumulation of electronic resources is currently an active area of research [IMSDR, OAIP, LeFu02]. Although their purposes and target audiences may differ, there are overlaps in the functionalities provided by Content Management Systems, LCMSs and generic repositories. These include the provision of facilities for: search and retrieval of content; import and export of content; version management and archiving or preservation of content.

5.1 Types of multimedia objects

The ARCO system is capable of handing a wide variety of media objects categorised into different types (Media Object Types). Several media object types are preconfigured with the system. These include: Simple Image, Image Collection, Panorama Image, Multi-resolution Image, Description, Sound, VRML/X3D 3D Model, QuickTime VR, and 3ds max Project.

Our system is based on a meta-schema design. This means that instead of keeping fixed data structures, the system stores dictionaries of supported data types and their properties as dictionaries in the database. The dictionaries can be modified and extended using ARCO administrative tools. As a result, new types of media objects can be easily added to the system when their use becomes necessary.

5.2 Metadata

Metadata is defined as "structured data about data". It can also be considered as information or data about resources and plays a critical role in the effective management of both physical and digital objects. Its purposes are numerous and include: description, management, resource discovery, preservation, curation and rights management of information objects.

Metadata has always been a major aspect of describing and managing museum holdings and collections; it continues to play a key role in digital asset management systems such as ARCO. However, a networked information environment requires additional considerations. Resources will only be re-used if they can be easily found, evaluated and adopted. In order to facilitate this process of resource description, discovery and evaluation, it is crucial that media objects are appropriately described, classified and indexed using standard metadata elements and controlled vocabularies.

Metadata and user requirements reviews [LP02] revealed that no single existing metadata element set was suitable for the range of processes envisaged in the ARCO system. It was also found that the cataloguing systems of many museums (including one of our two pilot sites) are based on SPECTRUM.

Consequently, the ARCO Metadata Element Set (AMS) [PWM*04], draws on two main standard vocabularies, that of DCMES and SPECTRUM, using the concept of *application profiles* [HePa00]. An application profile is a metadata schema that draws on existing metadata element sets, adapting and customising specific elements for a particular local application. A full specification of the AMS can be found on the ARCO website [AMS], however, briefly it comprises the following types of metadata: descriptive curatorial; technical; resource discovery; presentation; thematically grouped and administrative. AMS metadata are associated with the main elements of the ARCO data model: CO, AO, RO and MO (see Figure 2).

5.3 Managing repository contents

All persistent data in the ARCO system including the digital representations of cultural artefacts, associated MOs and metadata are stored in a database implemented on top of Oracle 9i ORDBMS. Museum staff can import, export and manipulate the data stored in the database in a user-friendly way by the use of the ACMA – ARCO Content Management Application (Figure 3). The ACMA tool is composed of several specific data managers with the most important being:

- Cultural Object Manager – for managing all data related to digital representations of cultural objects,
- Presentation Manager – for managing virtual exhibitions,
- Template Manager – for managing visualization templates, and
- Template Object Manager – for managing all multimedia data used in virtual exhibitions but not related to cultural objects.

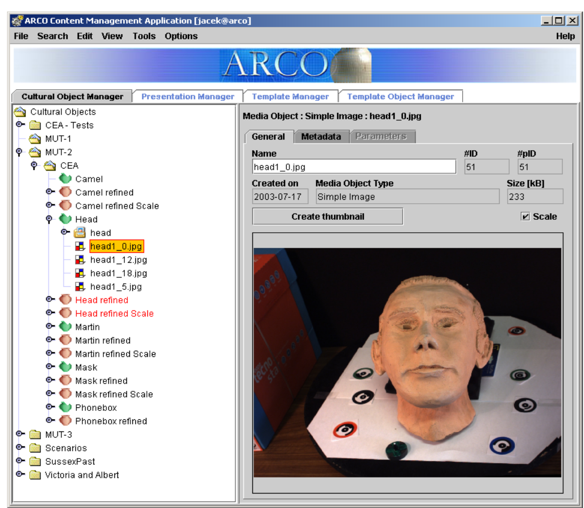

Figure 3: *ARCO Content Management Application*

The separation of content from presentation information is a significant design decision in enhancing the potential for COs to be useful in a variety of applications and environments.

