Building a VR-Museum in a Museum

George Lepouras, Dimitrios Charitos, Costas Vassilakis, Anna Charissi, Leda Halatsi
Human-Computer Interaction and Virtual Reality Research Group, Department of Informatics,
University of Athens, Ktiria Pliroforikis, Panepistimioupolis, Ilisia, Athens 15771, Greece, vr-lab@di.uoa.gr

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Abstract: Past years have seen the exploitation of multimedia techniques and lately the introduction of virtual reality methods to create new forms of presentation for museums' exhibitions. Virtual Reality can offer a number of advantages to museums, offering a way to overcome some common problems like the lack of space or the need of visitors to interact with the exhibits. A broad categorisation of virtual museums reveals that they vary from fully immersive cave systems to simple multimedia presentations. In our approach to develop a virtual reality museum we have designed a virtual environment (VE) where guests can visit a total of ten different museums. The processes of digitisation, architectural design and exhibit presentation are outlined and points of particular importance are explained. Exhibits from the real world museums have been digitised and integrated in the VE. The system has been implemented in two versions: one fully immersive and one with a stereo display.

1 Introduction

Museums, in general, host exhibitions in order to disseminate their message to the public. Within the museum's environment the form of exhibited objects' manifests the museum's message. Museum exhibitions and individual objects provide two kinds of information: scientific and cultural. Experience has shown that this information can be communicated more effectively by complementing plain exhibit presentation with additional media and by targeting other senses too [1, 2]. Research effort has been put on exploiting technological advancements to the museums' benefit. The term Virtual Museum was coined by Tsichritzis and Gibbs in their 1991 paper [3] where they describe the concept of a virtual museum and the technologies needed to realise it.

In an earlier paper [4], we addressed the general issues concerning the development of a Virtual Museum, accessible either through the Web or locally. The present paper focuses on the development of a locally executed virtual reality environment to be offered to visitors of the N. P. Foundation Museum of Cycladic Art[1]. This work is accomplished in the framework of the "Virtual Museums" project[2]. Ten museums participate in this project and provide 2D and 3D content to be digitised and included within the virtual museum.

The first section of the paper discusses the possible advantages from incorporating a Virtual Museum presentation within the context of a real museum. The second section attempts to broadly categorise cases of virtual museums that have been implemented within real-world museums. Finally, the third section presents our approach to designing and implementing the locally executed Virtual Reality Museum.

Recent years have witnessed the introduction of new forms of presentation in museums' exhibitions. Multimedia techniques have been widely used for enhancing users' experience and attracting more visitors to museums, as well as for providing a new means for communicating their content and consequently information. Nowadays, most modern museums offer multimedia info-kiosks, where visitors can get information regarding the museum's collections, special exhibitions, and other cultural activities. In some cases there is an option for a multimedia tour of the museum, where the visitor may 'preview' the museum content. 3D graphics and simulation technologies also offers the possibility of reconstructing lost or partially preserved objects and enabling visitors to experience an approximation of the original artefact (that being an ancient statue, a dinosaur or even a lost city). Additionally, the emergence of the World Wide Web provided the infrastructure for making museums available to a global level, since an on-line exhibition is accessible from almost anywhere in the world at any time.

1 The museum's web address is http://www.cycladic-m.gr/

2 The "Virtual Museums" project is sponsored by the Greek General Secretariat of Research and Technology within the EPET II Framework.

2 The need for a VR system within the museum environment

Multimedia, 3D graphics and virtual reality (VR) technologies encourage the adoption of more sophisticated interactive techniques, for the digital presentation of museum content. It is however understood that a virtual museum is not necessarily limited into being a simulation of a real, existing museum. Although, these technologies have mostly been used for creating an enhanced, on-line version of an original museum, they can also be utilised for augmenting the visitor's experience within the real museum environment.

