Building Virtual and Augmented Reality Museum Exhibitions

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Abstract

A system that allows museums to build and manage Virtual and Augmented Reality exhibitions based on 3D models of artifacts is presented. Dynamic content creation based on pre-designed visualization templates allows content designers to create virtual exhibitions very efficiently. Virtual Reality exhibitions can be presented both inside museums, e.g. on touch-screen displays installed inside galleries and, at the same time, on the Internet. Additionally, the presentation based on Augmented Reality technologies allows museum visitors to interact with the content in an intuitive and exciting manner.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual reality; K.3.1 [Computers and Education]: Computer Uses in Education - Collaborative learning, Distance learning; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities; H.5.2 [Information Interfaces and Presentation]: User Interfaces – Graphical user interfaces (GUI), Input devices and strategies, Interaction styles

Keywords: Virtual Reality, Augmented Reality, VRML, Cultural Heritage

1 Introduction

Virtual Reality (VR) technology has already reached the level of maturity allowing it to be introduced into real life applications such as medicine, education and cultural heritage. Recently, significant research effort has been also made in the area of Augmented Reality (AR). AR extends VR systems with the support for blending real and virtual elements into seamless composite scenes. By combining Virtual Reality with video processing and computer vision techniques, AR systems offer a natural view of real scenes enriched with virtual objects.

Virtual and Augmented Reality are promising technologies that can have wide impact on many domains also those not commonly associated with computer technologies. One of such domains is cultural heritage. Most museums do not have the space and resources required to exhibit their whole collections. In addition, the nature and fragility of some objects prevent museum curators from making them available to the public. Also, the interaction of museum visitors with the exhibited artifacts is very restricted, e.g. they cannot look at the artifacts from all angles, compare the artifacts, or study them in different contexts. In this respect, Virtual and Augmented Reality can offer a great help. These technologies provide solutions enabling visualization of 3D digital models of museum artifacts in both virtual and real environments. They also allow visitors to interact with the models in a variety of ways.

Museums are keen on presenting their collections in a more appealing and exciting manner to attract visitors. Some recent surveys in Europe show that about 35% of museums have already started (June 2003) developments with some form of 3D presentation of objects [Tsapatori 2003]. In many cases, these are only projects at some initial stage, but the number is rapidly growing and it is evident, that museums start to recognize the potential offered by these technologies.

Two main difficulties that museums encounter while trying to widely adopt the Virtual and Augmented Reality technologies in their standard way of operation are efficient creation of 3D models of artifacts and building virtual exhibitions based on these models. Significant research investment has been recently made in the area of 3D model creation. The technology becomes better, quicker and more affordable. It is expected that in a few years museums will be able to easily buy high-quality 3D scanners.

The availability of 3D models is a prerequisite but it is only the first step. For wide adoption of the technology, museums need efficient, cost effective and simple methods of creating virtual and augmented reality exhibitions based on their collection of 3D models. The work on setting up an exhibition should be performed by museum staff (e.g., curators), which cannot be expected to be IT experts.

At the same time, the system must provide museum visitors with an intuitive human-computer interface based on well-known metaphors. The users should be able to interact with digital contents easily and naturally like they can interact with objects in a real world. Everything that does not meet these criteria will not be understood and, therefore, will not be generally accepted.

In this paper, we describe a system, which may help museums to create Virtual and Augmented Reality exhibitions in a quick and intuitive way. The system comprises a simple to use authoring application, which allows content designers to set up virtual exhibitions in just a few minutes. The exhibitions can be presented both inside museums, e.g. on touch-screen displays installed inside galleries and at the same time on the Internet. The presentation is based on Virtual and Augmented Reality technologies and allows visitors to interact with the contents in an intuitive and exciting manner.

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The presented system has been developed as a part of the European Union Fifth Framework Programme IST project ARCO – Augmented Representation of Cultural Objects (IST-2000-28336) [ARCO 2003].

The remainder of this paper is organized as follows. In Section 2, related projects dealing with Virtual and Augmented Reality are presented. Section 3 provides a short overview of the ARCO project. Section 4 explains the concept of dynamic creation of virtual exhibitions. Section 5 gives a short overview of implemented user interfaces. More detailed description of the Virtual and Augmented Reality exhibitions can be found in Sections 6 and 7, respectively. Also in Section 7, an application of the system in the educational domain is presented. Section 8 concludes the paper and indicates future work.

2 Related Work

There are numerous examples of research on using Virtual and Augmented Reality. However, few projects use these technologies in the cultural heritage sector, and only some of them focus on real exploitation of the results. Before we describe our approach we briefly survey related projects that utilize VR or AR for cultural heritage applications.

The SCULPTEUR project – *Semantic and content-based multimedia exploitation for European benefit* – is developing a solution for museums to create and manipulate digital representations of museum objects. SCULPTEUR utilizes multi-stereo and silhouette techniques to create 3D museum object reconstructions stored in a database together with other multimedia data. The project is also aimed at developing a semantic layer providing a variety of search and content analysis opportunities. Moreover, the system gives users seamless access to the distributed databases of cultural data by offering a set of tools encompassing educational software products [SCULPTEUR 2003].

The 3D Murale project – *3D Measurement and Virtual Reconstruction of Ancient Lost Worlds of Europe* – is aimed at developing a system capable of recording archaeology excavation phases using Virtual Reality techniques. In addition to the artifacts also stratigraphical layers can be modeled. This requires utilizing diverse 3D capture techniques. Furthermore, the project offers the reconstruction of excavated remains of pottery, sculptures and buildings as well as their visualization in a way as they possibly looked like throughout ages [3D Murale 2003].

