Real Exhibitions in a Virtual Museum

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Abstract

When creating a virtual environment open to the public a number of challenges is faced. The equipment has to be chosen carefully in order to be sturdy, the application has not only to be robust and easy to use, but has also to be appealing to the use, etc. The current paper presents findings gathered from the creation of a multi-thematic virtual museum environment to be offered to visitors of real world museums. A number of design and implementation aspects is described along with an experiment designed to evaluate alternative approaches for implementing the virtual museum environment. The paper is concluded with insights gained from the development of the Virtual Museum and portrays future research plans.
Keywords: *Virtual environment, virtual museums, interaction design, evaluation*

Introduction

The last decades have witnessed a shift in the focus of the museums, from placeholders of exhibits to places devoted to education and at the same time entertainment of their visitors. Technology has facilitated this shift, by offering museums the means to create more vivid and attractive presentations for communicating their message to the public in a more effective manner. This can be achieved by complementing exhibit presentation with multi-sensory information (text, images, video, sound, interactive 3D graphics, kinaesthetic feedback etc.) appropriately designed and integrated within the context of an exhibition. Virtual Reality technology in particular, has already found its way in a number of museums or similar organisations in the form of Virtual Museum systems.

The term 'Virtual Museum' was coined by Tsichritzis & Gibbs[1]. In the context of this paper, the term Virtual Museum is used for describing an interactive but not necessarily immersive 3D graphics system, which aims at fulfilling the same goals as a real world museum. This definition expands the notion of a 'Virtual Museum' to that of an electronic museum comprising digitised content, which may be presented in the form of two dimensional media (usually images or video) or three dimensional objects and environments. Navigation within this content occurs in varying degrees of interactivity.

Virtual Museum Installations

Currently, Virtual Museum implementations vary from fully immersive cave systems to simple multimedia presentations. The most compelling sensory and affective experience is probably afforded by fully immersive or projection-based virtual reality 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 at the Foundation of Hellenic World [2] and the Dome-projection system used at the Hayden Planetarium [3]. On the other side of the spectrum one can find systems that can be accessed through Internet and/or viewed on low cost PCs and which let the user control interactively the viewing of individual 3D objects, panoramic views or static stereo images of 3D models. Examples of such systems can be found at the web site of the Tower of Pisa [4], the museum of Louvre [5] and the Hermitage Museum [6].

Between the above mentioned high-end and low-end Virtual Museums, several mid-range systems (Tokyo National Museum [7], The Getty Museum [8]) provide examples of more affordable and at the same time quite effective solutions, utilising desktop VR systems, with a standard high-resolution or stereo monitor or in some cases shutter glasses for a stereoscopic display.

Apart from the need for a vivid and more enjoyable presentation to its visitors a number of reasons can be stated, which justify the effort set for the development of a virtual reality museum.

- Lack of space: Since exhibition space in the majority of museums is usually limited, most museums display a fraction of the exhibits they own. Furthermore, 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 spatial context of the real museum.
- Environment visualization: a Virtual Environment system offers visitors the possibility to view a simulation of important objects, buildings or environments; these environments may either:
  - no longer exist today
  - be somehow damaged and in need of reconstruction or
  - 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.
- Secure environment: A Virtual Environment system is also a secure way of visiting an environment, which may be too difficult or too dangerous to physically visit (e.g. navigation within 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 afford a wider audience to view important exhibitions without the necessity of travelling far.

On the other hand the development of a virtual environment open to the public presents a number of challenges: equipment can be very expensive to acquire and to maintain, devices are often experimental and sometimes too fragile to be used within museum spaces, some visitors may suffer from simulator sickness, etc.

The design and development of a successful and compelling Virtual Museum system is a rather difficult and complex task which involves addressing cultural, ergonomic, technological and a series of other issues. This paper presents the experience drawn from a project, which aimed at creating a multi-thematic Virtual Museum hosting a variety of exhibits from ten different real world museums. The rest of the paper is structured as follows: section (2) provides a brief outline of the *Virtual Museums* project, section (3) describes several key issues regarding the design of the virtual environment, section (4) describes aspects of the implementation while section (5) presents an experiment designed to evaluate alternative approaches for implementing the virtual environment. The last section concludes with insights gained from the development of the Virtual Museum and portrays future research plans.

