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ARCO—An Architecture for Digitization, Management and Presentation of Virtual Exhibitions

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Abstract

A complete tool chain starting with stereo photogrammetry based digitization of artifacts, their refinement, collection and management with other multimedia data, and visualization using virtual and augmented reality is presented. Our system provides a one-stop-solution for museums to create, manage and present both content and context for virtual exhibitions. Interoperability and standards are also key features of our system allowing both small and large museums to select components and build a bespoke system suited to their needs. For example, museums can build a tool set focused on the whole solution or just the visualization.

1. Introduction

In recent years Virtual Reality (VR) and Augmented Reality (AR) have emerged as areas of extreme interest; the cost of building suitable VR and AR applications has fallen considerably, thus fuelling this interest. For example, in terms of simple hardware (a relatively low cost PC with cheap graphics accelerator, a touch screen and a simple interaction device, e.g. a Magellan SpaceMouse®.), some application software, and suitable browser plug-ins, one can build quite cheaply, a highly interactive VR and AR experience for a museum visitor. Such a low cost system has enormous benefits for the end-user in learning about their local heritage in an interesting way. These benefits are now being recognized by the museum community. Museum artifacts can be digitized and set into a virtual interactive context that provides a much more rewarding experience than perhaps seeing an artifact in a museum glass case with a simple description on a card.

Such virtual environments can offer much more than many current museum web sites offer, i.e. a catalogue of pictures and text in a web browser. Virtual Reality interfaces, interaction techniques and devices are developing at a rapid pace [1] and offer many advantages over traditional windows style interfaces. For example, many devices are now available that can be integrated into multi-modal virtual and augmented reality interactive interfaces [2]. Devices such as a simple Magellan SpaceMouse®. can be configured to eliminate the keyboard and standard mouse and can be intuitively coupled to the visualization screen such that touching and moving the mouse causes the user to navigate the virtual environment, sensors can be integrated within replica objects and can be used to control a story through a virtual environment. These sorts of interaction with AR offer many advantages for the disabled [3].

A major benefit of an AR based interface is that carefully designed applications can themselves provide

novel and intuitive interaction without the need for expensive input devices. Participants in AR learning environments can interact in a natural way that cannot be obtained in a virtual environment.

On the other hand a combined AR and VR application can offer other advantages to the participant, e.g. through a VRML browser the participant can examine cultural objects in the context of other multimedia data on a web page and then switch to an AR environment to examine the object more closely through tactile manipulation of fudicials or markers in the physical world [4].

Research into applications of AR and VR is widespread, and there are still many technological problems to be solved [5]. However, the potential benefits are well documented [6]. The most important issues concerning the effectiveness of a VR and AR system is the quality of the visualization and level of interaction such that they are sufficient to reinforce the learning process. It is important that a VR or AR application scenario does not just present virtual objects and descriptions; they must be set in a story that reinforces the learning. Museums are one of the best places to exploit VR and AR applications [7] because they offer challenging research opportunities, while providing novel ways to present regional or national heritage, as well as offering new consultation methods for archaeological or cultural sites and museums [8].

2. Related Work

The concept of using virtual exhibitions in museums has been around for many years. Museums are keen on presenting their collections in a more appealing and exciting manner, such as virtual exhibitions, to attract visitors both virtually and into the physical museum site. Recent surveys show that about 35% of museums have already started developments with some form of 3D presentation of objects [9].

Requirements related to the development of AR applications in the Cultural Heritage field have been well documented [8]. Many museum applications based on VRML have been developed for the web [4][10][11]. An example of an interactive virtual exhibition is the Meta-Museum visualized guide system based on AR, which provides a communication environment between the real world and cyberspace [7]. Another simple museum AR system is the automated tour guide, which superimposes audio on the world based on the location of the user [12].

The European Union has also funded many research projects in the field of cultural heritage and archaeology. For example, the SHAPE project [13] applies AR to the field of archaeology to educate visitors about the artifacts and their history. The 3DMURALE project [14] is developing and using 3D multimedia tools to record, reconstruct, encode and visualize archaeological ruins in VR using as a test case the ancient city of Sagalassos in Turkey. In the Ename 974 project [15] visitors can enter a specially designed on-site kiosk where real-time video images and architectural reconstructions are superimposed, and visitors can control the video camera and display images using a touch screen.

The ARCHEOGUIDE project [16] provides an interactive AR guide for the visualization of outdoor archaeological sites. Similar to ARCHEOGUIDE in terms of applied technology is the LIFEPLUS project. A fundamental difference between these projects is that LIFEPLUS additionally encompasses real-time 3D simulations of ancient fauna and flora [17].