To this end, there are a number of reasons, which justify the installation of a virtual environment (VE) system within a museum:

Lack of space: Most museums display a fraction of the exhibits that they own, since exhibition space is always limited. Some objects may be too fragile or valuable to be exhibited. Stored objects, can be effectively displayed by means of a VR presentation within the museum.

Vivid presentation: Although a simple multimedia presentation can also be used for displaying stored content, a VE system affords the museum visitor a more vivid and realistic experience. Exhibits can be interactively observed from different viewpoints or even manipulated. Haptic feedback technology may also enable visitors to touch and feel valuable objects, or may let people with vision problems sense an exhibit. It has to be stressed however, that the nature and individual characteristics of an exhibit (painting, photography, 3D object, etc) largely dictate the ideal technology that should be used for displaying it in a digital form.

Virtual Heritage visualisation: a VE system affords visitors the possibility to view a simulation of important objects, buildings or environments, which have been constructed at a much earlier point in time; these environments may either:

- no longer exist today
- be somehow damaged and in need of reconstruction or
- can not be easily experienced, either because they exist at a remote site or because their condition does not allow for their interior to be navigated.

Visualization of hazardous sites: a VE system is a secure way of providing the experience of visiting an environment, which may be too difficult or too dangerous to physically visit (e.g. inside a volcano or on the mountains of Mars).

Mobile exhibition: the digitised content of a museum may be experienced in a realistic manner via a mobile VE system, which can be easily transported to any exhibition site or remote location. This fact may give a chance to a wider audience to view important exhibitions without having to travel far.

Navigational aid: Some museums are quite vast and, in some cases, visitors may only be interested in certain exhibits, which exist at certain points within the museum. Instead of physically traversing the distances amongst these objects, visitors may view the desired exhibits from within the VR-equipped system. This is particularly important for visitors with accessibility problems.

Aiding the exhibition design process: a VE system may be used:

- during the iterative design process of a certain exhibition environment, as a means of evaluating the design, or
- after the completion of the design, as a means of communicating the result.

3 Overview of existing Virtual Museum systems

Up to this day, a number of museums have adopted VR techniques, mainly for offering an enhanced presentation to the visitor. In this section an overview and a broad categorisation of these systems along with supporting technologies is presented. The term VR is by definition used for describing an interactive 3D graphics system. However a quick review of several Virtual Museums, implemented so far, reveals that this term is also being used for describing an electronic museum, the content of which has been partly digitised and presented with the help of hypermedia or 3D graphics technologies.

An overview of a large number of “Virtual” Museums shows that the technologies employed, vary widely from fully immersive cave systems to simple multimedia presentations. An attempt to categorise these systems, according to the quality of the afforded experience (degree of immersion, type and resolution of display, etc.) is presented below:

High End Systems: The most compelling direct experience is afforded by fully-immersive or projection-based VE systems. These systems use cutting-edge technology and their cost is very high, therefore the number of such installations worldwide is limited. Examples of such systems are: the Cave (e.g. Foundation of Hellenic World, Athens) [5], fully-immersive systems that utilise HMDs for display and 3D interaction and tracking devices for navigation and interaction (e.g. Char Davies’ art installations: “Osmose” and “Ephemere”) [6, 7]. Finally, the Dome-projection system used at the Hayden Planetarium (visualization of space via a three-dimensional map on a dome) could be also considered as belonging to this category [8].

Mid-Range Systems: These systems can be found installed locally in museums due to their relatively high cost. However, they are more affordable and portable and thus appear to be a more effective solution as a display or evaluation tool. These are mainly desktop VR systems, using a standard high-resolution or stereo monitor and in some cases shutter glasses. Interaction and navigation within the virtual environment occurs by means of trackballs, joysticks or 3D input devices (e.g. Tokyo National Museum [9], The Getty Museum [10]).