6. Learning through interaction and exploration

The ARCO system enables presentation of museum artefacts in an attractive manner that can make visitors, especially children, more interested in cultural heritage. ARCO enables several ways of visualizing the cultural object data stored in the repository. These include multimedia presentations available on museum websites (both 2D and 3D), local interactive kiosk systems installed in museums, and advanced tabletop augmented reality environments.

In the example shown in Figure 4, 3D models of cultural objects are presented in a 3D virtual gallery being a reconstruction of one of the exhibition spaces in Victoria and Albert Museum in London. This form of presentation can be used both remotely over the Internet as well as in local interactive kiosk systems installed in museums. Visitors can gain information while travelling through a collection of 3D spaces and interacting with the objects encountered.

In Figure 5, a hybrid 3D/2D gallery is demonstrated. A user can navigate through 3D spaces displayed in the upper part of the window and interact with the 3D models of artefacts.

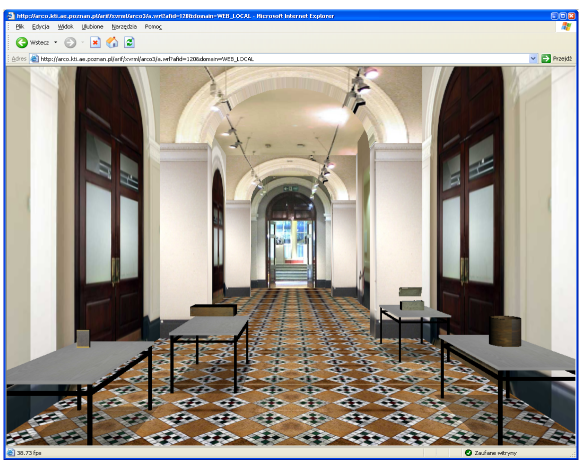

Figure 4: *Visiting 3D reconstructed museum galleries*

When a user selects a model, the descriptive information about the object is retrieved from the object's metadata and displayed in the lower 2D part of the window. Virtual exhibitions such as demonstrated in Figure 5 can be either preconfigured by curatorial staff of a museum or dynamically generated by the end-user (e.g. as a result of a query execution).

Figure 5: *Interactive virtual gallery*

ARCO further enables museums to build interactive learning scenarios based on augmented reality technology (Figure 6). On a computer screen users can observe mixed scenes composed of live video presenting a real space and virtual objects superimposed on the video. The virtual objects are aligned to special physical markers, which can be manipulated by a user. Such scenarios require only little extra equipment – a web camera and a set of printed markers – and provide very interesting and intuitive way of presenting objects.

In the example presented in Figure 6, a 3D model of an object and a question are displayed on one of the markers. Three possible answers are assigned to three other markers (see the bottom of Figure 6). The user can examine the model from different angles (the model is automatically rotated) and answer the question by turning over one of the answer markers. Depending on whether the answer is correct or not, an appropriate response appears in the AR scene. Also, a sound expressing approval or disapproval can be heard. There can be a number of questions associated with an object and a number of objects presented in the interactive quiz. The AR visualization can be supplemented with 2D and 3D Web-based presentations [WWW*04].

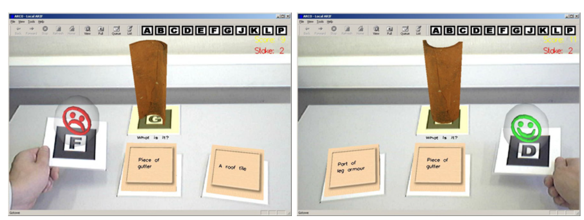

Figure 6: *Interactive game based on AR technology*

7. ARCO interoperability with learning content management systems

Whilst it is important that archives and repositories be as open as possible, it is also important that LCMSs be capable of handling as well as importing and exporting a wide variety of digital materials.

7.1. Overview of Learn eXact System

Learn eXact (Figure 7) [LE] is a second-generation e-learning suite based on XML, LOs and IMS/SCORM content specifications. It offers LCMS, digital repository and Learning Management System (LMS) modules, which may also interoperate with pre-existing modules.