The main advantage of the ARCO system over the projects described above are that ARCO offers a complete museum focused solution that can be configured for museum needs—we can build bespoke museum systems from interoperable ARCO components. But more importantly, ARCO offers methods for digitization, management and presentation of heritage artifacts in virtual exhibitions based on well understood metaphors that are also interactive and appealing [18].

3. ARCO System Overview

This section discusses the architectural components of ARCO that make up the whole tool chain.

3.1. ARCO Architecture

The ARCO system is designed to provide museums with a set of tools that allow them to digitize, manage and present artifacts in virtual exhibitions. These requirements define the specification of the system architecture, which is illustrated in Figure 1.

For the content production process ARCO provides two distinct tools for 3D modelling of museum artifacts: the Object Modeller (OM) and the Model Refiner (MR). The OM tool is a 3D stereo photogrammetry based hardware and software system designed and implemented based on the principles of Image-based Modelling. The MR tool is a 3D reconstruction refinement tool based on the *3ds max* framework that complements the functionality of the OM tool. More details about the OM and MR functionality are discussed in Section 4. Note that content production also includes acquiring other

multimedia data such as images, movies, etc. for input to the content management process.
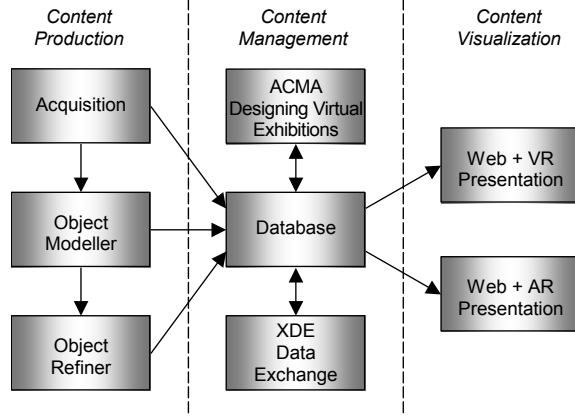

Figure 1: ARCO System Architecture

For the content management process ARCO provides a multimedia database management system based on Oracle9i and the ARCO content Management Application (ACMA). The database is the central component of the ARCO system in that it stores, manages and organises virtual artifacts into collections for display in virtual exhibitions. The database organisation and ACMA are discussed in more detail in Section 5.

The final part of the ARCO architecture is the content visualization process. The visualization of the digital representations of museum artifacts is performed by VR and AR interfaces. The interfaces combine Web-based form of presentation with either VR or AR virtual exhibitions.

The end user is able to browse content stored in the database either remotely through the web, in a museum kiosk, or to interact with the virtual objects in an AR table-top environment. A more detailed discussion of the end user interfaces is presented in Sections 5 and 6.

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 artifact in the ARCO system. 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 artifact used in the ARCO system;
- The RO is a refinement of an AO or another RO. There may be more than one RO created from a single AO or RO.
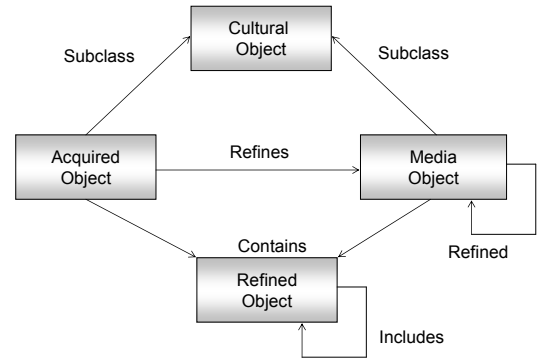

Figure 2: ARCO Data Model

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.

3.3. Metadata

A key element of the ARCO system is the specification of an appropriate metadata element set that underpins both the heritage and technical aspects of ARCO. We need both to describe museum artifacts and the technical processes that transform the artifacts from the physical to the virtual.

Accordingly, we have designed a metadata element set called AMS [19], which stands for ARCO Metadata Schema. AMS describes the cultural artifacts, their digital surrogates, and specific data for creating virtual exhibitions. AMS has to be able to satisfy the following metadata requirements. First, it should be able to describe the ARCO data model. Second, it should be able to satisfy all ARCO user groups' requirements, which are: the possibility to edit, view

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and search according to metadata terms. Third, it should be based on international standards so as to increase its potential for information mappings and interoperability. Fourth, it should incorporate museums' best practice to be compatible with current applications. Finally, it should include the following five types of metadata:

1. **Administrative**: to keep track of the creation and any modifications of a metadata record.

2. **Curatorial**: to record descriptive curatorial knowledge for the cultural artifact.

3. **Technical**: to record various technical parameters.

4. **Resource discovery**: to enhance the potential of cross-domain discovery of ARCO by search engines.

5. **Use**: to allow for a specific use of the resources.