The Virtual Museums project

The *Virtual Museums* was a project sponsored by the Hellenic General Secretariat of Research and Technology within the EPET II Framework. The project's objective was to create a virtual environment where visitors of the participating museums would be able to view and manipulate exhibits either through the Internet or via a locally installed system. This virtual environment would fulfil educational, research and cultural purposes. Additionally, the project would create all the software tools necessary for the museums' curators and system administrators to add and/or remove exhibits from the virtual environment according to their needs. This paper will focus on the design, development and evaluation of the locally installed Virtual Museum system.

Ten museums, which could cater for varied and diverse preferences of potential visitors, provided content for the Virtual Museum. One of them is a private museum (Museum of Cycladic Art of N.P. Goulandris Foundation) and the others belong to the University of Athens (Anthropology museum, Athens University History museum, Botanical museum, Zoology museum, Forensic science museum, Geology and Palaeontology museum, museum of Hygiene, museum of Archaeology and History of Art and museum of Mineralogy and Petrology). The development of the Virtual Museum system to be installed locally at participating museums comprised of four major phases:

- requirements analysis and specifications,
- design,
- prototyping and evaluation,
- full-scale implementation.

Requirements analysis and specifications

The design of the virtual museum has, to an extent, followed the model proposed by Parent [9]. Accordingly, for each of the museums, attributes and requirements such as the visitors' language, profession (i.e. student, researcher, etc.), preferences, age group, etc. were recorded, forming a detailed profile of participating museums' visitors. Furthermore, museum characteristics such as the aim of the museum, its special needs, existing infrastructure, exhibitions and collections were identified and subsequently recorded. All requirements were documented in requirements' data sheets and as a result formulated the design requirements and corresponding specifications for participants and for the virtual environment system. These requirements and specifications were the basis for the design of the Virtual Museum, since they determined the way in which content organisation and categorisation took place and generally how the creative phase of the design evolved.

According to the requirements analysis the following profile was drawn for museums' visitors:

Visitors for the participating museums covered a wide range of ages and backgrounds, with a large percentage of them being primary and secondary education school children and university students. For some of the museums (as in the case of the Forensic science Museum, which was open only for students of Medical Schools) almost all visitors shared a common profile, while in others a variety of profiles corresponding to age and education groups was identified. For other museums, it was impossible to create a common profile without that being too generic. To this end, it was necessary to create a virtual environment that catered for as many of the visitors' requirements as possible. Furthermore, although a percentage of the museums visitors were computer users, it was decided that no prior experience with the use of computing systems should be assumed in the users' profile of the virtual environment. Additionally, while in other Virtual Museum installations a computer-literate guide plays the role of directing visitors' navigation and attention through museum content and context, the designed environment should afford visitors the ability to fully control their own experience. This led to the need for creating an environment that was easy and intuitive to use and which a user could start exploring after a minimum learning time.

According to the requirements analysis visitors should have been able to perform the following range of tasks:

- Navigate in the Virtual Reality Museum
- Acquire information regarding exhibits
- Manipulate objects
    - Rotate objects
    - Move objects
    - Assemble and disassemble specific exhibits

The requirements analysis also provided specifications for the hardware of the proposed system. Since the installation had to be robust enough and of a medium cost that could withstand everyday use, a semi-immersive system was considered as the most appropriate solution.

Virtual Museum design

The design of the static aspect of the Virtual Museum comprised of two tightly coupled tasks: the architectural design of the museum setting and the design of exhibit presentation for all objects that were to be displayed. As previously suggested, the identified requirements and specifications for each museum determined how their content was organised into categories and consequently affected the design of the overall museum setting and the way that all exhibits were presented.

Of equal importance to these two tasks was the design of the dynamic aspect of the virtual environment, which involved the way that visitors navigated within the museum and how they interacted with the exhibits.

Architectural design

The environmental design of the museum setting primarily aimed at supporting the visitor in navigating, while maintaining a sense of orientation within the virtual environment. In order to achieve this, architectural knowledge has proved invaluable during the design and development of all spatial elements, for enhancing visitors' environmental knowledge and for directing participant attention towards certain points of interest within each exhibition. The environmental design of the museum, which involved the design of all spatial elements as well as the overall structure of the museum complex, followed the model proposed by Charitos [10].

