Interactive presentation of archaeological objects using virtual and augmented reality

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Abstract

The paper presents a system, called ARCO, which enables museums to build virtual exhibitions of artefacts based on virtual and augmented reality technologies. The forms of virtual reality exhibitions can range from simple three-dimensional presentation of digitised objects, through interactive presentation of 3D spaces such as reconstructed interiors or architectural objects, to highly-interactive 3D educational games. With augmented reality it is possible to build exhibitions that present selected virtual objects in the context of real objects or real places, enabling a user to interact with the virtual object in a natural way. The ARCO system has been deployed in several museums with very promising initial results. Examples of virtual exhibitions built with the ARCO technology as well as their practical use in the museum context are presented in the paper.

Keywords

Virtual reality, augmented reality, 3D web, virtual museum, archaeology. **1.**

Introduction

Archaeology is one of the application domains which can largely benefit from the use of modern multimedia technologies such as virtual and augmented reality. 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 artefacts is very restricted, e.g. they cannot look at the artefacts from all angles, compare the artefacts, or study them in different contexts. In this respect, virtual and augmented reality technologies can offer a great help. These technologies provide solutions enabling visualization of 3D digital models of museum artefacts in both purely virtual environments and mixed environments combining virtual objects and real objects. 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. Two main difficulties that museums encounter while trying to widely adopt virtual reality technologies in their standard way of operation are efficient creation of 3D models of artefacts 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 the near future museums will be able to easily buy

high-quality 3D scanners. However, 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 collections 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 content 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. The remainder of this paper is organized as follows. In Section 2 the state of the art in the domain of museum multimedia presentation systems is presented. Section 3 provides an overview of the ARCO system. Section 4 describes the process of designing virtual exhibitions in ARCO. Section 5 provides examples of virtual museum exhibitions built with ARCO.

2. Current situation

Modern museums already exploit various multimedia technologies to attract visitors - both visitors coming to the museum in person and visitors from the cyberspace - browsing museum web sites and on-line virtual exhibitions.

For the first type of visitors museums prepare on-site interfaces, such as kiosks, permitting them to browse through museum's digital collections and learn about artefacts. In most cases these interfaces take advantage of touch screen displays, while their content is programmed using technologies such as MS PowerPoint presentations, PDF files, HTML pages and Flash. The first two are very simple, but they lack real interactivity and complex behaviour. Use of

HTML, displayed through a web browser, is justified by quick and easy implementation of such interface. HTML browsers and editors are available free of charge, and HTML is reasonably simple to learn. Inexperienced users may create content using sophisticated WYSIWYG editors. However, simplicity of this solution is double-edged: presentations created with HTML have limited interactivity and complex content is often browser-specific. Creation of highly interactive content (using technologies such as ECMAScript, ActiveX, AJAX) usually exceeds capabilities of non-IT experts. Most importantly, HTML permits only 2D content presentation, which is not sufficient for building engaging virtual exhibitions.

The most common technology currently used for creation of kiosk interfaces is Macromedia Flash. Flash technology permits creation of eye-pleasant, graphically-rich, interactive presentations. With the use of Flash technology sophisticated educational scenarios may be presented. The main disadvantage

of Flash is its complexity. Creation of interesting virtual exhibition requires a lot of work and experienced programmers. Very often resulting presentations, while spectacular, do not offer easy customization, data dynamism, and further expansion capabilities. Another problem is weak acceptance of 3D content within Flash presentations.

Some museums invest in building custom interfaces (Wise 2002; Tyson 2003). Such solutions permit creation of interactive interfaces and use of user-friendly authoring environments. However, these interfaces are mostly focused on 2D not enabling 3D content presentation, produce content which is non-standard and therefore may be used only on displays inside the museum. Additionally, such content cannot be exchanged between museums that use different IT systems.

Second type of visitors come to the museum web sites on the Internet. In this realm, use of HTML technology is prevailing, while Flash interfaces, also used, are less frequent (British Museum 2007; Guggenheim Museum 2007).

The most promising form of presenting virtual exhibitions is interactive 3D. Museums start to apply 3D technologies in their interfaces accessible both inside the museums and on the web. Most frequently interactive photographs in form of QuickTime VR are used, however true 3D standards, such as X3D and VRML, become also increasingly popular. In some cases, custom complex interfaces prepared with the use of 3D authoring tools (e.g. 3ds max or Virtools; 3ds max; Virtools) are used. X3D/VRML standards are particularly interesting because they are not bound to any specific platform, enable presentation of content both inside the museum and over the Internet. They also offer true 3D approach enabling the user to freely navigate in a 3D space and manipulate the objects.