3.4. XML Data Exchange format

Another key element of the ARCO project is the use of XML technologies to enable data interoperability between the components of the ARCO system and between the ARCO system and external systems and applications. For this purpose we have implemented an XML schema called the XML Data Exchange (XDE) format [20]. Extensive use of XML [21] enables close integration of all ARCO tools into a coherent suite, at the same time providing communication mechanisms that make the ARCO system both internally and externally open.

The use of XML as a communication medium makes the ARCO system internally 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. The system will be adaptable to changing user requirements and environments, and it will be possible to gradually upgrade the system to use state-of-the-art software and new ARCO components. Examples of new components of interest for the museums are image processing tools, other 3D object modelling tools, other model refinement packages, rendering applications, and XML editing software. The XDE file contains cultural object, media objects, metadata and presentation information.

4. Digitizing Museum Artifacts

The purpose of the OM component is the digitization of cultural objects using image-processing techniques. A textured 3D mesh is inferred from images of the artifacts. The OM contains both hardware (for acquisition) and software (for 3D model generation).

The MR can be used in two modes: either directly to produce manually 3D models of artifacts or as a refinement tool to refine 3D models generated by the ARCO OM. In this context the MR contains two main interfaces with different functionality associated with each interface. The ARCO system can accept 3D models from almost any graphics format because the MR is based on 3ds max.

4.1. Object Modeller

The OM automatically generates a textured 3D model from stereoscopic images. The automation of the modelling task is made possible by using a dedicated image acquisition system (calibrated stereo rig and LCD projector). The image acquisition is initially controlled by the user. Then, the user launches the automatic reconstruction process, which results in an initial 3D mesh. This model is displayed and the operator is able to complete it by local modifications of the mesh, through basic tools (supression of vertex/face, smoothing etc.,). The OM focuses on two key areas of interest:

- Development and integration of a full reconstruction process based on projection of structured light. The projection is managed by the acquisition PC linked to a standard LCD projector.
- Increase the automation of the 3D mesh merging process.

Final accurate refinement of the 3D mesh is performed in the downstream MR tool. The main functionalities exhibited by the OM are:

- Image acquisition of the artifact;
- Reconstruction of a 3D mesh from stereoscopic pairs of images;
- Texture extraction;
- Merge of 3D meshes;
- Data exchange between the OM and the ARCO database.

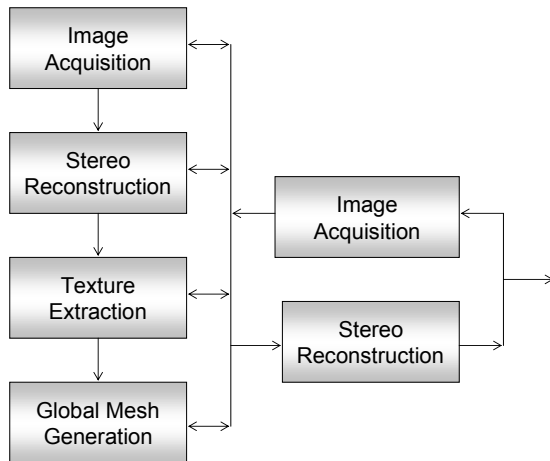The components of the OM are described in Figure 3.

Figure 3: Object Modeller Architecture

The image acquisition process is based on image analysis and is optimised to make the 3D modelling as automatic as possible. As the reconstruction is based on stereo image processing, the acquisition is performed by a stereo rig, including two digital cameras. The cameras are connected to a PC (via IEEE1394 link) where images are captured and saved on a local disk. The basic output of the acquisition system is two stereoscopic images.

The stereo reconstruction process uses the projection of light patterns onto the artifacts. Several patterns are successively projected using an LCD projector connected to a laptop computer. During the projection sequence, image acquisition is synchronized by the OM software. A 3D mesh is generated automatically from the acquired images. Users can refine the result by suppressing some inconsistent vertices or faces in the mesh. The output is a consistent 3D mesh, which may be refined using the Model Refiner tool.

An automatic tool for texture extraction from images is provided. This process is done simultaneously to the stereo reconstruction described above. Texture mapping requires the input of both captured images and the 3D mesh to generate a textured 3D polygon mesh of the digitised artifact.

The global mesh generation or complete 3D model is created from several stereo reconstructions to cover the whole surface of the object. View registration and the mesh merging tool compose this step. View registration consists of positioning in the same frame all the meshes, given by stereo reconstruction. Then, all the meshes are merged into the final model. The final mesh requires several refinement steps provided by the MR tool. Figure 4 illustrates a 3D model digitized by the OM tool.