In recent research on exploitation of modern technologies in cultural heritage, an increasing role of Augmented Reality can be observed. A notable example is the ARCHEOGUIDE project intended to develop a wearable AR tour guide at cultural heritage sites [ARCHEOGUIDE 2003]. ARCHEOGUIDE allows visitors to see virtual reconstructions of ancient buildings. A user is equipped with a see-through Head-Mounted Display (HMD) and wearable computing equipment. The equipment is responsible for visualization of appropriate information on the HMD depending on the visitor's position and orientation in the site. Similar to ARCHEOGUIDE in terms of applied technology is the LIFEPLUS project. A fundamental difference is the presented contents that in case of LIFEPLUS additionally encompass real-time 3D simulations of ancient fauna and flora [LIFEPLUS 2003].

Another example of an outdoor solution is the Ename 974 project aimed at virtual reconstruction of an extensive archaeological site located at Ename, Belgium [Ename 974 2003]. Visitors are offered with virtual reconstruction of early-medieval buildings in stationary AR kiosks. Users can see visualizations of virtual models overlaid on video data captured by a camera. Using touch screen displays they can control the camera and the displayed data.

Another group of systems exploiting AR techniques to visualize cultural heritage encompasses indoor applications. An example of such a system is the Virtual Dig Experience installed in the Seattle Art Museum [Virtual Dig 2003]. Using VR and AR techniques visitors, particularly children, can discover artifacts for themselves. Users are presented not only with the artifacts but also with their archaeological context. Real objects such as brushes and small shovels are used for user interaction. The Virtual Dig has been developed based on the HI-SPACE [HI-SPACE 2003] and ARToolKit [ARToolKit 2003] packages.

The Virtual Showcase project [Bimber et al. 2003; Virtual Showcases 2003] is intended to eliminate the necessity of using unusual methods of presenting cultural objects, which is one of the weaknesses of most VR and AR systems. The project aims at integrating the AR technology into a traditional museum showcase format. Virtual images can be projected on the sides of a specially designed showcase allowing users to explore both the real objects and their virtual representations.

3 ARCO System Overview

The ARCO project – *Augmented Representation of Cultural Objects* – aims at developing the whole chain of technologies to help museums to create, manipulate, manage and present digitized cultural objects in virtual exhibitions accessible both inside and outside museums. The overall architecture of the ARCO system is presented in Figure 1.

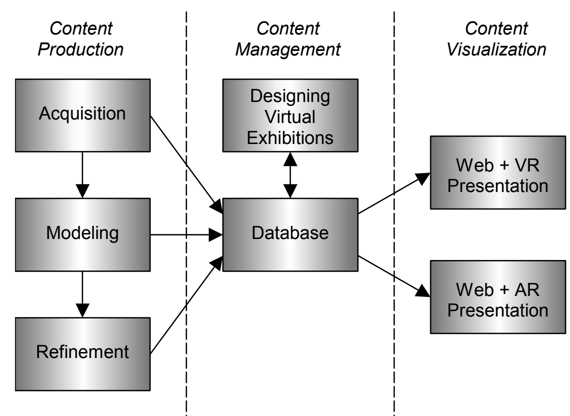

Figure 1. The overall architecture of the ARCO system

The ARCO system consists of three main architectural components: content production, content management, and visualization.

The content production includes all tools and techniques used to create digital representations of museum artifacts. The method of modeling depends on features of the objects. Objects with simple geometry can be modeled with a state-of-the-art modeling package such as *3ds max* equipped with a set of additional plug-ins developed in the ARCO project. The plug-ins simplify the process of creating virtual models of cultural objects by providing a user with functionality tailored to perform particular modeling tasks. Objects with complex geometry are modeled with a stereo digital camera system also developed within the project. This system is capable of automatic generation of textured 3D models from stereoscopic images [Patel et al. 2003]. 3D models obtained from the object modeling tools may require further content refinement such as reconstruction of missing parts or repair of polygon meshes. Repair operations such as merging meshes, eliminating overlapping polygons, welding and capping holes are carried out.

Digital representations are stored in the ARCO database and managed with ARCO Content Management Application (ACMA). Each digitized cultural object is represented as a set of media objects and associated metadata [Mourkoussis et al. 2003]. Examples of media objects are images, 3D models, descriptions, movies and sounds. Virtual exhibitions are designed by the use the Presentation Manager, which is one of the tools available in ACMA. A designer can easily create virtual exhibitions by creating exhibition spaces and assigning cultural objects and visualization templates to the spaces. The cultural objects can be then visually arranged in the exhibition spaces by the use of a simple VR authoring interface.

The visualization of the digital representations of museum artifacts is performed by Virtual and Augmented Reality interfaces. The interfaces combine Web-based form of presentation with either VR or AR virtual exhibitions. The Web-based form of presentation allows users to search and browse the database contents by the use of a well-known interface, whereas the VR and AR exhibitions let them examine virtual reconstructions of selected objects in 3D environments. The virtual exhibitions displayed in the end-user interfaces are dynamically generated based on parameterized visualization templates and the database contents. The use of different visualization templates and template parameterization allows different visualization of the same content. The virtual exhibitions can be also customized for a particular user or created in response to a user query.

4 Dynamic Virtual Exhibitions

The ARCO system uses X-VRML visualization templates to dynamically create virtual exhibitions presented in the end-user interfaces. X-VRML is a high-level XML-based procedural language that adds dynamic modeling capabilities to virtual scene description standards such as VRML and X3D. The dynamic modeling technique enables the development of dynamic database-driven virtual reality applications by building parameterized models (templates) of virtual scenes that constitute the application, and dynamic generation of instances of virtual scenes based on the models, data retrieved from a database, current values of model parameters, query provided by a user, and user privileges or preferences [Walczak and Cellary 2002; Walczak and Cellary 2003; X-VRML].