3. The ARCO System

The ARCO system - *Augmented Representation of Cultural Objects* - consist of a set of tools and technologies to help museums to create, manipulate, manage and present digitized cultural objects in virtual exhibitions accessible both inside and outside museums (Walczak *et al.* 2006). The overall architecture of the ARCO system is presented in Figure 1.

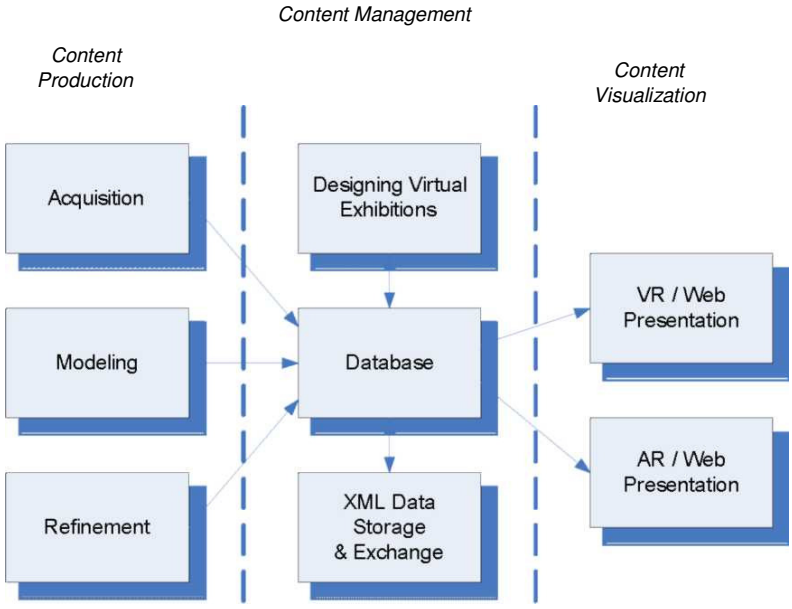

Fig. 1. The overall architecture of the ARCO system

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

The content production includes all tools and techniques used to create digital representations of museum artefacts. The method of modelling depends on features of the objects. Objects with simple geometry can be modelled with a state-of-the-art modelling package such as *3ds max.* Objects with complex geometry can be modelled using techniques such as laser scanning, photogrammetry with structured light and video-based acquisition. 3D models obtained from the object modelling tools may require further content refinement such as reconstruction of missing parts or repair of polygon meshes.

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 artefacts is performed by the VR and AR user 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. Designing Virtual Exhibitions

The ARCO system uses the Flex-VR approach (Walczak 2008) to dynamically create virtual exhibitions presented in the end-user interfaces. The dynamic modelling technique enables 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, 2003).

The use of presentation 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 presentation 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 presentation template, i.e. a template together with values of template parameters (see Figure 2). The process of designing a virtual exhibition can be performed by the use of a simple 2D application connected to the ARCO database.