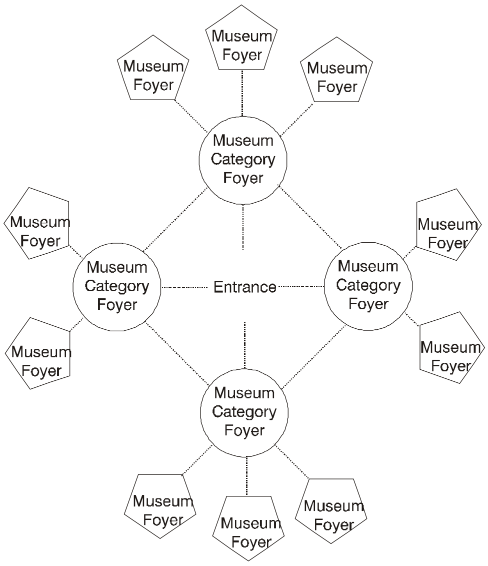

Figure 1. 2D view of the basic museum structure

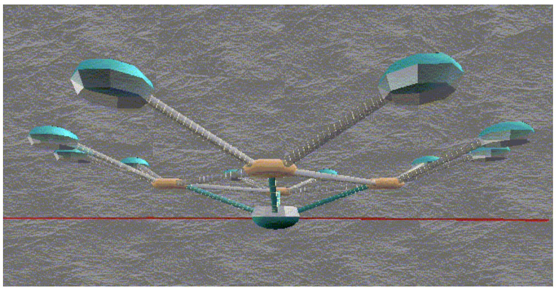

Figure 2. 3D view of the basic museum structure

The overall museum structure expands in three dimensions. Certain characteristics of spatial elements such as the use of symmetry in the overall plan or in the plan of certain spaces as well as the selective use of transparency on the material of certain surfaces, aimed at aiding visitor's navigation and orientation. The symmetrical star-shaped overall plan aims at making it easier for visitors to perceive and comprehend the overall structure of the museum complex and consequently to navigate within it. During design it was questioned whether a symmetrical plan could help or hinder users' navigation in the museum complex. An alternative structure discussed was one resembling a space-station, a circular one, where the user would either follow the halls, from museum to museum or would select the museum she wants to visit by means of teleports at specific places in the museums (like a kind of elevator). However, this plan was rejected by curators as being too restricting for users and not allowing exploration activities. The symmetric shape can on the one hand help the user acquire easily an overview of the museum structure, knowing that moving towards a lower level would always bring her to a museum category foyer or further down to the entrance. On the other hand, navigational cues such as icons, text labels, maps and colours, aided the user in recognising in which thematic category she was and how she could move to the preferred museum space.

Entrance to the museum occurs at the lower level and from there upwards the setting comprises a set of different foyer spaces, positioned at the two upper levels and connected by a series of paths. This structure aims at supporting distribution of movement within the museum setting in the best possible manner. The ten individual museums are organised into four thematic categories: museums of the Flora and Fauna (Botanical museum, Zoology museum), museums of the Earth (museum of Mineralogy, museum of Palaeontology/Geology), Historical/archaeological museums (Gouladris Museum of Cycladic Art, Archaeological Museum of the Department of Philosophy - University of Athens, Museum of History of the University of Athens) and Human-centred museums (museum of Anthropology, museum of Forensic Science, museum of Hygiene. Each thematic category corresponds to a 2nd level "museum category" foyer space. After the visitor enters the entrance hall, she is then directed to one of the thematic category foyer spaces from where she can select which individual museum to visit, starting from this museum's foyer space.

Paths connecting foyer spaces have a semi-transparent surface material, enabling visitors to be aware of their location within the overall structure as they explore the museum and accordingly orientate themselves in the complex. Repetitive frame-objects are positioned along these paths for enhancing the sense of movement and providing feedback on the distance traversed while moving along the path.
The spatial design of each individual museum was dictated by categorisation of its exhibits, according to requirements provided by museum curators, as well as their selection of particular exhibits to be displayed. The spatial organisation of each exhibition was also determined by the way activities were organised within each museum and therefore depended on the aim and objectives of each individual exhibition.

In regard to the level of realism characterising the virtual museum the design had two alternatives: follow a close to reality depiction of a museum or purge “classic” forms and design a novel museum, not necessarily of a realistic form. To this end, the latter approach was selected: the design of form in the Virtual Museum did not attempt to imitate real world elements and their characteristics [11]. Such a design approach, although often followed in similar cases, was thought to be limiting the potential of the VR medium for creating a synthetic museum space. Additionally, participating museum curators understood the Virtual Museum as a 'new' and somehow 'imaginarxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx\\y' museum that called for a novel approach towards its spatial design.
Therefore, with respect to the level of realism characterising the form of space in the virtual museum, certain generic real world environmental elements were maintained, while an attempt was made to investigate non-realistic forms and elements, which were thought to improve the effectiveness and impact of the exhibition. The adoption of certain navigation techniques like teleportation and lack of gravity led to certain environmental characteristics (discontinuity of space, need to support 3D navigation), which were taken into account in the design of environmental form.