The X-VRML language enables parameterization of the virtual scene generation process, enables selection of the scene contents and provides powerful methods of accessing data stored in databases. The data retrieved from a database can influence the process of creation of the final virtual scene resulting in modification of its structure, contents, and appearance.

Although X-VRML provides a generic framework for building dynamic content templates, its design reflects specific requirements of database-driven VR applications. Thus, it offers important advantages over other Web technologies for dynamic content creation, such as Web page generators or the XSLT. Applications can use X-VRML processing on both the server and the client sides. High-level VR-specific elements such as classes or event handlers make the application code significantly shorter and more readable. Direct access to databases supports both data visualization and persistency. The language is by design extensible allowing creation of advanced domain-specific modules that simplify the process of designing advanced virtual exhibitions. The fact that X-VRML is based on XML ensures smooth integration with new VR and other Web standards.

The X-VRML templates are used in ARCO to generate both the 2D HTML and 3D VRML or X3D contents. By using different templates the same contents can be displayed in different ways. Also, since the templates are parameterized, different visualizations 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.

The use of X-VRML visualization templates enables separation of the process of designing complex virtual scenes from the process of creating actual virtual exhibitions, allowing the latter to be easily performed by museum staff without extensive knowledge in computer science and 3D technologies. All the visualization rules necessary to build virtual exhibitions and most of the graphical properties of the exhibitions are encoded in the visualization templates. A content designer can create a virtual exhibition by simply collecting the cultural object models, setting their visualization properties and creating an instance of a visualization template, i.e. a template together with values of template parameters. The process of designing a virtual exhibition can be performed by the use of a simple 2D application connected to the ARCO database.

The structure of the virtual exhibitions is determined by the structure of special *exhibition spaces* stored in the database. 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 particular topics. The exhibition spaces are represented by folders, which may contain two types of elements:

- cultural objects and
- X-VRML template instances.

When an end-user enters an exhibition space, all cultural objects that are assigned to this particular exhibition folder are displayed by the use of an X-VRML template instance that is assigned to this folder. A template instance is an X-VRML template supplied with actual values for some of its formal parameters. The template parameter values are provided by a content designer by the use of the Presentation Manager tool.

Depending on the set of parameters that are set in the template instance, the end-user may be required (or not) to provide parameters for displaying the exhibition contents. The following cases are possible:

- Some of the required template parameters are not set – the end-user must first provide values for these parameters (e.g., search criteria) and then the exhibition space may be visualized,
- All required parameters are set but there are optional parameters that are not set – the exhibition space is visualized immediately, but the end-user may change some of the presentation parameters (e.g. the default historical period),
- All template parameters are set – the exhibition space is displayed immediately and the end-user may not change its parameters.

This flexible assignment of parameter values for X-VRML templates makes it possible to easily combine search interfaces, customizable browse interfaces, as well as fixed virtual exhibitions.

Due to the X-VRML template parameterization, different visualizations can be achieved by the creation of template instances derived from the same template but supplied with different sets of parameter values. For example, a difference between two instances of the same template used in two spaces may be the value of a parameter defining the wall texture.

In order to speed-up the process of designing ARCO virtual exhibitions and to ensure consistency of presentation in exhibition spaces, the concept of *inheritance* of template instances was introduced. In this approach, if a specific exhibition folder does not contain its own template instance, the instance contained in its parent folder is used by default (recursively). This solution enables using one template instance for the whole tree of folders in the exhibition, saving the preparation time and ensuring visual consistency of presentations.

In the ARCO system, the same exhibition may be displayed differently in different environments by the use of different visualization templates. To achieve maximum flexibility with respect to different visualization methods, the concept of *presentation domains* was introduced. A presentation domain is the environment in which the presentation interface is used.

The current ARCO prototype addresses two Web domains and one AR domain. The Web domains are: *WEB_LOCAL* for use on local displays installed inside museum galleries and *WEB_REMOTE* for use on the Internet. The contents for local displays are optimized for full-screen use on fixed resolution touch-screen displays. The contents must contain all navigation elements and the size of the elements must be appropriate for touch-screen operation. Since both the hardware and the network configuration are controlled by the museum, high-quality graphics can be employed within the local presentation domain. On the contrary, the WEB_REMOTE domain provides contents for typical Web presentations on computers – with different hardware and software configuration – connecting over the Internet. The third domain: *WEB_AR* corresponds to Augmented Reality presentations used inside the museum. The list of presentation domains is extensible allowing museums to further differentiate the method of visualization in different contexts when necessary.

Each X-VRML template is associated with a list of allowed presentation domains, but each template instance corresponds to a single domain. In an exhibition space, multiple instances of templates for different domains may be created, but at most one instance for each domain. While accessing a presentation, a user browser specifies which domain should be used. Then, the appropriate instance of the template is used to dynamically produce the contents. This permits the creation of different visualizations of the same contents for use in different environments, e.g. local Web, remote Web, Augmented Reality.

An example exhibition space hierarchy displayed in the Presentation Manager tool is shown in Figure 2.