Lower End Systems: The majority of Virtual Museums can be accessed via the Internet by everyone who owns a low cost PC. These could either be systems for interactively viewing individual 3D objects (VRML based, Cult3D, etc.), pseudo-3D systems for displaying interactively controlled panoramic views (IPIX, QTVR) or mechanisms for viewing static stereo images of 3d models. The most common approach is the use of multimedia for presenting information about the museum's exhibits, but this cannot be considered a virtual reality system In any case. Typical examples of these systems can be found at the web site of the Tower of Pisa [11], the museum of Louvre [12] and the Hermitage Museum [13].

4. The design of the virtual museum

3.1 Museums' requirement analysis

The design of the virtual museum followed a task analysis methodology; specifically that proposed by Parent [14]. For each of the 10 museums a profile of its users was drawn, where attributes such as their language and their profession (i.e. student, researcher, etc.) were recorded. Additionally, an outline of the museums characteristics was sketched describing the museum's aim, special needs, existing infrastructure, etc. Finally a task analysis profile was composed, which included issues such as the rationale for the virtual environment, the activities it would support and the requirements for storage and retrieval. Consequently, design requirements for participants and for the target application were identified. These requirements determined the way in which content organisation and categorisation took place and generally how the creative phase of the design evolved.

3.2 Exhibit digitisation

Depending on the exhibit and the requirements set, a number of techniques were used for the exhibits' digitisation and the creation of 2D and 3D objects. The creation of 3D objects followed one these three techniques:

- 3D photography
- 3D scanning
- 3D modelling

3D photography was the easier and most straightforward of the three methods. The object was first captured by the camera as a set of photographs, which were then imported in a proprietary software and stitched together. Finally a three dimensional description of the object including the images mapped on its surfaces was deducted and exported in a format compatible with VR software. This method was not the best in terms of quality, but was more convenient for capturing objects when 3D scanning techniques could not be used (due to their surface qualities or size) or were difficult to model.

3D scanning was used in most objects where quality and detail of the representation was essential and where their surface properties allowed for laser scanning. For example, almost all of the ancient objects were scanned via this method, since the need for a precise reproduction of the original artefact could not be fulfilled by the other two methods.

Finally, when the original object mainly comprised of geometrical forms, it was feasible to produce a precise 3D representation by means of existing 3D modelling tools (as in the case of a telescope or a machine). These methods allowed for creating hierarchical models, which afford more flexible manipulation of individual smaller components that the object comprised of. For example, a model of a machine may help a participant visualise the way that it works and afford certain modifications on its operation.

In parallel with the digitisation of exhibits the architectural design of the virtual museum was carried out.

3.3 4.3 Architectural design

The museum message is communicated by an exhibition to individual participants through museum exhibits. Messages may be directly communicated via the content of exhibits but they are also influenced by:

- the way that exhibits are individually positioned
- the relation of each exhibit to the general organisation of the exhibition.

Therefore, the spatial organisation of exhibits within the virtual museum has a significant effect on the message communicated to participants via this exhibition.

It can be suggested that environmental characteristics of the virtual museum, such as lighting, positioning and orientation of exhibits and physical structure of exhibition spaces, may determine the behaviour of museum visitors when navigating or viewing an exhibition within a museum and their will to view certain exhibits [15]. It is therefore understood that the environmental design of the museum significantly affects the message communicated to visitors as well as their behaviour within the virtual museum and consequently the degree to which target and user requirements are accommodated.

All aspects of the virtual museum experience have been organised so as to add to the participant's knowledge acquisition and entertainment. It has to be stressed, however, that the design of the "virtual" exhibitions in the ten museums participating in this project mainly focuses on the educational aspect of the museum experience, rather than the aesthetic one.

Additionally, emphasis has been given on the functionality of the environment regarding user navigation and content presentation. The design of space within the museum has attempted to aid the participant into navigating within the VE, while maintaining a sense of orientation provided by appropriately designed environmental information. The utilisation of architectural knowledge has proved invaluable in enhancing the participant's environmental knowledge and in directing participant attention towards certain points or messages within the exhibition space.

