

An Interactive Visualisation Interface for Virtual Museums

F. Liarokapis, S. Sylaiou, A. Basu, N. Mourkoussis, M. White, P.F. Lister

University of Sussex

Abstract

Cultural institutions, such as museums are particularly interested in making their collections accessible to people with physical disabilities. New technologies, such as Web3D and augmented reality (AR) can aid museums to respond to this challenge by building virtual museums accessible over the Internet or through kiosks located in accessible places within the museum. In this paper, we propose a prototype user-friendly visualisation interface that uses Web3D and AR techniques to visualise cultural heritage artefacts for virtual museum exhibitions. User interactions within the virtual museum are performed in an effective way with the help of assistive technology, so that users can feel completely related with the virtual museum artefacts and so benefit in terms of education and entertainment.

Categories: Virtual and Augmented Reality, Museums, Web Interfaces, Physical Disabilities.

1 Introduction

With the aid of new technologies museums have recently started to deal with the challenge of presenting their collections in an appealing and understandable manner [MMS*03]. The typical content for museum guides and presentations is usually restricted to multimedia presentations (i.e. interactive CD-ROMs). However, there is a growing interest in virtual museum exhibitions that make use of Web3D and augmented reality (AR) techniques. In this paper we use the term Web3D to mean programming technologies such as X3D and VRML that integrate virtual environments, 3D graphics and interactivity in web applications. With the addition of AR, these techniques can offer to all virtual museum visitors (including people with physical impairments) the sense of 'being there' [Cha02]. Additionally, the use of the World Wide Web can enable access to these virtual museum exhibitions from almost anywhere.

In the case of museum visitors with physical impairments Web3D and AR have the potential to 'minimise the effects of disability', i.e. access. However, despite the fact that the demands of these visitors are continuously increasing, and these new access technologies have significantly improved,

there are few systems that are based on an interactive and user friendly interface that meets current demands.

One example is the Meta Museum [MKN96], which is a project with the goal of enhancing people's knowledge exploration experience in an educational way by mixing virtual reality (VR) and artificial intelligence (AI) techniques. Ename is heritage project that makes use of VR and multimedia techniques to aid visitors to understand and experience our past [PCK*00]. Moreover, virtual showcase is an AR platform for digital storytelling in museum environments [BES03].

Although there is a lot of work done in virtual reality for museum environments there is not much done concerning AR environments. The Augmented Museum [RN95] is an early experimental application in which the user can perceive descriptions of museum objects. A more recent system is an AR-based user interface that provides interactive exploration of museum's exhibits is presented in [MMS*03]. Another example is an AR interface based on spatial sounds and a semantic web approach is designed for a natural history and science museum [HKW*04].

One of challenges for interactive systems is the seamless integration of virtual and real information through the use

of AR techniques [DPG02]. AR systems aim to augment the real world with computer-generated (virtual) objects [ABB*01].

In this paper we propose a prototype user-friendly visualisation interface that uses Web3D and AR techniques to visualise cultural heritage artefacts for museum environments that is potentially of great benefit to people with special needs. Interactions within the system are performed in a natural and effective way so that these users can feel completely related with the system and its digital content.

The remainder of this paper is organised as follows. First, we discuss issues focused on disability access to museums and potential solutions. The next section describes the overall architecture of the system followed by a description of the visualisation scenarios of the system. Finally, the paper is concluded with a brief discussion of future developments.

2 Disabled Access to Museums

Most museums are keen in exploiting new visualisation techniques and presentation technologies, in order to attract more visitors, but mostly to justify their *raison d'être*, which is to 'acquire, conserve, research, communicate and exhibit material evidence of people and their environment for purposes of study, education and enjoyment' [ICOM04]. In order to accomplish their tasks, museums can follow various strategies, depending on the available exhibition space and available resources.

According to the Disability Discrimination Act (DDA) in the UK disabled people have equal rights of 'access to goods, facilities and services' [DDA04], therefore museums have now to consider how they can comply with the act. This poses a serious problem for many museums where the cost of installing access strategies may be prohibitive. For example, many small museums that are located in a listed building have conflicting requirements. How does one make the decision to put a lift into a 500 year old medieval Wealden hall house such as 'Anne of Cleves' [SP04]?

The Resource Disability Action Plan that has been created by the Council of Museums, Archives and Libraries has stressed the need to discover effective ways of using new technologies that provide to disabled people virtual access to museums [RDAP04]. The system that we will present has capabilities that can address this action plan.

New technologies have always provided valuable help to people with visual, acoustic, learning, speech and motor disabilities to live and work independently [GBG*03] and allowed them to participate to life activities by eliminating, or sometimes disappearing, existing problems and barriers. Various researchers have pointed out/emphasised the significant role of Virtual Reality as an assistive to

impaired people technology in the future [WSF97], [Rin98], [GBB03].