While the delivery and tracking model is based on SCORM 1.2, content authoring is also capable of multi-standard and multi-device compliant deliveries. The LMS also supports competency management, mobile delivery and knowledge management features.

Learn eXact is basically composed of three modules: a content authoring tool (the eXact Packager), a LMS (the eXact Siter) and a digital repository (the eXact Lobster – Learning Object Storage Repository).

The system supports importing, indexing, assembly and packaging of any external Web content (such as images, videos, HTML, VRML and animations). Content created within Learn eXact can be stored in XML format and rendered automatically for different devices.

7.2. Interoperability between ARCO and Learn eXact

In order to be able to exploit the ARCO multimedia repository of digitised cultural artefacts to build re-usable cultural LOs, the ARCO system has been integrated with Learn eXact. Interoperability between ARCO and Learn eXact enables both cultural resources and related metadata to be imported from the ARCO repository to Learn eXact for use in the creation of complex LOs.

In addition, since a LO can be seen as an aggregation of different tagged resources, these component resources can be exported from Learn eXact into ARCO for storage in the digital repository.

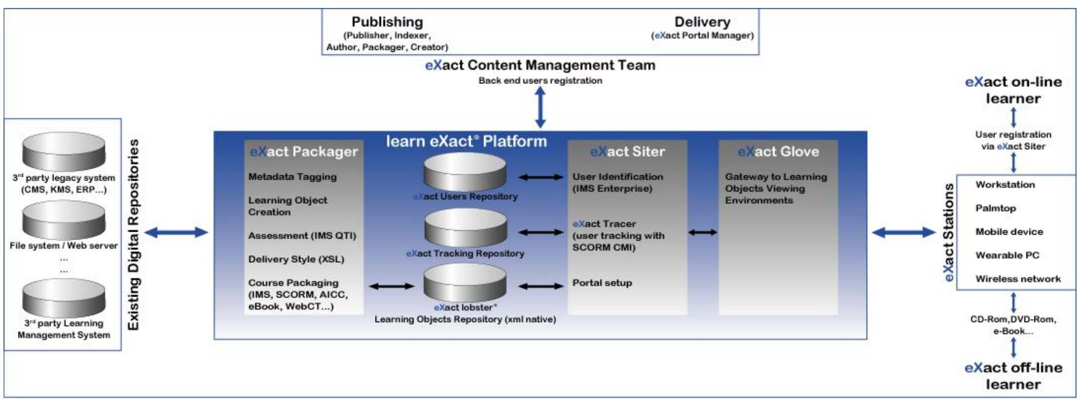

Figure 7: *Learn eXact architecture*

Integration between the two systems, as shown in Figure 8, exploits the XDE interoperability format implemented in ARCO (see section 4.1). The XDE is based on XML, its structure being specified as an XML Schema. The structure of XDE is influenced by the structure of the ARCO database because it is used to carry the same type of data. However, it also contains specific elements that are used only in XDE, and the overall file organization is optimised for data exchange rather than for data storage.

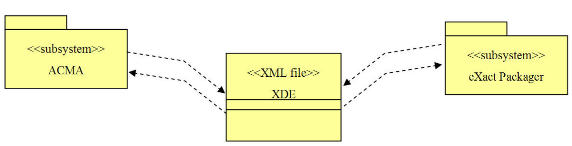

Figure 8: *Data exchange between ARCO and Learn eXact*

As depicted in Figure 8, communication between the two systems is implemented between ACMA and the eXact Packager. Using ACMA one can export a cultural object or a collection of cultural objects into the XDE format. When cultural data are imported from the XDE, the eXact Packager parses the XML file searching for references to the archive of physical multimedia files (images, videos, animations, VRML etc.) and the metadata associated with each resource. Extracted ARCO metadata, initially organised according to the AMS, are mapped to IMS Metadata 1.2, which is the specification proposed by IMS and based on the IEEE LTSC LOM [LOM] standard used for the description of LOs and their application. Figure 9 shows one step of the data exchange between ARCO and Learn eXact: acquired resources (media objects and metadata) are imported into the learning platform.

When data are exported from eXact Packager to ACMA, a user can choose to export a single resource or the IMS CP, which contains the cultural LO. Figure 10 illustrates how data are mapped to the XDE format in both cases.