Regarding the level of realism that characterises the environmental elements of the virtual museum, this paper argues that while the use of realistic metaphorical representations may allow for transfer of knowledge and skills involved in everyday activities, the use of realistic environmental elements limits the potential of VEs for creating novel forms, environments and situations. Therefore, the designed museum maintains certain generic environmental elements of the real world and attempts to investigate non-realistic forms and elements which are thought to improve the effectiveness and impact of the exhibition. In certain cases, however, a simplified simulation of a realistic setting has been considered as a more appropriate approach and has been adopted accordingly (e.g., the museum of Zoology).

A number of other issues, which have dictated the design of environmental elements within the virtual museum and which relate to the inherent characteristics of space in virtual environments [15], are referred to here:

- Space in a VE may be discontinuous A participant can teleport from one position within a VE to a remote position within the same VE when traversing between these two positions is not considered essential for the needs of the particular application. For example, traversing within certain paths in the museum environment is considered essential for the purpose of enhancing the generation of cognitive maps of this environment by participants. In the meantime, movement within these paths is aided by an automatic escalator-like function which rids participants of the effort to manoeuvre via a narrow longitudinal space.
- Physical laws do not necessarily apply to VEs. The law of gravity is considered limiting and not essential for dictating navigation of participants within the virtual museum. Indeed the lack of gravity and consequent fly-through navigation mode is seen as more appropriate for a VE that expands in three dimensions. On the contrary, the materiality of most objects is stressed by the use of collision detection on them. This property is considered essential for the purpose of clearly bounding and thus defining the museum environment and making the overall experience more effective and consistent.
- Since gravity has not been implemented, the sense of vertical/horizontal in this VE depends on environmental cues, which may enhance the sense of orientation [16]. Such cues have been carefully integrated in the environmental design (red horizon, textual signs, etc.)

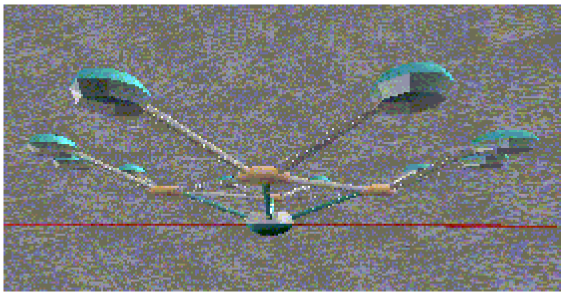

Figure 1: View of the overall VR museums' complex

The 10 museums that the designed VE consists of, have been organised into 4 categories according to their content:

- *Human-centred museums* (Anthropology, Forensic Science, Hygiene)
- *Historical/archaeological museums* (Gouladris Museum of Cycladic Art, Archaeological Museum of the Department of Philosophy - University of Athens, Museum of History of the Athens University)
- *Museums of the Earth* (Mineralogy, Geology)
- *Museums of the Flora and Fauna* (Botanical, Zoology)

The spatial design of the museum has been dictated by these categories as well as categorisation of exhibits within each individual museum according to the requirements provided by museum organisers as well as their selection of particular exhibits for display. The spatial organisation of each exhibition is also determined by the way activities are organised within each museum and this fact depends on the aim and objectives of each individual exhibition.

Several factors determine the form of each spatial entity within the museum :

- The nature, size, and number of exhibits it includes.
- The specific needs for each exhibit category.
- The way that the museum spaces are interconnected with the overall museum complex and its sub-domains.
- The 3D navigation technique used in the VE.
- The method of viewing a set of exhibits.