With our system a disabled person can interact with a virtual museum exhibition in two different ways. In the first way the visitor can access a virtual museum kiosk located within easy access from the museum entrance. With such a kiosk the visitor could see and interact with virtual artefacts from around the museum. In the second scenario, a virtual museum exhibition can be delivered via the Web to the users' PC. People with physical impairments can virtually visit the museum exhibition using standard assistive technologies for PCs.

People that have disabilities as a consequence of a stroke can benefit from a VR system in their cognitive rehabilitation process [RB97], [JBM*01], [BSH*02], [CPL*03]. Through a visit to a virtual museum exhibition that uses VR and AR techniques, these people can simulate a visit to a 'real' museum environment, develop skills and recover knowledge that may be partially lost. The system described can play an important role to the transitional stage of the disabled people from the current situation to the previous activities.

Usually in everyday life activities, disabled people confront not only physical, but also psychological obstacles that discourage them to participate in various activities. Apart from the various measures that need to be undertaken, environments that use VR techniques can simulate experiences and facilitate significantly impaired people. In our case, the virtual museum exhibition can be a simulation of a 'real' museum exhibition and help people with disabilities to acquire an awareness of the exhibition space, or even to develop an orientation map of the rooms' exhibition, so as to navigate to it more easily, when they decide to visit it. Consequently, the interaction with the system aids the impaired people to enhance their mobility and life skills and at the same time it helps them to reduce anxiety that may feel when they visit a completely unknown place.

Our system currently exhibits rich multimedia features allowing visitors to explore virtual artefacts in many different ways through text, video, images and 3D. Additionally, it can also be easily used by people with vision disabilities, such as partially sighted people and by people with learning impairments, such as people with dyslexia, since the virtual museum exhibition is web based and controlled by XML configuration files and XSL templates allowing us to change the presentation of virtual museum web pages, thus complying with web disability access guidelines.

In addition, the features of our system are flexible and can change according to the personal needs of each disabled person. The size of the fonts and the objects, as well as their contrast with the background can be easily increased for people with low vision and dyslexia. Also the colours can be modified for colour-blind people.

Finally, our system improves the quantity and the quality of information provided about the museum exhibitions, contributes to the dissemination of knowledge and raises awareness about Cultural Heritage matters among disabled people. It therefore helps them to reduce the exclusion and isolation feeling that they may feel, to build confidence and to improve their life quality. It provides them with independence and self-confidence and it can help them to integrate into society more easily. This is very important for people with impairments, because 'by enhancing this social self-efficacy, it is anticipated that carry-over will occur into education, employment, independent living, family support, and economic independence' [GBG*03].

3 System Overview

The client-server architecture of our system is based on a typical three-tier configuration that consists of an XML data repository (back-end), a communication servlet (middleware), and a visualization interface (client) [WLM*04]. Figure 1 illustrates the deployment diagram of our architecture.

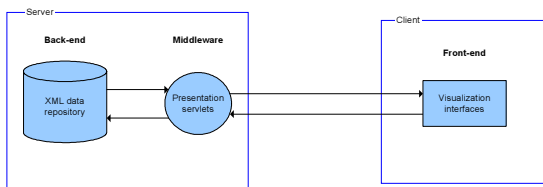


Figure 1: Three-tier architecture

The back-end or XML data repository consists of a hierarchical data model structure based on XML Schemas. This data model describes the relationships between the multimedia data such as VRML models, images, etc. and metadata (i.e. curatorial, preservation and technical metadata) that support and enable the management and storage of virtual museum exhibitions. Associated with the back-end are presentation templates implemented in XSL stylesheets that define the 'look and feel' of our web based exhibitions.

The middleware presentation servlets are implemented using java servlet technologies configured to provide the requested multimedia data from XML repository after a client request. Finally, the client visualization interface is implemented by integrating Web3D and AR technologies so as to retrieve data from the repository and present virtual exhibitions to the end-user. This paper is largely focused on describing the visualization interface, which provides the end-user experience in the virtual museum exhibition. Our interactive visualisation interface proposes a simple but practical solution for visualising museum artefacts in a number of scenarios so that they can fit various museum needs. In the following sections the software and hardware technologies used in the architecture of the system are briefly discussed.

4 Visualisation Interface

The visualisation interface is a windows application that integrates a web browser, such as Internet Explorer, and our customised AR table top environment. The most representative feature of the system is that we have defined a technique for dynamically uploading multimedia information into the visualisation client [WLM*04]. An overview of the interaction between the libraries used in our prototype system is presented in Figure 2.