Figure 4: 3D model digitized by the Object Modeller

4.2. Model Refinement

The MR tool is based on 3ds max and provides both a framework for the museum user to create models of simple artifacts, and a polygon workbench used to refine the output of the OM.   Typical operations required for refining OM output are:

- Remove mesh: provide a means of removing overlapping faces, edges and points
- Weld mesh: zipping to joining meshes together
- Cap holes: provide a means of filling 'holes' in the object
- Re-map textures: provide a means of re-mapping textures at the sub-object level, i.e. faces
- Clean: remove erroneous surfaces (also implemented in the OM tool)
- Optimise: decimate meshes, i.e. reduce polygon count
- Smooth: controllable smoothing of areas, which involve tessalation and displacement of vertices
- Tessalate: subdivide selected polygon areas or sub meshes
- Re-mesh: to give a better overall smoothing process
Figure 5 illustrates the OM model after some refinement in the MR tool.

Figure 5: Example refinement operation—Cap Holes

Other features provided by the MR include:
- XML import and export from/to the XDE format;
- Database connectivity.

Digitization and creation of 3D models are only a part of the process of creating digital surrogates of museum artifacts. Other multimedia data are also created, such as images, image sequences (QuickTime VR or movie files), audio files, etc.

5. Managing the Cultural Object Database

All persistent data in the ARCO system including the virtual representations of cultural artifacts, associated MOs and metadata are stored in a database implemented on top of Oracle 9i ORDBMS. The database design represents a meta-schema approach – data entities stored in the database do not have attributes fixed by the database schema. Instead, dictionaries of object types and attributes for specific types are stored in the database as data. Also, metadata attributes are stored in the database as XML documents conformant to easily extensible AMS. This approach enables adding or modifying types of data supported by the system without the need to modify the database schema.

Museum staff can import, export and manipulate the data stored in the database in a user-friendly way by the use of the ACMA (Figure 6). The ACMA tool is composed of several data managers with the most important being:
- Cultural Object Manager – for managing all data related to virtual representations of Cultural Objects,
- Presentation Manager – for managing virtual exhibitions,

- Template Manager – for managing X-VRML visualization templates, and
- Template Object Manager – for managing all multimedia data used in virtual exhibitions but not related to Cultural Objects.
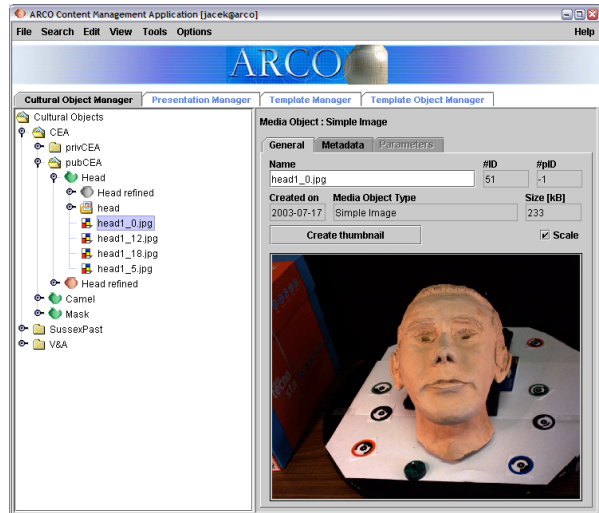

Figure 6: ARCO Content Management Application

6. Creating Virtual Exhibitions

Digital representations of cultural objects can be presented in virtual exhibitions. Virtual exhibitions are designed by the use of the ACMA Presentation Manager. The structure of the exhibitions is defined by the structure of *exhibition spaces*. Each exhibition space may represent an entire exhibition, a part of the exhibition related to a particular subject, a museum room, etc. Subspaces may be used to divide exhibitions into smaller parts, e.g., focused on a particular topic. The exhibition spaces consist of folders containing two types of elements:
- Cultural Objects and
- X-VRML template instances.

The contents of exhibitions displayed in the end-user interfaces are created dynamically based on X-VRML visualization templates [22][23]. The templates are used to generate both the 2D HTML and 3D VRML/X3D contents. Since the templates are parameterized, different visualizations of the same content can be generated from a single template when supplied with different parameter values. The parameter values are either preset by an exhibition designer or provided dynamically by an end-user.

In the ARCO system, the same exhibition may be visualized differently for use in different environments. To achieve maximum flexibility with respect to different visualization methods, the concept of

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presentation domains was introduced. A presentation domain is the environment in which the presentation interface is used. The current ARCO prototype addresses three main domains: *WEB_LOCAL* for use on local web-based displays inside museums, *WEB_REMOTE* for use on the Internet, and *WEB_AR* for use in AR presentations. The list of presentation domains is extensible allowing museums to further differentiate visualization in different contexts when necessary.