The mapping of the single resource and CP to the XDE format follows some specific rules: when the user exports a single resource, the eXact Packager generates an XDE file containing a single CO composed of a single MO. The MO points to the exported resources while the IMS Meta-data of the resource are mapped back to AMS and associated with the CO.

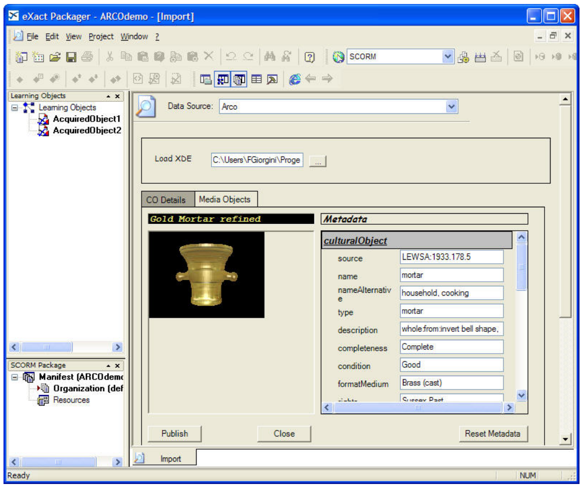

Figure 9: *Data import from ARCO to Learn eXact*

Mapping of a CP to XDE is more complex since the CP contains a list of objects and their metadata (highlighted in green in Figure 10) and is tagged with specific metadata (blue). The generated XDE file consists of a single CO tagged with the metadata of the CP (mapped to AMS). The CO is made up of several MOs, one for each resource in the CP. Finally, the IMS metadata of the resources in the CP are mapped to the AMS and linked to the related MO.

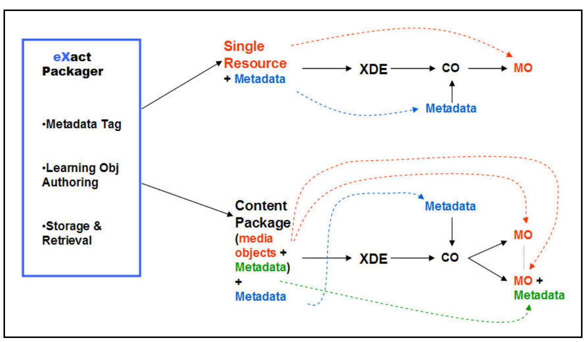

Figure 10: *Data export from Learn eXact to ARCO*

8. Conclusions and further work

We have demonstrated that by maintaining a repository of primary multimedia cultural objects and making them easily accessible, it is possible to support two differing types of instructional models. Basic facilities within the ARCO system allow museum professionals to create effective learning scenarios for edutainment purposes –a semi-formal way of learning which is particularly appealing to children and the younger generation of museum visitors.

In addition, multimedia objects may be exported to external LCMSs for use in more formal teaching courses or the creation of more complex LOs which can be used in a variety of Virtual and Distributed Learning Environments. The major advantage of being able to export primary resources into the Learn eXact system is that they can be transformed into LOs by the addition of appropriate metadata, thereby making them available for adoption in any eLearning sytem that supports LOs.

Repositories such as the one developed in ARCO, are instrumental in making vast amounts of digital cultural heritage resources readily available online for 24/7 global access –in contrast, most museums do not have the space to display all their physical holdings simultaneously or permanently. We envisage that such repositories will play an important role as data-providers in an open access model such as that enabled by the Open Archive Initiative's Metadata Harvesting Protocol [OAIP], providing open access to digitised resources.

We have found that the quality and quantity of resource discovery and technical metadata are crucial in the re-use and re-purposing of primary multimedia objects. Of course, the digitised quality of primary resources is also a major issue when creating them for multiple purposes (curators prefer valuable, and often fragile artefacts to undergo the digitisation process only once). In addition, digital rights management and copyright are equally pertinent aspects, which will determine the extent of sharing and re-use of primary resources.

The ARCO system has undergone several iterations of assessment and evaluation during its development. It is currently under-going field trials at the Victoria and Albert Museum in London and the Sussex Archaeological Society in Sussex, UK.

Acknowledgements

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