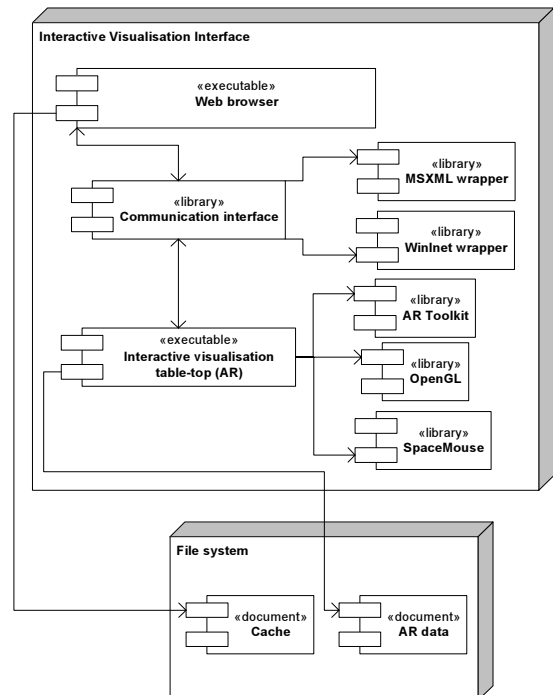


Figure 2: Architecture of visualisation interface

The architecture of our interactive visualisation interface (Figure 2) relies on three basic components: the *web-browser*; the *interactive visualisation table-top AR*; and the *communication interface*. The first two are standard alone applications and therefore they are marked as *executable* while the third component describes our mechanism for communication between the applications and marked as *library*. All components are 'wrapped' together using MFC classes providing a single user-friendly interface that can switch visualisation from web to AR.

Furthermore, XML is used for the specification of the configuration files as well as for the transferring of the virtual exhibition information through the internet (section 4.1). The communication interface uses a wrapper around WinInet and MSXML 4 to retrieve virtual exhibition artefacts from the server. The technical details about the operation of this part have been recently presented in [WLM*04]. The AR environment uses the vision tracking libraries of ARToolkit [KBP*00] while the graphics operations are built on top of the OpenGL API.

Furthermore, the VR interactions within the system are based on SpaceMouse SDK [SXP04].

In terms of hardware equipment the proposed visualisation system has been tested successfully with different configurations ranging from desktops to laptops. Our experimental configuration is based on a Dell Inspiron 9100, a video camera (Sony Handycam DCR TRV-18E), four USB Logitech web-cameras (QuickCam Pro 4000), a SpaceMouse (Magellan SpaceMouse Plus XT [SXP04]) and a set of physical marker cards.

All components of our visualisation interface have been carefully selected so that they can be easily explored by people who have little or no previous experiences with such technologies. In the following sections, first the XML configuration applied in the AR visualisation is briefly described and then the interactive visualisation table-top AR environment is presented in detail.

4.1. XML Configuration

Although XML provides effective ways for information representation since it can manage heterogeneous data it is not a trivial task to access and display the information contained in XML files [DSC⁰³]. For this reason, our system depends on XML file-based configuration system to achieve a high-level degree of flexibility and extensibility. The configuration XML file is mapped into a complex hierarchical memory structure at start-up. This is done through custom functions on top of a wrapper around MSXML 4 (Figure 2). Another configuration structure is also maintained that contains configuration data relevant only during the run-time of the application.

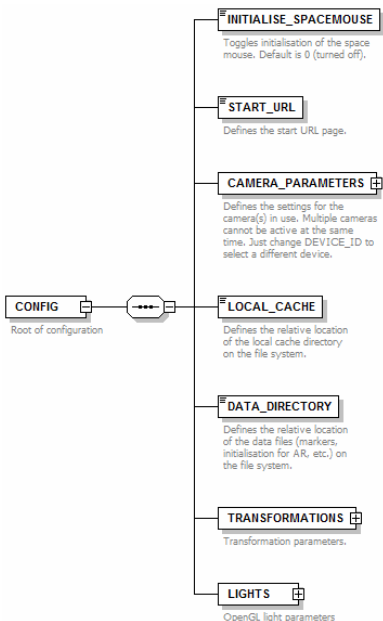


Figure 3: XML configuration schema

The user is presented with a very user friendly GUI for editing the XML configuration data. Once the user updates this data, the changes are immediately flushed to the XML file and the memory structure is updated.