The ARCO system provides two main kinds of user interfaces for browsing cultural heritage exhibitions: *Web-based interfaces* and *Augmented Reality interfaces*. Both user interfaces work in a client-server architecture as shown in Figure 7.
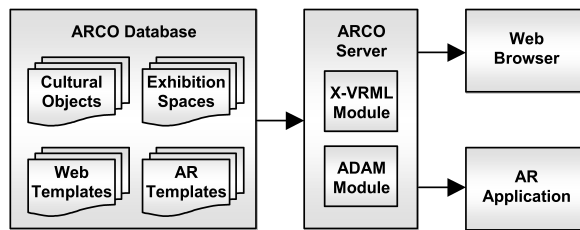

Figure 7: Visualization architecture

The ARCO Server dynamically generates contents for visualizations of exhibition spaces in different presentation domains based on appropriate X-VRML templates. Different sets of templates are used for the Web-based interface and for the AR interface.

The server consists of the X-VRML Module and the ADAM (ARCO Data Access Module) subcomponents communicating with the ARCO Database. The X-VRML Module processes visualization templates and generates output in either VRML/X3D or HTML. The ADAM module is responsible for delivering multimedia objects retrieved from the database.

In the Web-based interface a user can browse information presented in a form of 3D VRML virtual galleries or 2D Web pages with embedded multimedia objects. The Web-based interface requires a standard Web browser such as Internet Explorer with a VRML plug-in (e.g., ParallelGraphics Cortona). This kind of user interface can be used both on local displays inside a museum (*WEB_LOCAL* presentation domain) and remotely on the Internet (*WEB_REMOTE* presentation domain).

To enable visualization of selected objects in an AR environment a special application, called AR Application, has been developed. The AR Application is used instead of a typical Web browser used in the Web-based interfaces. The AR Application apart from displaying standard Web contents is able to visualize virtual scenes in an AR environment (*WEB_AR*

presentation domain). The application integrates two components: a Web browser and an AR browser. For the AR visualization a camera and a set of physical markers placed in a real environment is used. Video captured by the camera is passed on to the AR browser that overlays virtual representations of Cultural Objects using the markers for object positioning [24].

6.1. Virtual Reality Exhibitions

An example interface enabling visualization of virtual exhibitions in a Web browser is presented in Figure 8.
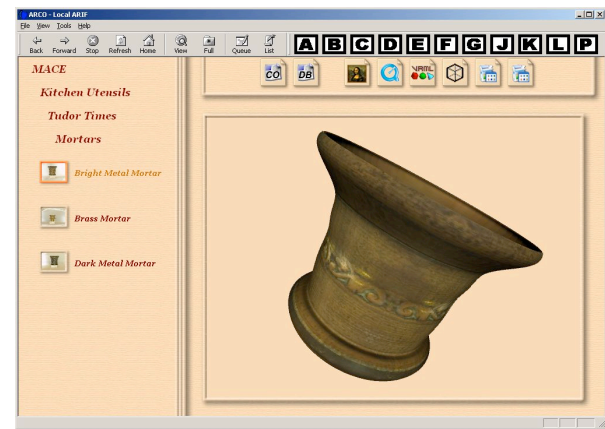

Figure 8: Web-based visualization of cultural objects (WEB_REMOTE domain)

This visualization consists of 2D Web pages with embedded 3D VRML models and other multimedia objects and can be used remotely over the Internet. Users can browse the hierarchy of exhibition spaces and COs represented as a tree on the left side and particular MOs and metadata associated with the COs by clicking on appropriate icons at the top of the page.

Virtual exhibitions can also be visualized in the Web browser in a form of 3D galleries. Examples of such visualization templates are depicted in Figure 9. The first picture presents a generic virtual room designed for presenting COs. In this visualization, users can browse objects simply by walking along the room and can retrieve more detailed information using interaction elements integrated into object stands. The second example illustrates a virtual exhibition presenting museum artifacts in a 3D room being a reconstruction of a real gallery –an exhibition corridor in the Victoria and Albert Museum in London.
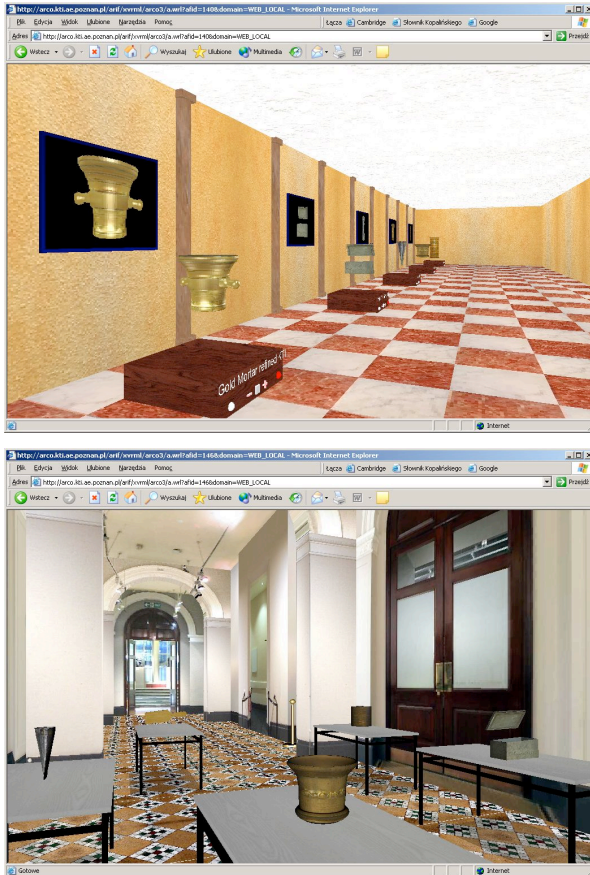
Figure 9: Example 3D virtual exhibitions