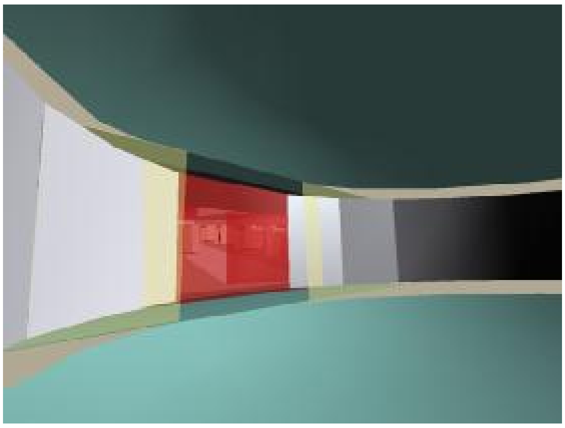

Figure 2: A museum foyer

The overall museum complex expands in three dimensions, the depth of the hierarchical structure of the complex corresponding to the dimension of "height". The structure of the museum mainly comprises of three different types of *foyer*, which accommodate the distribution of movement within the museum complex:

1. entrance hall
2. museum-category foyer and
3. museum foyer.

The participant enters the overall museum complex at a hall, which has a centralised form. Since the application is initially designed for a limited number of participants (1-2) this hall as well as all foyer spaces are not very large but simply serve as a spaces for distributing movement towards each of the 4 categories of museums. Each category corresponds to a foyer, which further distributes the navigating participant to each of the museums. As participants look up towards the museum complex from within the entrance hall, which has a semi-transparent top surface, they are able to view the structure of the whole museum and be aware of what to expect as they make their way into this structure.

Navigation between the entrance halls and foyer is performed via paths, which have a longitudinal cylindrical shape and a square section. Repetitive frame-objects are positioned along these paths for enhancing the sense of movement and providing a feedback on the distance traversed while moving along the path [17].

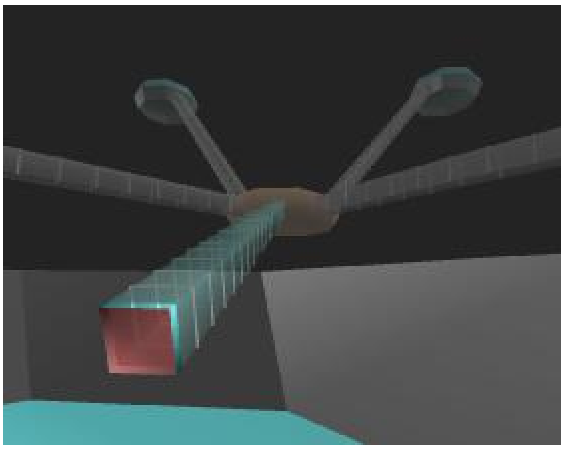

Figure 3: View of museum complex from within the entrance hall

The use of teleportation has been adopted at "higher" levels of the museum structure, for reducing movement and facilitating navigation within the VE. This is also considered essential for affording the inclusion of more exhibition halls in the future, without the necessity of significantly changing the spatial design of each museum.

Figure 4: View from a transitional space towards path exhibition halls

Figure 5: View along a path exhibition hall

At the individual museum level, participants enter each museum's foyer and may navigate to a number of transitional spaces from where they have a choice of paths or halls to follow in order to view parts of the exhibition. Each path or hall corresponds to a group of exhibits. At the end of these paths and halls there is a portal which teleports participants back to the transitional space where they can make their next navigational decision through the museum content.

3.4 Exhibit presentation

The museum message is communicated via the exhibition and its exhibits to individual museum visitors. It is understood that this message is perceived by visitors in a subjective manner, according to their interests, knowledge and imagination. A number of issues regarding the presentation of exhibits may have an impact on messages communicated to museum's visitors:

- the content of each individual exhibit,
- the manner in which the exhibit captures the visitor's attention,
- the position of the exhibit within the exhibition.

For example, one can present a set of ancient tools by concentrating on the tools' usage (religious, cooking, hunting, etc.), on the manufacturing procedure, on the medium they have been constructed from (clay, stone, metal), on the chronological era they belong, etc. Depending on the message that we want to send to the visitors, we will present the exhibits in a different manner. In the previous example, we can group together tools with the same usage, to focus on this characteristic, we can put spotlights or we can isolate certain exhibits to draw attention on them. Adding explanations, in the form of text or narration can enhance the user's experience and provide necessary informational cues.