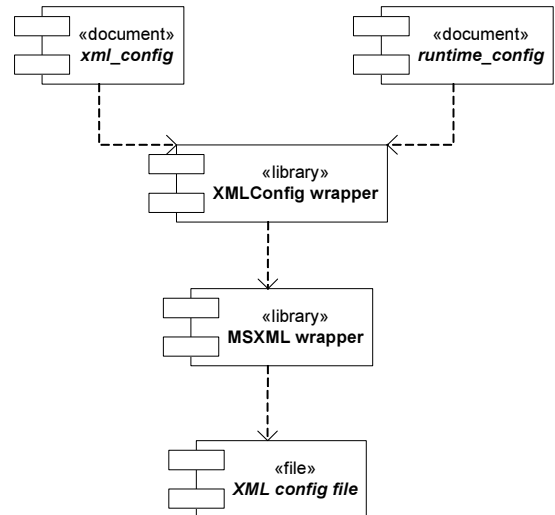


Figure 4: Library architecture

The XML based configuration parameters are responsible for maintaining information related to general application settings like a *virtual museum exhibition homepage*, a *cache directory* and a *data directory*. In the visualisation side *camera*, *lighting*, and *default transformation settings* can be applied to all new virtual objects placed in the AR scene.

The run-time configuration data is related to volatile information like camera video zoom, user-applied transformations on virtual objects, etc. and some other parameters used internally in the application.

4.2. Interactive Visualisation table-top AR

The purpose of the interactive visualisation table-top AR interface is to allow all sorts of museum visitors including people with vision disabilities, such as partially sighted people or with learning impairments and dyslexia, to enjoy museum exhibitions composed of virtual cultural artefacts.

Technically, the visualisation interface consists of two clients: the *web-client* and the *AR-client*. The web-client is responsible for the visualisation of the museum artefacts into the web through the use of XML technologies (section 4.1). On the other hand, the AR-client superimposes virtual artefacts into indoor environments and performs basic computer graphics (CG) operations. An overview of the architecture of the AR-client is shown in Figure 5.

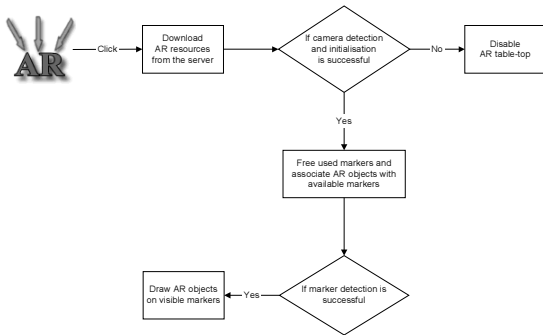


Figure 5: Operation of the AR-client

When the user clicks on the appropriate AR link (section 5) then the appropriate resources are downloaded from the server. In case the camera is plugged into the computer, the marker detection algorithm checks for predefined physical marker cards existing in the real environment. If the search is successful then the VRML object is overlaid on the marker cards.

In addition, we have implemented a number of visualisation techniques in order to effectively present museum artefacts into the visitors. For the Web3D visualisation we have embedded the well known VRML Cortona browser into the Web-visualisation client so that the users can render the 3D artefacts on the screen. As far as the AR visualisation is concerned there are more specific CG and computer vision operations such as: *ground plane*; *interactive lighting*; and *dynamic camera switching*;

4.3. Ground plane

One of the most important issues of AR visualisation systems is to achieve a high level of realism [LWL04]. It is therefore, very important to visualise what is inside of a virtual object [RW02]. This requires the definition and implementation of a virtual ground plane. The purpose of the virtual ground is to give the users the illusion that the marker cards define the origin of the AR environment. An example of this is illustrated in Figure 6.

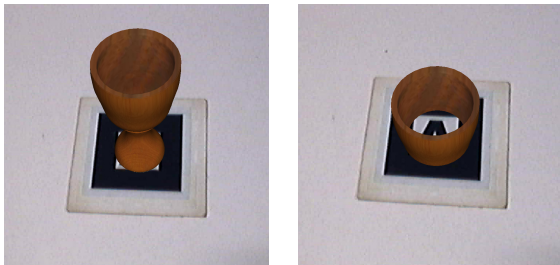


Figure 6: Clipping using an invisible plane

Originally, the definition of the plane was done using colour but this was giving the impression of something synthetic and was making the system look unreal.

Therefore, it was finally preferred to use an invisible and infinite plane.

4.4. Interactive lighting

ARToolKit offers the basic functionality for providing three different types of virtual lighting. Based on the work illustrated in [RW02] we have implemented a technique based on OpenGL to interactively change the lighting conditions in real time performance as illustrated in Figure 7.