6.2. Augmented Reality Exhibitions

In addition to the Web presentation, users can examine selected Cultural Objects in the AR environment by the use of the AR Application. The AR Application embeds a standard Web browser enabling intuitive navigation and selection of objects similarly as presented in Section 6.1 (Figure 10). Additionally, the users can select some Cultural Objects and observe their digital representations in the context of real artifacts in an AR scene.

The AR browser overlays virtual objects upon video frames captured by a camera giving users an impression that the virtual objects actually exist in the real environment. The users can indicate where the virtual objects should appear in a real scene using special physical markers. In ARCO, markers have a form of square cardboard pieces with letters and special signs printed on their surfaces [24].
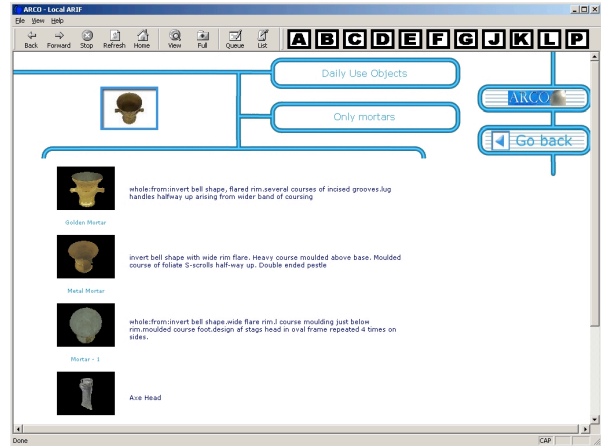

Figure 10: The Web browser component embedded in the AR application (WEB_LOCAL domain)

In Figure 11, an example marker is presented on the left, and a virtual object projected on the marker is shown on the right.
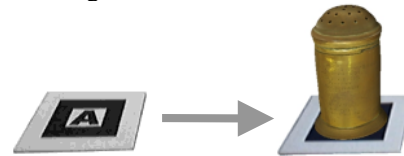

Figure 11: Virtual object superimposed on a marker

Users can interact with the displayed objects using both the markers and standard input devices. In the first method, a user can manipulate a marker in front of a camera as it is presented in Figure 12 and look at an overlaid object from different angles and distances. This is a natural and intuitive method of interaction with virtual objects.
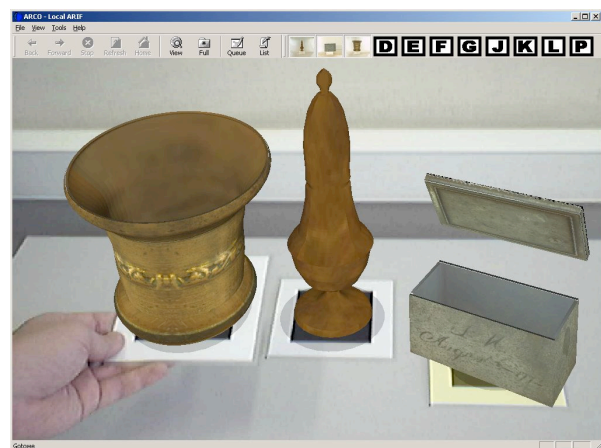

Figure 12: Real scene augmented with superimposed virtual models

Under some circumstances, the interaction presented above is not sufficient. To allow a user to examine virtual objects from each side (including bottom) and moving objects relatively to the markers (possibly static), the virtual objects can be also manipulated using a keyboard or some other input device such as the SpaceMouse®.

The AR browser can visualize a wide range of virtual scenes from visualizations of single MOs to scenes presenting a number of Media or COs. The content and layout of the visualized scenes are determined by visualization templates that define which MOs and what metadata should be presented and how these elements should be composed into one scene.