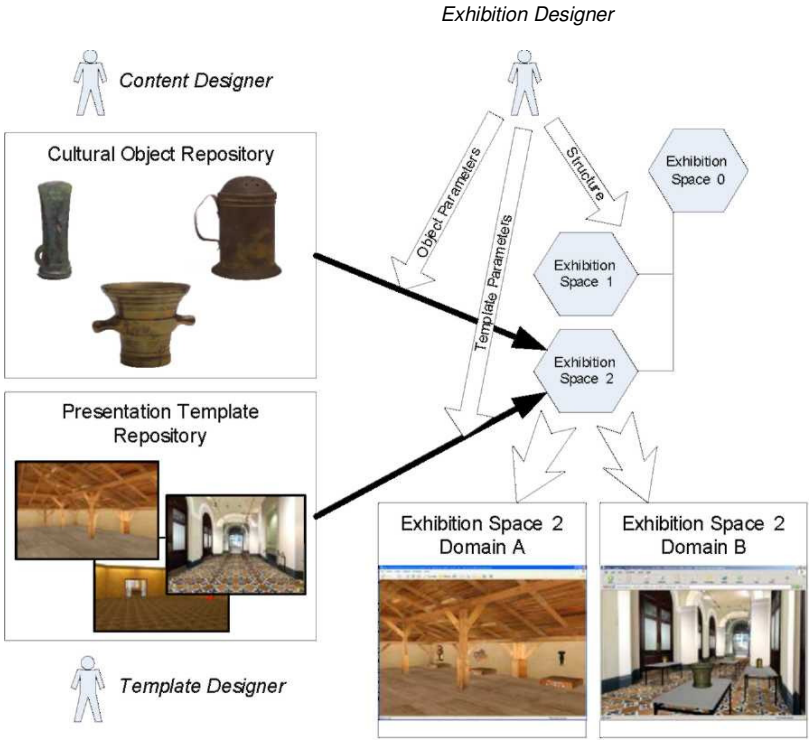

Fig. 2. Designing virtual exhibitions in ARCO

The structure of 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 three types of elements:

- cultural objects,
- presentation template instances and
- cultural object automatic selection rules.

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 a presentation template instance that is assigned to this folder. A template instance is a 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 (see Figure 3).

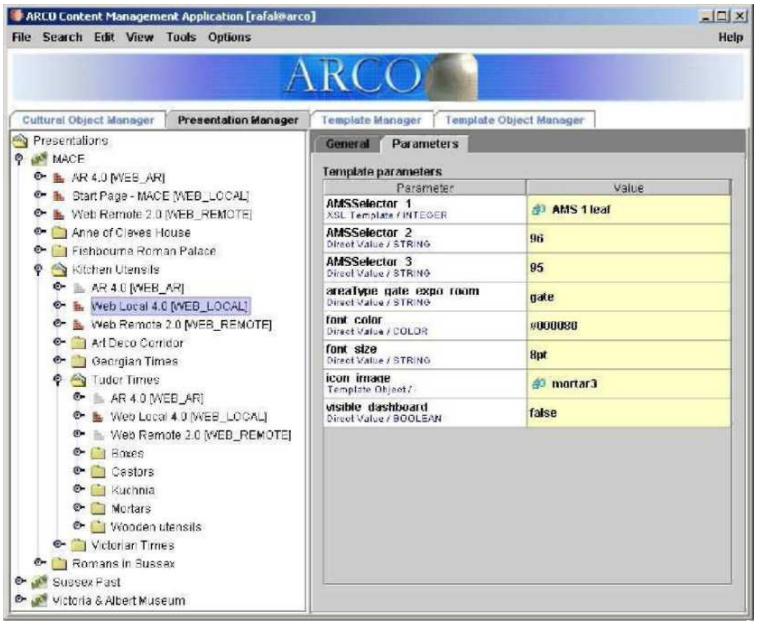

Fig. 3. Setting template parameter values in the Presentation Manager

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 templates makes it possible to easily combine search interfaces, customizable browse interfaces, as well as fixed virtual exhibitions. Due to the 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 presentation templates. To achieve maximum flexibility with respect to different visualization methods, the concept of presentation domains was introduced. A presentation domain corresponds to the environment in which the presentation interface is used. Example presentation domains may be LOCAL, REMOTE and AR. The LOCAL domain is designed for use on local displays installed inside museum galleries. The REMOTE domain can be used on the Internet. The content for local displays is optimized for full-screen use on fixed resolution touch-screen displays. The content 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 REMOTE domain provides content for typical Web presentations on computers - with different hardware and software configurations -connecting over the Internet. The third domain: 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 presentation 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 content. This permits the creation of different visualizations of the same content for use in different environments, e.g. local Web and remote Web.

5. Example Virtual Exhibitions

Examples of ARCO interactive VR exhibition galleries are depicted in Figures 4 and 5.

Fig. 4. Example of 3D virtual gallery (text in Polish)

Figure 4 presents a generic 3D gallery designed for presenting cultural objects in a virtual room. In this visualization, users can browse through objects simply by walking along the gallery and can retrieve more detailed information using interaction elements integrated into object stands. Figure 5 illustrates a virtual exhibition of museum artifacts in a 3D room being a reconstruction of a real place - a corridor in Victoria and Albert Museum in London.