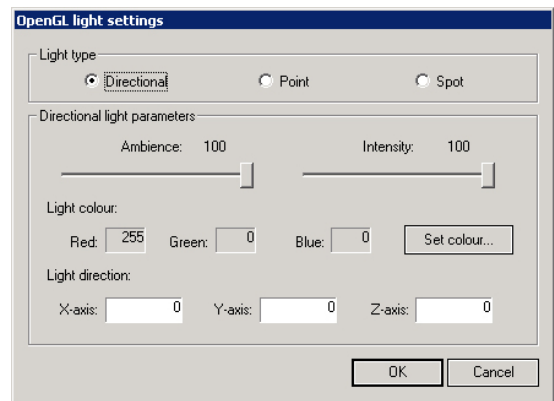


Figure 7: Interactive lighting

Figure 7 presents one of the dialog boxes contained in the application containing three different light types including: directional; point; and spot light. The user can change the light type interactively during visualisation by selecting one type of light (directional is the default). In addition other attributes that can be interactively changed include the ambience, the intensity, the colour and the direction of the light source.

4.5. Dynamic camera switching

One of the very important features available through the use of XML configuration file and WIA (Windows Image Acquisition) is the capability to dynamically switch the cameras when the AR table-top environment is active.

With a camera active and the video being displayed in the AR table-top view, it is possible to switch to a different camera as long as WIA recognizes the video capture devices. All such cameras might be connected to IEEE1394 ports or USB ports. The cameras do not need to be of the same type. The user should invoke the camera parameters dialog. To avoid de-initializing of an active camera, the AR table-top view is automatically de-activated (so that the camera is not in use) and hidden. The user then has the choice to select any camera from a list of connected cameras (Figure 7).

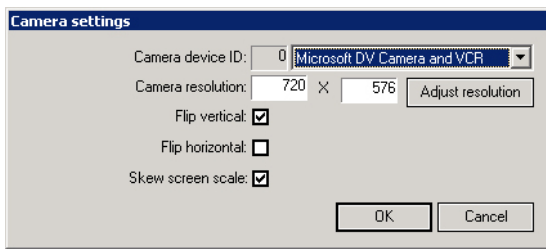


Figure 8: Camera switching

When a camera device is selected, the video resolution is adjusted to the default resolution of the camera. The user has the option to set the camera resolution to a custom value but, this value is verified for camera support before the camera is activated. For example, some Logitech USB web-cams support 320x240 and 640x480 resolutions; the default is the former. If the user sets 1024x768, it is not accepted and the user is requested to enter a supported resolution. When the user updates this change in settings and dismisses the configuration dialog, the AR table-top view is re-initialized with the new camera and is unhidden.

5 Virtual Museum Scenarios

In this section, a number of visualisation scenarios designed for our interactive interface are presented. In the simplest case, users can access museum galleries over the internet and get related information from our dedicated repository (Figure 9).



Figure 9: Web visualisation

Figure 9 illustrates our customised form of web-visualisation based on XSL stylesheets, which presents thumbnail information about a virtual museum presentation. Each thumbnail represents a link a different page, which contains extra information about the virtual museum artefact such as metadata, images and a 3D representation of the artefact (Figure 10).



Figure 10: VRML visualisation environment

In Figure 10, a 3D representation of the virtual museum artefact is rendered in a Cortona client embedded in our application. The user can manipulate the VRML object using the mouse (see section 6.3). In addition to that, we have also integrated an 'AR' button, which is the link between the Web3D and the AR visualisation. By clicking onto the button the VRML artefact is inserted into the AR environment as shown in Figure 11.



Figure 11: Single artefact augmentation

Another capability of the system is that it allows the visualisation of the artefacts contained in our customised virtual museum presentations, by inserting multiple objects into multiple marker cards. More specific, when the user browse on the web-visualisation level (Figure 9) the AR button allows the automatic registration of the artefacts contained in the presentation onto the table-top environment. Figure 12 illustrates a collection of artefacts overlaid on five marker cards.

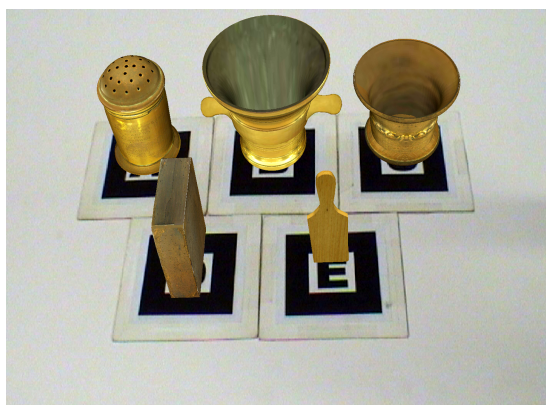


Figure 12: Virtual museum presentation

Similarly, the user can select another virtual museum presentation, which exists on our repository and visualise their artefacts on the table-top environment as shown in Figure 13.