Figure 13: Simple exhibition built in an AR environment

In Figure 13, an example virtual exhibition in the AR environment is presented. The exhibition contains visualizations of three Cultural Objects. Each Cultural Object is visualized in the form of a scene comprising two Media Objects: a 3D model and an image. The 3D model is rotating so a user can see it from each side. In addition to Media Objects there is also some metadata displayed.

6.3. Learning Scenarios

One of the important goals of the ARCO system is presenting museum artifacts in an attractive manner that would make people, especially children, more interested in cultural heritage.

ARCO enables museum curators to build interactive learning scenarios, where visitors can gain information not only by browsing it, but also by answering series of questions presented in the form of a quiz. As an example, we will describe scenario illustrating how the Fishbourne Roman Palace was built [25]. At the beginning of the quiz, a user is provided with a welcome Web page, where a brief

story about the palace can be found. Moreover, the user can read a short introduction to the quiz including its rules and goals. Then, the user can start the quiz and answer a series of questions for each object presented in the AR environment. An example quiz scene presented to the user is depicted in Figure 14.
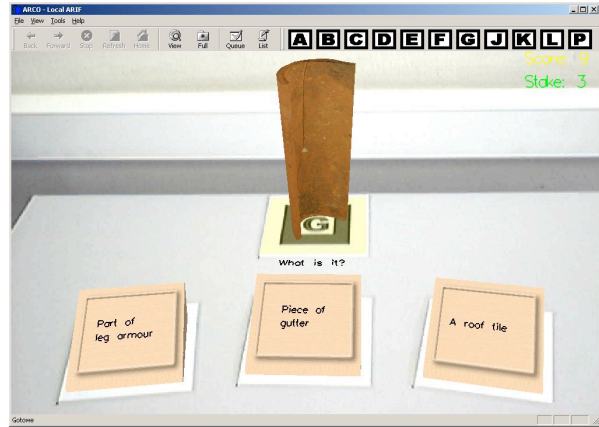

Figure 14: Example quiz scene

On one of the markers, a 3D model of a construction element and a question are displayed. Three possible answers are assigned to three other markers (see the bottom of Figure 14). 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 in the AR scene appears as presented in Figure 15. Also, a sound expressing approval or disapproval can be heard.
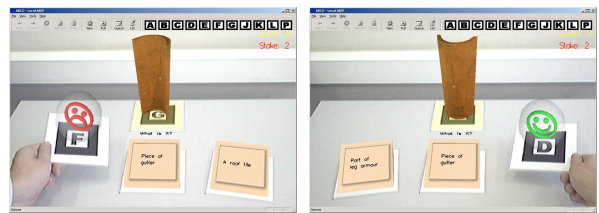

Figure 15: Wrong and correct answers

There can be a number of questions associated with an object and a number of objects presented in the interactive quiz. The AR visualization is supplemented with a Web-based presentation including VRML scenes. At the end of the quiz, a Web page containing a short summary of the quiz is presented (Figure 16). In particular, the content of the page can depend on the results achieved by the user. In this way, the application provides users with an additional incentive to repeat the quiz in order to achieve a better result, thereby increasing a learning effect.
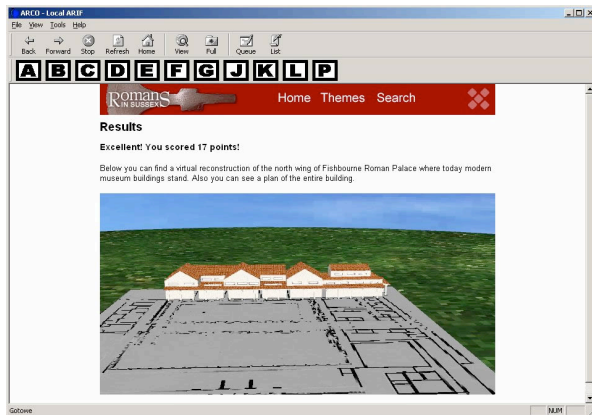
Figure 16: Results Web page

Mixed Web and AR scenarios can also be based on 3D galleries. An example of a 3D scene where users can walk around and look at presented virtual models is shown in Figure 17.
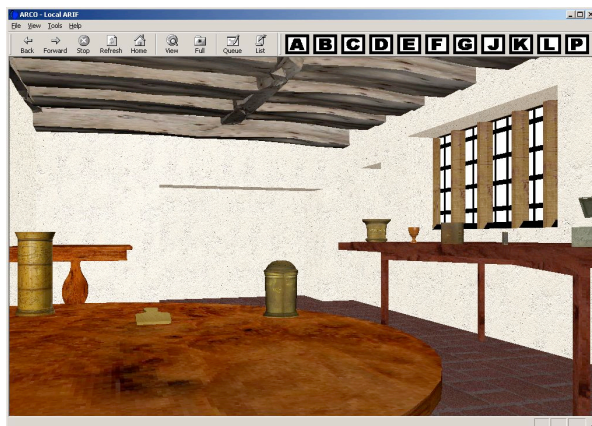

Figure 17: A 3D virtual kitchen

A user can select an object simply by clicking on it and then learn more about the object by answering questions in a similar way as in the previous scenario. Moreover, a user can hear sound effects associated with the displayed objects or a story read by a museum curator.