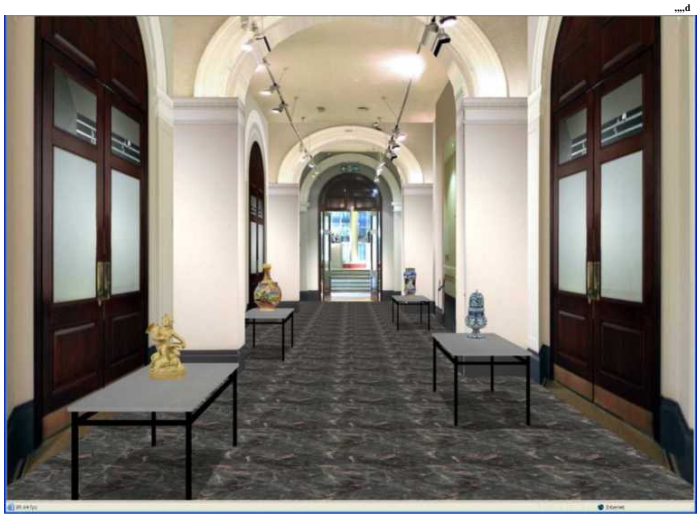

Fig. 5. Example 3D reconstruction of a real gallery

Using the Flex-VR approach it is possible to build more advanced interactive content. In Figure 6, an example of a 3D interactive game is presented. In this game, each of the content objects is associated with a scenario script, which governs its appearance and behavior in the virtual scene. In this example,

each object is represented by its geometrical model and a label indicating the object's material (retrieved from metadata). The users' task is to associate each object with appropriate label and then press the 'Accept' button. From the content designer perspective, creation of such scenario requires only assigning a group of objects and a behavior template to an exhibition space. No programming or 3D designing skills are necessary.

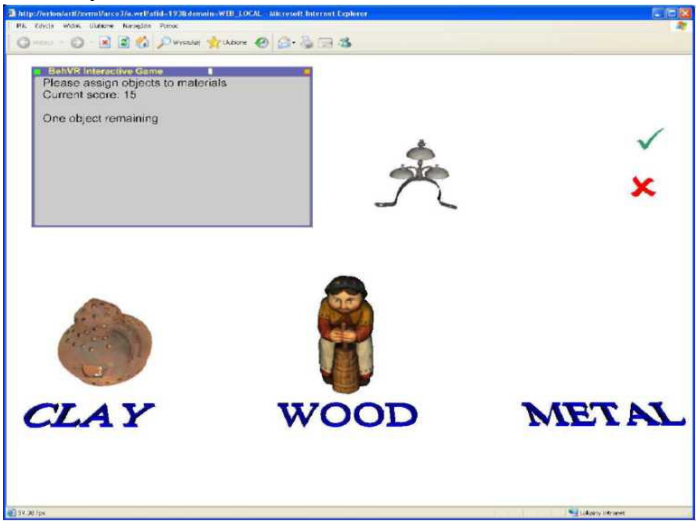

Fig. 6. 3D interactive game

In some circumstances, pure virtual environments may be insufficient, because they do not give the ability to see virtual objects in the context of real objects. This problem can be solved by the use of Augmented Reality visualization techniques that enable visualization of virtual objects in real environments and interacting with the objects in a direct way.

In the ARCO system, AR visualisation is possible by the use of a specially designed AR Application. The application 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. Users can indicate where the virtual objects should appear in the real scene using special physical markers. The markers have a form of square cardboard pieces with letters and special signs printed on their surfaces. A user can manipulate a marker in front of a camera as it is presented in Figure 7 and look at an overlaid object from different angles and distances. To make navigation intuitive to the users, the AR Application can also display standard 2D and 3D Web contents.

ARCO enables also building interactive AR scenarios, where, in addition to passive browsing, users can be involved in exercises, quizzes, games, etc. Interactive presentations can be composed of a number of different 3D models and other multimedia data. The system can be used to create learning scenarios. As an example, an interactive presentation about excavated pottery, which can be used as a

teaching material during an archaeology lesson, is shown below. An example scene presented to a learner is depicted in Fig. 8.