Design of exhibit presentation

A museum, in a real or virtual world, communicates certain messages to its visitors through exhibiting its content. The message visitors receive and the way in which the message is perceived and understood can be greatly influenced by the individual positioning of the exhibit as well by the overall organisation of the exhibition. For example, by setting an exhibit on a pedestal the visitors may have a chance to admire special characteristics of the object, while by organizing related exhibits into a group a visitor may be able to perceive as well as compare these objects and to understand certain relations between them. Environmental characteristics of the virtual museum, such as lighting, positioning and orientation of exhibits as well as the 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 [12].
The virtual museum enabled museum curators to try alternative routes for exploration through the content and also offered a chance to achieve something there were not able to do in the real world museum: duplicate exhibits. In a virtual museum an exhibit can easily be integrated within two or more collections, possibly conveying a different meaning each time.

The virtual environment also gave the opportunity to present exhibits in certain ways that were not possible before. For example, the penguin in the zoology museum was easily represented in a diorama in the virtual museum, instead of being presented as an embalmed object/animal in display as was the case in the real world museum, as illustrated in the next figures.

Figure 3. Photo of the penguin exhibit in the real world museum

Figure 4. Diorama of the penguin in the virtual museum

Interaction design

The environment of the Virtual Museum can be characterised as a large, dense and relatively static (with the exemption of dioramas) [13]. Bowman et al. [14] provide an overview and references to techniques as well as guidelines for 3-D interaction design. According to the requirements analysis, a VR Museum visitor's navigation is primarily explorative, implying that visitors would probably wander around rather than search for specific exhibits. However, for visitors who explore the environment with the aim of finding specific exhibits, directional cues and teleportation mechanisms were positioned in appropriate areas. The technique selected for navigation falls in the general category of "steering", where the user points to the direction of travel. Although a number of alternative techniques exist this was considered a simple to learn and efficient technique, with respect to the objectives of a virtual exhibition.

Since exploration was the primary navigation task, it was assumed that there was no need to implement a technique that would allow the manipulation of objects, while navigating within the environment. When a user gets close to an exhibit, the pointer changes in order to indicate the possibility of manipulation. Due to the multi-thematic nature of the virtual museum, a user may find some parts of the museum more interesting than others. For this purpose, it was considered essential to implement a variable navigation velocity, which would enable the visitor to move faster in some parts of the Virtual Museum and slower in others. Successful implementation of such functionality depends greatly on the pointing device used.

On the basis of the requirements analysis and taking into account the survey of 3D input devices [15], there was a choice of three devices that could withstand hard, every day usage and at the same time offered the possibility of small learning curve: a simple 2D mouse, a Joystick and a 3D mouse (Magellan™ mouse).

Evaluation

As described in the previous section, an aspect of the research effort given to this project has focussed either on the architectural aspect of designing space or on the design of navigation and the manipulation of objects within the virtual environment. However, successful implementation of navigation and manipulation techniques largely depends on the overall design of the virtual environment as well as the input device selected. The prototype aimed at testing a series of design issues such as the layout of halls, the form of architectural space, and the textures of walls as well as the positioning of exhibits in relation to navigation and manipulation of objects by the visitors. This evaluation aimed at providing useful insights into the design aspects of a virtual exhibition as well as the suitability of the selected input devices.

Method

Experimental design

Since the experiment attempted to clarify issues concerning the appropriateness of design solutions, the methodology mirrored a real-world situation where a museum visitor would spend as little time as possible to get acquainted with the virtual museum system, and then would spend some time, ranging from five to ten minutes, exploring the environment.

Participants

On the basis described above, experiment participants were visitors of the museum of Zoology who volunteered to take part in the assessment. A total of 25 subjects, 14 male and 11 female participated in the experiment. The subjects were mostly students and researchers of the University of Athens, their ages ranging from 20 to 34. Most participants had some computer experience, while only 2 of them had some experience with VR/3D games. From the answers given to the questionnaire, it was gathered that all participants had used a mouse before, about half of them had used a Joystick and only two of them had some previous experience with the Magellan.