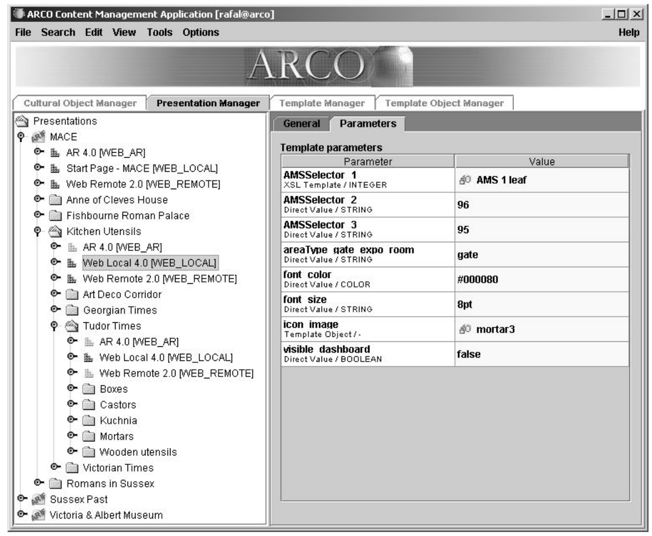

Figure 2. Example exhibition hierarchy displayed in the Presentation Manager

There are three independent exhibitions set up in this example: *MACE*, *Sussex Past* and *Victoria & Albert Museum*. The *MACE* exhibition uses three template instances for visualization of the contents in different domains. The *AR 4.0* is used for the *WEB_AR* domain, *Start Page* for the *WEB_LOCAL* domain, and *Web Remote 2.0* for the *WEB_REMOTE* domain. There are four sub-spaces in the *MACE* exhibition space. By default, the template instances used in the main exhibition space are inherited by the sub-spaces. However, in the *Kitchen Utensils* sub-space only one template instance is inherited (*AR 4.0*) and two new template instances are created. *Web Local 4.0* is an instance of another template used for visualization in the *WEB_LOCAL* domain, while *Web Remote 2.0* is another instance of the same template as used in the main space, but created with different parameter values. In the *Tudor Times* sub-space, two of these template instances are inherited, while one new instance is used for the *WEB_LOCAL* presentation domain. The panel on the right shows values of template parameters set in the template instance.

5 User Interfaces

The ARCO system provides two main kinds of user interfaces for browsing cultural heritage exhibitions: Web-based interfaces displayed in a *Web Browser* and Augmented Reality interfaces displayed in a special *AR Application*. The system employs a three-tier architecture as shown in Figure 3.

The X-VRML Server dynamically generates contents for visualization of exhibition spaces in different presentation domains based on appropriate template instances. Different collections of templates are used for the Web-based interface and for the Augmented Reality interface.

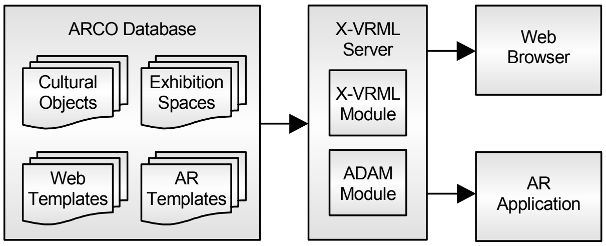

Figure 3. Architecture of ARCO visualization subsystem

The X-VRML Server consists of the X-VRML Module and the ADAM (ARCO Data Access Module) subcomponents communicating with the ARCO Database. Both components are implemented as servlets connected to a standard HTTP server. The X-VRML Module processes visualization templates and generates output in either VRML, X3D or HTML. Templates and template instances are retrieved from the database by an X-VRML program stored outside the database. The ADAM module is responsible for delivering multimedia objects retrieved from the database to the client applications.

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 Augmented Reality 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 Augmented Reality environment (*WEB_AR* presentation domain).

The architecture of the AR Application is presented in Figure 4. The application is implemented as a MFC (Microsoft Foundation Classes) application integrating a Web browser and an AR browser components. The application is responsible for synchronization between the components while a user is browsing virtual exhibitions in the Web browser. The application keeps track of the currently displayed objects and provides necessary information to the AR browser [Wojciechowski et al. 2003].

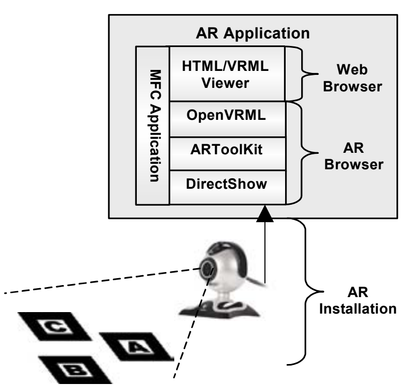

Figure 4. Visualization components

The AR Application retrieves the contents generated by the server and visualizes it in a standard 2D/3D form in the Web browser component and in an AR form in the AR browser component. For the AR visualization, a camera and a set of physical markers placed in a real environment are used. Video captured by the camera is passed on to the AR browser, which overlays virtual representations of cultural objects on the video using the markers for object positioning.

A camera and a screen for visualizing cultural objects can be built into a kiosk placed in a museum environment. Also, there should be an operating space available to users for the marker manipulation. Based on such an environment several scenarios can be implemented. For example, the application can be operated with a touch-screen display where a user can easily navigate virtual exhibitions using the Web browser component and display selected cultural objects in the AR environment. In another scenario, the AR application can be run on a standard display in a full-screen mode with virtual models pre-assigned to markers. In this case, users do not have access to the Web interface.

As the Web browser component a typical Internet browser window with a VRML plug-in is used, whereas the AR browser is implemented as a window capable of displaying a video backdrop with superimposed virtual objects. The AR application utilizes the DirectShow library for capturing input frames from a camera, the ARToolKit library [ARToolKit 2003] for analyzing the frames and calculating marker positions and orientations relative to the camera, and the OpenVRML [OpenVRML 2003] library for rendering virtual objects superimposed on the captured video frames.

6 Virtual Reality Exhibitions

6.1 Visualization Interfaces

Museum objects can be visualized in a Web browser (e.g. Internet Explorer) in a form of 2D Web pages with embedded 3D VRML models as shown in Figure 5.