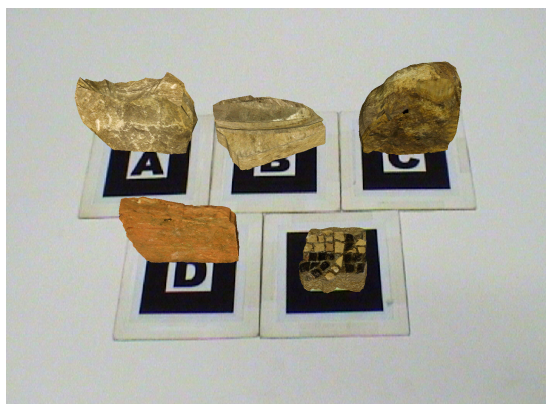


Figure 13: Another virtual museum presentation

The user can pick up the marker cards and examine the artefacts that correspond to the cards (section 6.1). However, the greatest advantage of the system is that it offers to remote users the ability to extend the artefacts contained in the presentation into their own space, in their room.

6 Interactive Interfaces

The design of an effective visualisation interface for museum environments means that museum users (local and remote visitors) will quickly familiarise with it. To achieve this we have developed a prototype interface for museum environment, which can handle three different forms of interaction including: *tangible interactions*; *graphical user interface (GUI) interactions*; and *hardware interactions*.

6.1. Tangible Interactions

Our tangible interface is based on the techniques presented in [BKP01] where the user can move freely a set of predefined markers in the real world and the object stays aligned on it as long as the marker is in line of view of the camera (Figure 14). Based on this framework, we have designed a set of marker cards which are used as the physical interface between the user and the AR environment. Each card is constructed of hard cardboard with a black and white marker glued on it. In order to generate a distinct set of marker cards, letters borrowed from the English alphabet and were used and trained using ARToolKit software. An example of how a user can interact with a virtual museum artefact is shown in Figure 14.

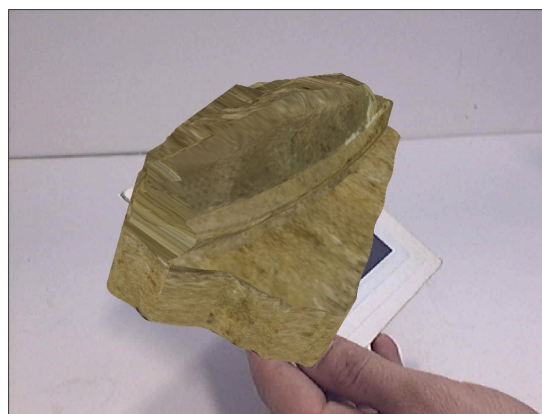


Figure 14: Natural interaction

Figure 14 presents how a user can pick up a marker card and examine the 3D representation of the virtual museum artefact. This tangible interaction could be applied very effectively to disable persons since it allows the exploitation of huge perceptual capabilities of humans (museum visitors) when interacting with virtual artefacts.

6.2. GUI Interactions

Another way to interact with the virtual information in the real environment is to use the GUI (Graphical User Interface) [LWL04]. The GUI is built using MFC (Microsoft Foundation Classes) to allow interoperability with windows environments. The implemented menu contains all the necessary information required to perform a simple but robust AR visualisation in real time performance (Figure 15).



Figure 15: GUI interaction

An example of GUI interaction is illustrated in Figure 15 where the user performs a rotation using the appropriate dialog box. The advantage of this type of interaction is that it provides means precise manipulations. This feature can be extremely useful for users like museum curators or archaeological students who might be interested in accurate interactions.

6.3. Hardware Interactions

Another type of interaction is based on the concrete utilisation of standard hardware input devices like the mouse and keyboard and also sophisticated hardware devices such as the SpaceMouse. In the simplest case, the mouse is used to manipulate the VRML objects in the 2D monitor and to change the rendering properties (wire-frame, camera, etc). Although the mouse is the only device used in the web visualisation, it is sufficient to get a pretty good idea of the museum artefacts (Figure 16).



Figure 16: Mouse interactions in web-view

On the other hand, on the AR-visualisation the keyboard and the SpaceMouse are employed. The keyboard offers exactly the same functionality as the GUI does (section 6.2) but it has the advantage that it is used as a fast way to perform either graphics operations such as translations, rotations (Figure 15) etc., or video operations like camera properties (Figure 7).

Furthermore, VR interaction devices can provide new means of interaction in AR environments. SpaceMouse Plus XT provides a combination of a nine button menu together with a six degree-of-freedom (DOF) mouse (Figure 17). Each button of the device can be programmed to perform any type of operation. In our case, three buttons are assigned to enable basic transformations (rotations, translations and scaling) while the other buttons allow the user to perform basic graphics operations (lighting, clipping, etc).