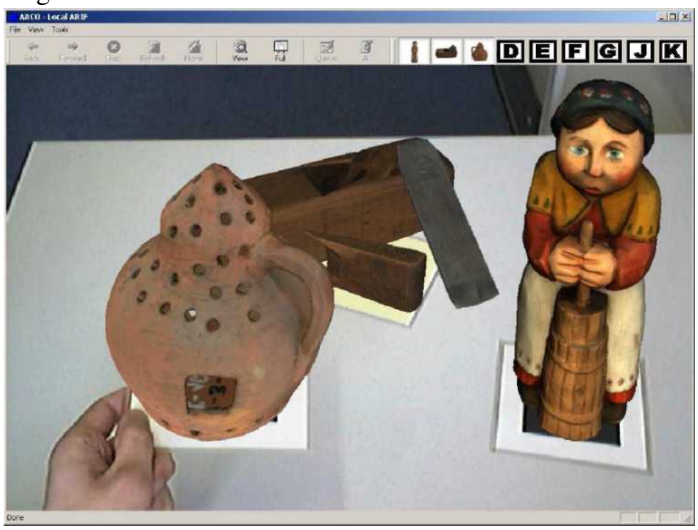

Fig. 7. Real scene with superimposed virtual objects

The 3D model of an artifact and a question are displayed on one of the markers, while three possible answers are displayed on three other markers. The model can be manipulated by moving the marker. There is also a command displayed at the bottom of the window informing users what they should do. A user can answer the question by flipping one of the answer markers. Depending on whether the answer is correct or not, an appropriate 3D model appears expressing approval or disapproval. In addition, accompanying sound can be heard.

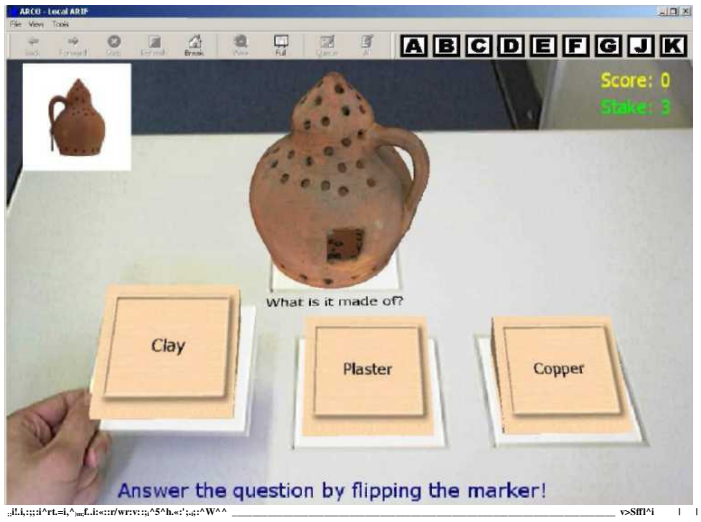

Fig. 8. Archaeology lesson — example of question visualization

A number of game points for each correct answer can be scored. In the 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 subsequent objects. When all objects comprising the interactive presentation have been shown, the results and a short summary of the quiz are presented on a Web page. Due to the parameterization of the presentation template, the content on the Web page can be different depending on the achieved results.

ARCO in an Archaeological Museum

Implementation of the ARCO System in museums should allow the creation of attractive low-cost exhibitions that otherways would never be held. It is of remarkable importance for the promotion of cultural heritage, as well as of the country as a whole, particularly when it is faced with financial constrains. Of similar importance - especially for the younger generation of museum visitors - is the possibility to transform, thanks to the ARCO technology, the very image of the museum itself: from the place where one can only passively watch the cultural objects placed in the show-cases, to the place, where the original artefacts are followed by interactive, virtual exhibitions of - potentially - unlimited scope, that enrich the main traditional exhibition. One can presume that the access to such presentations from home as well as and from school through the Internet (and in the future - through the interactive, digital TV) on a worldwide scale, will exert the significant impact upon the education of the young generation. Such a powerful and flexible system as ARCO enables archaeologists to generate several different types of products, i.e.:

1/ Internet 3D presentations of traditional museum exhibitions (mainly - the permanent ones), 2/

additional presentations of sets of artefacts that will enrich traditional exhibitions

a/ locally - at the museum (i.e. at info kiosks),

b/ remotely - through the Internet,

3/ Monographic (problem-oriented) exhibitions (artefacts and their multimedia descriptions based upon the contents of the ARCO database),

4/ Educational programmes for young people (ie. educational games), ended with tests that could check the newly acquired knowledge.

5/ Artefact catalogues for professionals.

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Figures

Fig. 1. The overall architecture of the ARCO system

Fig. 2. Designing virtual exhibitions in ARCO

Fig. 3. Setting template parameter values in the Presentation Manager

Fig. 4. Example of 3D virtual gallery (text in Polish)

Fig. 5. Example 3D reconstruction of a real gallery

Fig. 6. 3D interactive game

Fig. 7. Real scene with superimposed virtual objects

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