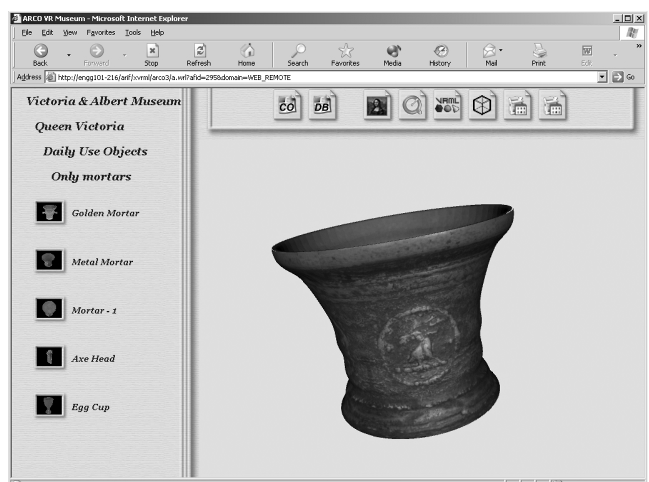

Figure 5. Web-based visualization of cultural objects

Users can browse a hierarchy of cultural objects represented as a tree on the left and display the media objects and associated metadata available for the selected cultural object by clicking on different icons at the top of the page. This particular form of visualization has been designed for remote use over the Internet.

Cultural objects presented in a Web browser can be also visualized in a form of 3D virtual galleries. Examples of such galleries are depicted in Figure 6 and Figure 7.

Figure 6. Example 3D virtual gallery (see also color plate)

The first picture (Figure 6) presents a generic 3D gallery designed for presenting cultural objects in a virtual room. In this visualization, users can browse objects simply by walking along the gallery and can retrieve more detailed information using interaction elements integrated into object stands. The second example (Figure 7) 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.

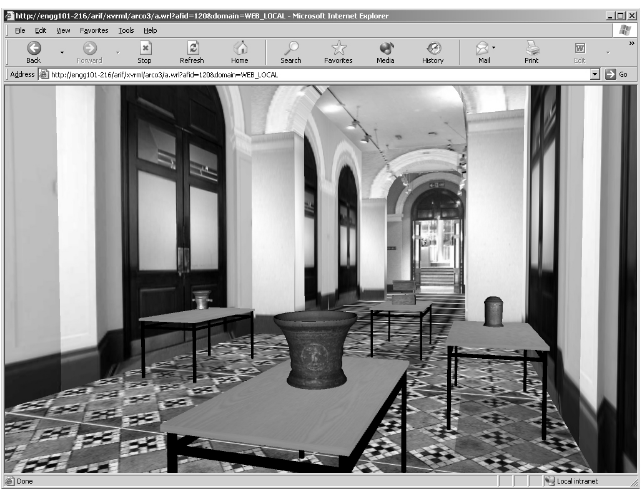

Figure 7. Example 3D reconstruction of a real gallery (see also color plate)

6.2 Authoring Interfaces

In addition to presenting the virtual galleries to end-users, the Web-based VR interfaces can be also used for authoring virtual exhibitions. An example authoring interface is presented in Figure 8. Using this interface, a designer can refine a virtual exhibition created in the Presentation Manager by arranging objects in the exhibition area. The objects can be positioned by simply moving them the virtual scene. The changes are automatically recorded in the database. When a visitor enters the exhibition by the end-user interface, the objects will be located exactly as arranged by the designer.

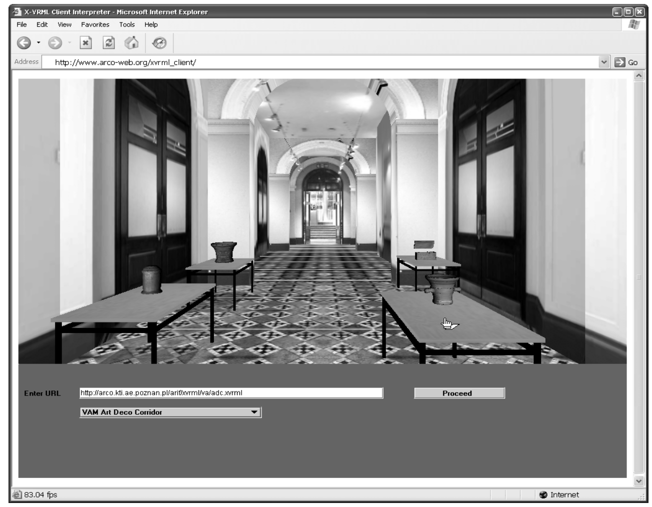

Figure 8. 3D visual authoring interface

The authoring interface is based on a client-side X-VRML processor and an X-VRML model of the gallery extended with implementation of persistency. As opposed to server-side processing, which is performed only once and a fixed VRML model is produced, in the client-side processor, interpretation is performed on the client side during the whole lifetime of the virtual scene. This allows exploiting the full potential of the X-VRML language – in particular implementation of persistency [WALCZAK, K. AND CELLARY, W. 2002].

7 Augmented Reality Exhibitions

7.1 Visualization of Cultural Objects

The Augmented Reality exhibitions require the use of the specially designed AR Application. To make the navigation intuitive to the users the AR Application can display standard Web contents as presented in the previous section. It also provides a user with a toolbar for accessing standard navigation functions. Users are able to browse objects in the same way as in a standard Web browser. If the current exhibition space contains cultural objects, they are listed on a Web page or presented spatially in a 3D virtual room. An example Web interface displayed in the AR application is shown in Figure 9.

Figure 9. The AR application displaying standard Web contents

This example, generated based on a 2D visualization template, represents an entrance to a virtual museum, where a user can choose one of the four exhibitions available on the right.