Depending on the museum's nature/characteristics different approaches have been explored in presenting exhibits. In some cases presentation may have attempted to resemble real world museums, in a sense that a neutral spatial context is provided wherein significant objects are exhibited. However, visitors are able to perform tasks that they would not be able to carry out in the real museum. They can move or rotate objects in order to inspect them. In some cases we have to exploit virtual reality technology in order to construct an interactively experienced diorama for presenting the original exhibits more vividly.

Museums such as the Human-Centred ones or the museums of the Flora and Fauna contain exhibits that are better presented in an environment that looks like their natural surroundings. For example, one of the exhibits of the zoology museum was a penguin.

Figure 6: Photograph of a penguin model

In the original exhibition the penguin was presented as one object rather than an animal in its natural surroundings. The visitor had to visualise (using knowledge acquired from other sources, i.e. documentaries, school books, museum guides) the penguin living in its natural environment. This limitation of the real world museum could be overcome in the virtual reality museum by creating a diorama. In this exhibition the visitor enters a hall where the penguin is presented on an iceberg. The visitor can view the penguin, while the sound of waves splashing against the iceberg is heard.

Figure 7: Diorama reproduction of the penguin model

Although in the current version of the virtual environment visitors cannot really interact with the penguin, as they would with a real world animal, the experience is yet more vivid than the one afforded by the original exhibition.

3.5 System implementation

The implementation phase of the virtual environment progressed in parallel for some time with the design and construction of the architectural aspect and the digitisation of the exhibits. Once the layout of a museum's hall or foyer was sketched, the model was constructed by means of 3D modelling techniques and iterative design was applied till the environment matched the requirements. Consequently exhibits were added to the rooms and presentation modifications took place. Finally, behaviours and actions were programmed for supporting :

- appropriate navigation modes within the VE
- affording certain modes of interactive manipulation of exhibits.

To aid the process of manipulating the objects and their various versions (low, medium or high resolution, 2d or 3d) a database was created where all museum resources were stored.

Since the requirements differ among the ten museums, a number of different versions of the system have been created. These versions differ in terms of the peripherals supported:

- In the lower-end desktop version of the system, a monitor accompanied by a pair of shutter glasses are used as devices providing stereo display and a Magellan Space Mouse is used as a 6-DOF input device. This version is expected to be installed in museums, where peripherals have to be able to withstand frequent, everyday use by visitors.
- In the high-end version, users wear a Head Mounted Display and a Cyberglove, mounted with trackers, which monitor their movements/gestures. This is a version intended for researchers, since these peripherals are more fragile and frequent, not careful use can easily damage them.

4 Concluding remarks

New technology offers a great opportunity for museums to make their exhibitions available to more people in ways that was not feasible before. Although a virtual exhibition cannot replace or diminish the value of experiencing the original exhibits, there are cases where it can enhance the visitors' experience and draw new guests to museums.

In our approach ten museums with exhibits that vary from archaeological to geological and from hygiene to forensic have been combined within the context of a virtual environment. Such a system offers the visitor the possibility to view a selection of each museum's collections without having to travel. It is important to stress the significance of using a VE system as a means of exhibiting the content of a museum in another remote exhibition space, since it may afford a larger number of people the possibility of experiencing important exhibitions without having to travel far and may also lead to important collaborations amongst museums worldwide and consequently to enhancing the communication of knowledge and culture internationally.

While designing and implementing such a system, a great effort should be put on the spatial aspect of the VE, since this has a significant impact on the message communicated to visitors and on their behaviour within the VE.

Finally, we should emphasize the significance of virtual reality techniques in helping museums' guests visualise exhibits in a manner that is not possible in a real museum.

We are currently investigating different methods for presenting exhibits to virtual museum guests. In particular, we are looking into creating fully interactive dioramas, where exhibits will have selfawareness and guests will be able to interact with them.

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