Figure 17: SpaceMouse interactions

Figure 17 illustrates how a user can interact with the virtual museum artefact in 6 DOF. This is performed by just clicking on button 1, and then by slightly moving the mouse in any direction. To make the interactions look more realistic we have allowed the user to manually adjust the level according to his/her taste.

7 Conclusions and Future Work

A user-friendly and interactive visualisation interface specifically designed for visualising museum artefacts either remotely or locally is proposed. The system combines Web3D and AR technologies into a single architecture to allow the exploration of museum visualisation using both technologies. In addition, human-computer interactions have been designed in such a way so that they can be easily applied using different software methods (i.e. GUI) or hardware devices (i.e. SpaceMouse).

The XML based configuration system has given us the ability to extend the application to introduce new features easily. One such new set of features, which will be added in future, is dynamic assignment of markers leading to features like circular queue for AR objects; user-interface for training new markers, etc. Another area of further work relates to the evaluation of the system which will be performed through systematic user studies.

Furthermore, the system can be improved in the future by incorporating assistive technologies. People with motor disabilities that move only their head could use mouth sticks, head wands, single-switch access and sip and puff

switch. Oversized trackball mouse can be used by people with tremors in the hands. Eye-tracking devices are capable of helping people with limited -or not at all- control of their hands to navigate through the virtual museum exhibition. Voice recognition software could allow people to control pages with voice commands.

As it is already mentioned, people with vision problems might explore the system with a mouse and hear the auditory information that accompanies the virtual museum exhibitions. Additionally, for persons with low vision, screen magnifiers or screen readers that are able to speak the text that is in a computer screen can be included to the system. Problems of very low vision, or blindness, can be confronted with the aid of refreshable Braille displays that are electromechanical devices that can display the text that appears on the screen by rendering Braille dots to a refreshable tablet.

Another area of further work is related with the evaluation of the system usability by users with various impairments. At this stage relevant questionnaires will be created having in mind the REAL model, which stands for *Relevance, Efficiency, Attitude* and *Learnability* and is described by Löwgren [Löw93]. Moreover, results of similar User Evaluation trials with people with special needs will be taken into account [SCB97], [NBC*99], [MPM*04].

Acknowledgments

Part of this research was funded by the Marie Curie Actions Human resources and Mobility Marie Curie training site: Virtual Reality and computer graphics, project HPMT-CT-2001-00326.

References

- [ABB*01] Azuma, R., Baillot, Y., Behringer, R., et al., Recent Advances in Augmented Reality. *IEEE Computer Graphics and Applications* 21, 6 (Nov/Dec 2001), 34-47, (2001).
- [BES03] Bimber, O., Encarnação, M., and Schmalstieg, D., The Virtual Showcase as a new Platform for Augmented Reality Digital Storytelling. *Proceedings of the workshop on Virtual environments 2003*, Zurich, Switzerland, 87-95, (2003).
- [BKP01] Billingham M., Kato H., and Poupyrev I.: The MagicBook: A Transitional AR Interface, *Computer Graphics*, 25, 745-753, (2001).
- [BSH*02] Boian R., Sharma A., Han C., Merians A., et al., Virtual Reality-Based Post-Stroke Hand Rehabilitation, *Proceedings of Medicine Meets Virtual Reality 2002 Conference*, IOS Press, 64-70, Newport Beach CA, January 23-26, (2002).
- [Cha02] Champion E., Cultural Engagement In Virtual Heritage Environments with Inbuilt Interactive Evaluation Mechanisms, *Proceedings of the Fifth Annual International Workshop PRESENCE 2002*, Porto Portugal, October 2002, 117-128, (2002).
- [CPL*03] Castelnovo G., Lo Priore C., Liccione D. et al., Virtual Reality based tools for the rehabilitation of cognitive and executive functions: the V-STORE, *PsychNology Journal, Volume 1, Number 3*, 310-325, (2003).
- [DDA04] Disability Discrimination Act 1995, Available at: <http://www.disability.gov.uk/dda/>, (last accessed: 12/9/2004).
- [DPG02] Dubois, E., Pinheiro, P., Gray, P., Notational Support for the Design of Augmented Reality Systems. *Interactive Systems. Design, Specification, and Verification, 9th International Workshop, DSV-IS 2002*, Rostock Germany, June 12-14, 74-78, (2002).
- [DSC*03] Drap, P., Seinturier, J., Canciani, M., et al., A GIS tool box for Cultural Heritage. An application on Constantine, Algeria, historical center, *Proceedings of the 4th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage*, 203-212, (2003).
- [GBG*03] Germann, C., Broida, J.K., and Broida, J.M., Using Computer-Based Virtual Tours to Assist Persons With Disabilities. *Educational Technology & Society*, 6(3), 53-60, (2003).
- [HKW*04] Hatala, M., Kalantari, L., Wakkary, R., et al., Ontology and rule based retrieval of sound objects in augmented audio reality system for museum visitors, *Proceedings of the 2004 ACM symposium on Applied computing*, Nicosia, Cyprus, 1045-1050, (2004).
- [ICOM04] International Council of Museums (ICOM), Available at: <http://icom.museum/statutes.html>, (last accessed 12/9/2004).
- [JBM*01] Jack, D., Boian, R., Merians, A.S., et al., Virtual Reality-Enhanced Stroke