In addition to the Web contents, users can examine selected cultural objects in the AR browser. 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 and enabling comparison of virtual and real objects. The AR visualization engenders a sense of real measurements of the virtual reconstructions that is difficult to achieve with pure VR techniques.

The users can indicate where the virtual objects should appear in a real scene using special physical markers. In ARCO, the markers have a form of square cardboard pieces with letters and special signs printed on their surfaces, similarly as in [Kato 2000]. In Figure 10, an example marker is presented on the left, and a virtual object projected on the marker is shown on the right.

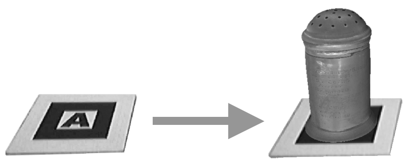

Figure 10. Virtual object superimposed on a marker

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 11 and look at an overlaid object from different angles and distances. This is a natural and intuitive method of interaction with virtual contents.

In some cases, however, the presented above interaction 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 another input device such as the SpaceMouse® [SpaceMouse 2003]. The latter kind of interaction can be particularly important in a museum environment, where visitors should be restricted in respect of access to standard input devices.

Figure 11. Real scene augmented with superimposed virtual models (see also color plate)

The AR browser can visualize a wide range of virtual scenes from visualizations of single media objects to scenes presenting a number of media or cultural objects. The selection of media objects and metadata to be visualized and the form of their presentation are determined by X-VRML visualization templates.

In Figure 12, 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 visualized. The cultural object name is displayed on the stand, while selected metadata elements are presented in front of it. Furthermore, there are also some additional 3D objects such as a stand and a picture frame that are integral parts of the applied visualization template. The template parameterization allows a content designer to easily alter the cultural object visualization. In our example, each cultural object has been visualized with a different stand height provided as a value of a template parameter.

Figure 12. Simple exhibition built in an AR environment (see also color plate)

7.2 Controlling Scene Contents

Users are able to control which objects are present in the scene using a toolbar with buttons corresponding to the predefined markers (see top of the application window in Figure 12). If a marker is associated with a cultural object then a thumbnail of the cultural object is displayed on the toolbar button instead of the marker icon.

Users are provided with a flexible mechanism of assigning virtual objects to markers. They can assign a selected object either explicitly to one of the markers or to the first unassigned marker registered by a camera. In the latter case, if there is more than one object waiting for assignment they are queued (see Figure 13). To register an object displayed in the Web interface for visualization in AR, a user has to push one of the toolbar buttons corresponding either to a specific marker or to the object queue.

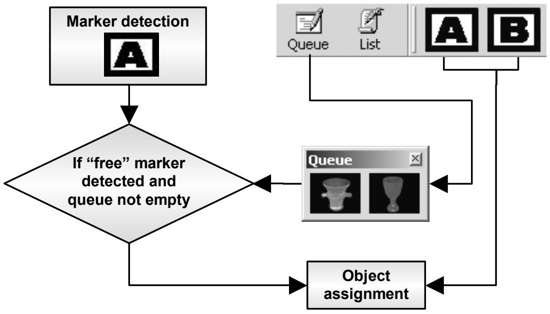

Figure 13. Object assignment to a marker

A user can remove a virtual object from the AR environment in two ways. They can uncheck the toolbar button corresponding to the marker associated with the object or they can use a special marker designed for removing objects from a scene. Each marker for displaying virtual objects can be associated with another marker dedicated to removing assigned virtual objects. The markers for removing virtual objects are printed on the other side of the markers for displaying virtual objects. In Figure 14, an example of a displaying marker and a corresponding removing marker are presented. The removing markers have distinctive black borders that allow users to easily distinguish them from the markers used for object visualization.

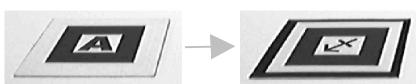
Figure 14. Markers for displaying and removing virtual objects

Once a camera captures a removing marker, the virtual object associated with the corresponding displaying marker is removed from the AR environment. Thereby, the displaying marker becomes free so other objects can be assigned to it. Figure 15 illustrates the use of a removing marker.

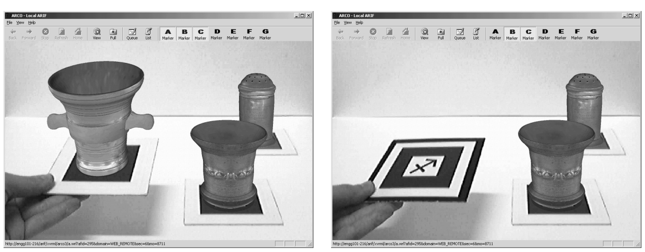
Figure 15. The use of a removing marker

7.3 Building Learning Scenarios

One of the most important goals of the ARCO system is enabling presentation of museum artifacts in an attractive manner that would provide people, especially children, with an incentive to learn more about cultural heritage. To achieve this goal, ARCO provides interactive scenarios, where in addition to passive information browsing, users can also be involved in exercises, quizzes, games, etc.

The ARCO system enables museum staff to build interactive learning presentations involving diverse forms of data presentation such as HTML pages, VRML models, and interactive AR scenes. Two examples of such presentations are: “Fishbourne Roman Palace – the construction” [http://www.sussexpast.co.uk /fishbo/fishbo.htm] and “Anne of Cleves House – the history of cooking in Tudor times” [http://www.sussexpast.co.uk/aoc/ aoc.htm].

The Fishbourne Roman Palace presentation implements an interactive quiz based on 3D models of excavated remains of materials used in the palace construction. 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. Also, the user can read a short introduction to the quiz including its rules and goals (see Figure 16).