7. Museum Pilot Site Perspective

The ARCO system has been designed with both large and small museums in mind. Particularly for the latter, time and resources (i.e. money, expertise and equipment) will always be in short supply, and the ARCO technology allows museum curators with average IT skills, to get to grips with AR and VR environments, and make the most of those environments in the display of artifacts. Small museums can make the most of ARCO in several

different areas including display, curation, design, education, access, commerce and research. These discrete areas are discussed below and the potential of using ARCO in each is indicated.

7.1. Display

ARCO provides the excitement of displaying the museum artifact 'in the round', while allowing visitors to view the object from all angles (including objects too fragile to show). These objects can be viewed in virtual exhibitions, either for gallery display, or e-travelling exhibitions; and liberates the object from its imprisonment in the museum display case.

7.2. Curation

ARCO allows museums to make the most of museum databases by interoperating with common museum databases, such as *Modes* (in the UK). Through comparison of different images across time ARCO allows the possibility of monitoring conservation. ARCO can be used to generate virtual loans and to answer specific public enquiries remotely. The system is designed so that museum curators with average IT skills in small museums can produce quality VR images quickly.

7.3. Design

The creation of the Virtual Gallery allows the arrangement of 3D objects inside the gallery to test different designs before producing a temporary exhibition. As an educational exercise for museum users it allows users to choose their objects for their exhibitions, ARCO uses the walk-through gallery concept as a navigational aid on the web.

7.4. Education

In the educational field ARCO is based on the 'pick up and place' concept. Card-markers are used as the link between real and virtual worlds and allow people to pick up and manipulate objects and see their hands within the computer screen. Educational games have been implemented to place objects in correct chronological order. Museum users can answer questions about the object or re-locate to a room or a place where they might have originally been used or found a particular object.

7.5. Access

Making the past more accessible for everyone is one of the most important issues in the greater field of cultural heritage. Physical access can be realized by showing the upper floor galleries or objects in historic properties where physical access can be otherwise difficult. In addition, intellectual access allows

museum visitors to choose the viewpoints they want to see and not the viewpoints chosen by the curator. Remote access offers web access for schools and researchers. Finally, psychological access allows a user, through the AR interface, to forget about the technology and sensuously explore the object in three-dimensions.

7.6. Commerce

All museums need money and ARCO provides solutions to go commercial. This may be achieved by creating for example 3D images for display on an e-commerce site or by generating a catalogue of 3D objects to supplement a picture library. A CDROM and web supplement to museum printed catalogues is another solution that will allow more accurate identification of objects in case of loss or security issues.

7.7. Research

Closer inspection of the detail of individual objects provides better comparisons of size, volume, and decoration. Moreover, better publication of important collections of artifact types with linked 3D object databases moves the researcher closer to the object's reality suggesting new avenues of research, e.g. the uses and ergonomics of different pottery vessels.

7.8. Experiences

ARCO is all about learning, interaction and experiencing at the same time. The improvement of learning permeates all the suggested uses of ARCO in a museum environment. Interaction is performed via artifacts that put the user in control, suggesting both new angles of visual experience, and new angles of intellectual enquiry. It is a significant step closer to accessing the physicality of material objects as sensual, more rounded, more tangible experiences.

This impressive battery of ARCO-facilitated scenarios for the small museum will transform both the display and learning potential of cultural objects, and allow small museums to compete in technology terms with their better-funded regional and national counterparts.

8. Conclusions

The ARCO system provides a complete solution for digitization, management and presentation of museum virtual exhibitions. We have addressed digital acquisition, storage, management and visualization in interactive VR and AR interfaces by adopting a component based approach. Furthermore, mixing and matching of individual components is supported

through the use of XML and the XDE for interoperability purposes. As indicated by the numerous applications and advantages described in Sections 6 and 7, a system such as ARCO has the potential to revolutionise the use of computer-based systems in museums in the future, so that they are no longer regarded as mere tools for cataloguing purposes, but rather as ways of engaging and enhancing the experience of their users. In the following months we aim to assess and evaluate more fully the functionality provided by the system, ideally within the museum community.

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10. References

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