- Rehabilitation, *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, Vol. 9, No 3, (2001).
- [KBP*00] Kato, H., Billingham, M., Poupyrev, I., et al., Virtual Object Manipulation on a Table-Top AR Environment, *Proceedings of International Symposium on Augmented Reality 2000*, Munich, 5-6 Oct., 111-119, (2000).
- [Löw93] Löwgren J., *Human-computer interaction*. Studentlitteratur, Sweden, (1993).
- [LWL04] Liarokapis, F., White, M., and Lister, P.F., Augmented Reality Interface Toolkit, *IEEE Proceedings Of International Symposium on Augmented and Virtual Reality, IV04-AVR*, London, 761-767, (2004).
- [MKN96] Mase, K., Kadobayashi, R., and Nakatsu, R., Meta-Museum: A Supportive Augmented-Reality Environment for Knowledge Sharing, *Proceedings of International Conference on Virtual Systems and Multimedia '96*, 107-110, (1996).
- [MMS*03] Macva, I., Mihalic, L., Susperregui, A., et al., Application of New Interfaces in Museum Environments: The Virtual Showcase, *Proceedings of XIII Congreso Espanol de Informatica Grafica. Actas*, 361-364, (2003).
- [MPM*04] McNeill, M., Pokluda L., McDonough, S., et al., Virtual Reality in Rehabilitation: User Evaluation, *Eurographics Ireland Chapter Workshop Proceedings*, Cork, 7-15, (2004).
- [NBC*99] Neale, H.R., Brown, D.J., Cobb, S.V.G., et al., Structured evaluation of virtual environments for special needs education, *Presence: Teleoperators and Virtual Environments*, Vol. 8, No. 3, June 1999, (1999).
- [PCK*00] Pletinckx, D., Callebaut, D., Killebrew, A., et al., Virtual-Reality Heritage Presentation at Ename, *IEEE Multimedia April-June 2000*, Vol. 7, No. 2, 45-48, (2000).
- [RB97] Rizzo A, Buchwalter, G., Virtual Reality and Cognitive Assessment and Rehabilitation: The State of the Art, *Virtual Reality in Neuro-Psychology*, 19 (6), 213-220, (1997).
- [RDAP04] Resource Disability Action Plan, Available at: <http://www.mla.gov.uk/documents/dap.pdf> (last accessed 12/9/2004).
- [Rin98] Ring, H., Is neurological rehabilitation ready for 'immersion' in the world of virtual reality? *Disability and Rehabilitation*, 20 (3), 98-101, (1998).
- [RN95] Rekimoto, J., Nagao, K., The World through the Computer: Computer Augmented Interaction with Real World Environments, *Proceedings of UIST'95*, November 14-17, 29-38, (1995).
- [RW02] Regenbrecht, H., Wagner, M., Interaction in a collaborative augmented reality environment, *Extended Abstract in Proceedings of CHI 2002*, April 20-25, 2002, Minneapolis, Minnesota, USA. ACM, 504-505, (2002).
- [SCB97] Standen P.J., Cromby J.J., and Brown D.J., Evaluation of the use of VE with students with special learning difficulties. *Proceedings of the Annual conference of the British Psychological Society*, Edinburgh, April 1997, (1997).
- [SP04] Sussex Past – Museums & Properties, Anne of Cleves House, Available at: http://www.sussexpast.co.uk/property/site.php?site_id=14, (last accessed 12/9/2004).
- [SXP04] SpaceMouse XT Plus, Available at: http://www.aventec.com/documentation/3DControllers_Docs/MagellanSpaceMousePlusXT_E.pdf, (last accessed 10/9/2004).
- [WLM*04] White, M., Liarokapis, F., Mourkoussis, N., et al., ARCOLite - an XML based system for building and presenting Virtual Museums using Web3D and Augmented Reality, *IEEE Proc. Theory and Practice of Computer Graphics 2004*, 8-10th June, 94-101, (2004).
- [WSF97] Wilson, P. N., Foremen, N., & Stanton, D., Virtual reality, disability and rehabilitation. *Disability and Rehabilitation*, 19 (6), 213-220, (1997).