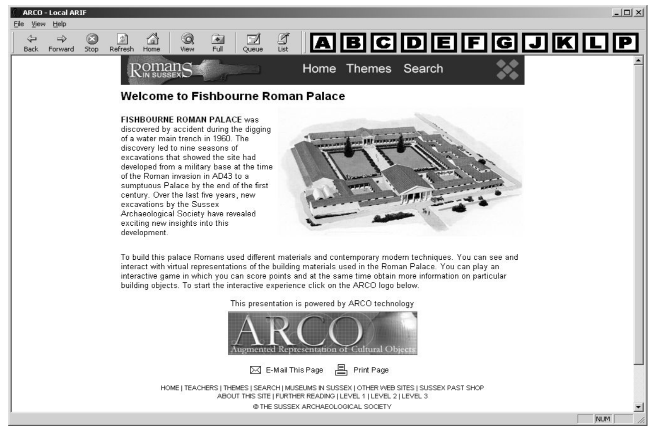

Figure 16. Learning scenario – welcome Web page

A user can start the quiz by clicking on the ARCO icon. Then, the application is automatically switched to the AR view. An example scene presented to the user is depicted in Figure 17.

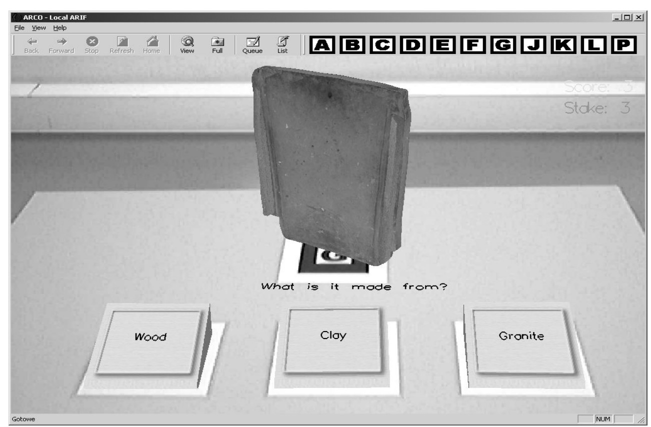

Figure 17. Learning scenario – example question visualization (see also color plate)

The 3D model of a construction element and a question are displayed on one of the markers, while three possible answers are displayed on three other markers (see the bottom of Figure 17). The model is being automatically rotated, so a user can see it from different angles. The model can be also manipulated by moving the marker. The user can answer the question by turning over one of the answer markers. Depending on whether the answer is correct or not, an appropriate virtual model appears expressing approval or disapproval as depicted in Figure 18. Also, an accompanying sound can be heard.

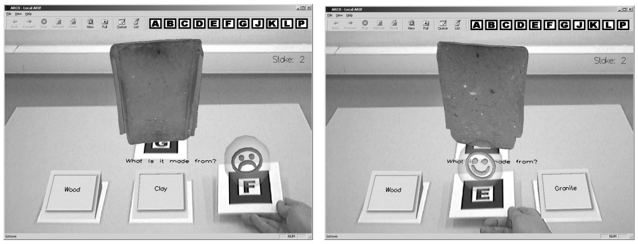

Figure 18. Wrong and correct answers

A number of points for each correct answer can be scored. However, in case of a wrong answer, the number of points to score is decreased. For each model presented, several questions can be asked. When all questions are answered the application automatically switches to the Web browser, where more detailed information can be displayed including embedded images, movies and VRML scenes. Then, the user can continue the quiz and learn more about following objects.

When all objects from the currently selected exhibition space have been presented, the final result is presented on a Web page. Due to X-VRML template parameterization, the content on the Web page can be different depending on the achieved results. An example result page is presented in Figure 19. The Web page contains a short summary of the quiz. A 3D reconstruction the palace can be also presented as a prize if the scored number of points is sufficient.

Figure 19. Example quiz result page

The next scenario is based on a 3D reconstruction of the Anne of Cleves House kitchen with 3D models of the kitchen utensils as used in the Tudor times. Users can navigate in the virtual room and can examine the presented models (see Figure 20).

A user can learn more about particular objects simply by clicking on them. Then a series of questions is being asked 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.

Figure 20. 3D learning scenario – virtual kitchen (see also color plate)

The learning scenarios can be created by the use of the ACMA Presentation Manager similarly as in case of simple virtual exhibitions. Additionally, in case of the learning scenarios, for each object the content designer can define how the object should be presented within the scenario. This can be accomplished by associating with the object an XML description containing the presentation information. An example of such a description is presented in Figure 21.

```
<?xml version="1.0"?>
<quiz>
 <tasks>
  <task question="What is it?" value="1">
   <answer correct="true">A roof tile</answer>
   <answer correct="false">Piece of gutter</answer>
   <answer correct="false">Part of leg armour</answer>
  </task>
  <task question="What is it made from?" value="2">
   <answer correct="true">Clay</answer>
   <answer correct="false">Metal</answer>
   <answer correct="false">Stone</answer>
  </task>
  <task question="How was it shaped?" value="3">
   <answer correct="false">Carved with a chisel</answer>
   <answer correct="true">Moulded</answer>
   <answer correct="false">Cast or smelted</answer>
  </task>
 </tasks>
 <summary>
   The imbrex roof tile is made of clay which has bed
   shaped by hand./The curved shape was formed around
   a mould.
 </summary>
</quiz>
```

Figure 21. Example XML description of a cultural object within a learning scenario

The object description contains a list of questions to be asked with possible answers. At the end, a short summary is contained. In a similar way, the designer can set the logic for each exhibition space to determine what actions should be taken during the interactive scenario (e.g., switch between the sub-components, play sounds, load contents into the browsers, etc.).

8 Conclusions and Future Work

The presented solution for building virtual exhibitions of cultural objects enables museums to display their digitized collections using different forms of data presentation such as Web pages and Virtual and Augmented Reality techniques. The ARCO system provides a complete solution where museums can decide which objects, how and where should be published. The choice of the most suitable presentation techniques depends on a particular application and the target group of users.

The use of X-VRML templates makes the process of building virtual exhibitions in the museum context efficient by separating the tasks of designing the visualization and preparation of the contents. These tasks are performed by staff with different competence. New virtual exhibitions can be easily created and existing exhibitions can be modified by the use of a simple 2D application without required expertise in 3D graphics.

All virtual exhibitions in the end-user interfaces are generated dynamically making it possible to differentiate the contents and the way of presentation depending on the parameters provided by end-users. The use of the presentation domain concept allows different visualization of the same collections of cultural objects depending on the target environment.

Using the ARCO system, museums can build interactive learning scenarios, which can transform visitors from passive viewers and readers into active actors and players. In the latter case, the learning process is much more effective. Museum curators can easily prepare customized scenarios suitable for children of different age groups. Moreover, such presentations can be used not only within a museum, but also in a school class.

From the end-user perspective, the ARCO system offers a novel approach for exploring cultural object collections. In addition to exploring a well-known Web interface, users can interact with selected objects in Virtual and Augmented Reality environments. Users can examine and learn about the objects in a tabletop mixed environment by manipulating digital reconstructions of the artifacts in the context of real objects.

The feedback provided by museum users after initial demonstrations of the system proves that the relatively new Augmented Reality technique is a very good supplement to much more mature presentation methods such as Web and Virtual Reality. The solution based on computer vision techniques for AR makes it possible to avoid using expensive hardware that could be a serious obstacle from most museums' point of view. Consequently, even museums with limited financial resources can afford the system and take advantage of the achievements of Virtual and Augmented Reality.

Future works in the ARCO project include the design of advanced visualization templates for presenting cultural objects in a more attractive and appealing way. Also, new learning scenarios based on the implemented technology will be implemented. The possibility of using haptic devices and projection hardware in respect of usability in real applications will be also investigated. Finally, the components of the AR installation will be integrated into a more compact form, which could be easier installed in a real museum environment.

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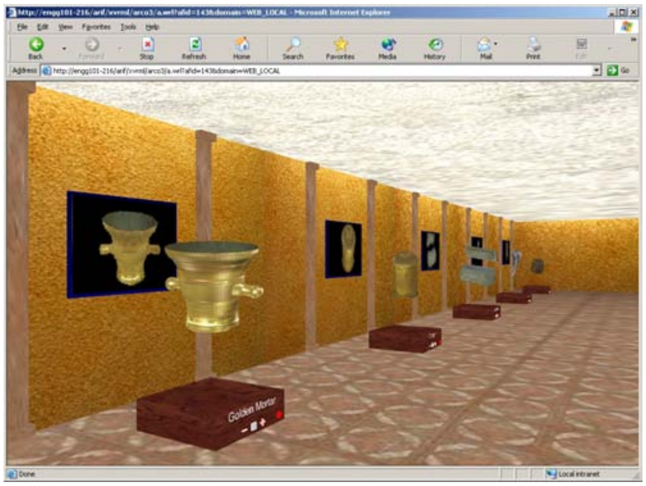

Figure 6: Example 3D virtual gallery

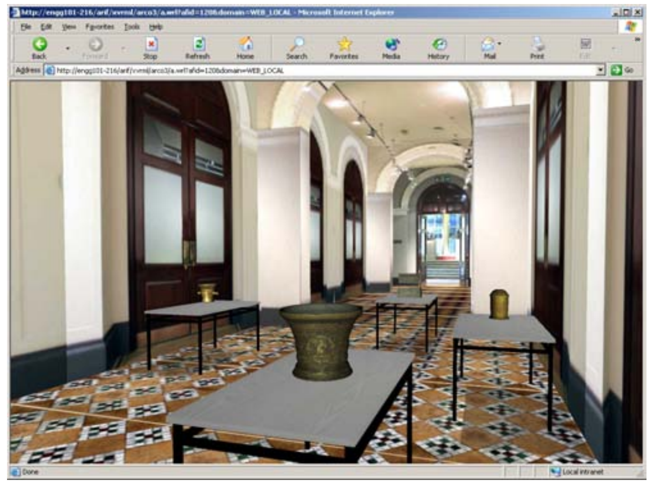

Figure 7: Example 3D reconstruction of a real gallery

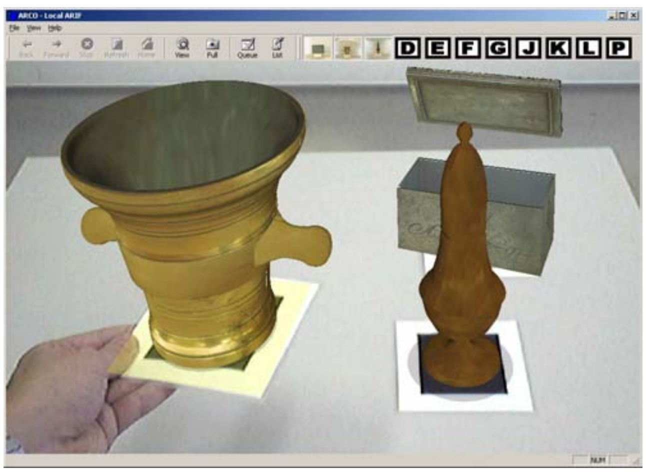

Figure 11: Real scene augmented with superimposed virtual models

Figure 12: Simple exhibition built in an AR environment

Figure 17: Learning scenario – example question visualization

Figure 20: 3D learning scenario – virtual kitchen