Procedure

The set-up of the experiment employed a desktop VR version of the system, as planned for installation at participating museums. This system comprised of a PC workstation, equipped with shutter glasses for stereo display and, as previously stated, three different input devices: a standard mouse, a Joystick and a Magellan mouse. The software platform used was Sense8's WorldUp 5.0. The next table summarises the device functionality.

Table 1 Movement assignments of the three devices used in this experiment

Action	Mouse	Magellan	Joystick
Move Up,	Right mouse button	Pull/Push in	Pull + Fire button 2

Action	Mouse	Magellan	Joystick
Down, Left, Right	+ move mouse in direction	direction	
Move Forward, Backwards	Left mouse button + move mouse in direction	Push/Pull in direction	Push/ Pull in direction
Turn Left, Right	Left mouse button + move mouse left/right	Rotate clockwise/ counter-clockwise	Push left /right
Rotate Object on vertical (Z) axis	Left mouse button + move mouse	Rotate clockwise/ counter clockwise	Move stick left/right
Rotate Object on X, Y axes	Right mouse button + Left mouse button + move mouse	Rotate cap on corresponding axis	Move stick + Fire button 1
Toggle between Movement and Object Handling	Space Key from Keyboard	Space Key from Keyboard	Space Key from Keyboard

To calibrate devices the following procedure was used: for each of the devices a set of basic actions covering the complete set of allowed actions was defined and was performed consecutively with each input device. Time needed to execute each action was recorded and adjustments were made to the device sensitivity in order to calibrate them so as to operate consistently. For the experiment needs the virtual museum of forensic science was employed (next figures).

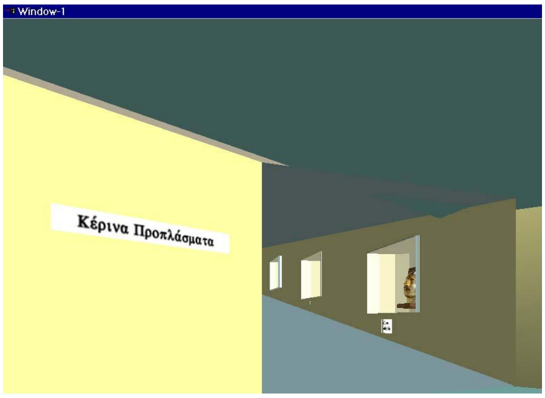

Figure 5: Hall in the museum of forensic science

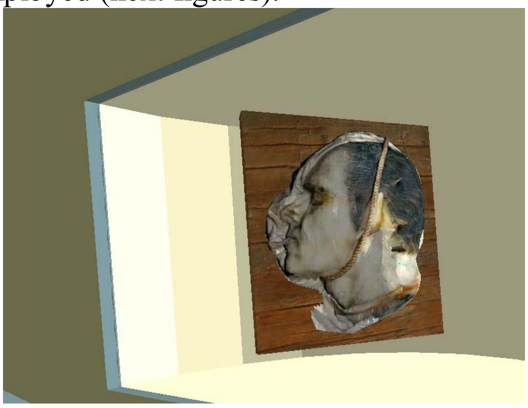
Figure 6: "The hanged man" exhibit

In the beginning of the experiment participants were introduced to its aim and objectives and had a chance to spend few minutes (less than five) in the virtual environment, so as to get acquainted with the input devices and to learn the difference between the two modes of operation (navigation and exhibit manipulation). The instructor also presented them with the route they would follow during the experiment and the tasks they had to perform. Since the input devices differed in their functionality[1], it was assumed that previous knowledge from carrying out the experiment did not affect the subjects' performance with each input device. To this end, a within-subjects approach was selected, where all

[1] For example in order to move forward with the mouse one had to click and drag the mouse forward, while with the joystick had to simply push the lever forward.

participants would use all input devices. Each participant would start with one device in random and then move to the next.
Participants were asked to carry out a number of tasks covering most basic actions that a user would execute in the virtual environment (movement and exhibit manipulation). In particular, subjects would start from the main hall, move along a corridor towards an exhibit, toggle between navigation and manipulation mode, rotate the exhibit and return to navigation mode again. The user would then continue performing the same tasks with other exhibits.
Participants' sessions were recorded by means of a video recorder. Participants could stop at any point and ask questions or make comments to the instructor. The instructor would keep notes of all comments or questions, as well as problems faced by participants. Analysis of these notes provided great help in redesigning various aspects of the virtual environment, as well as user's interaction. At the end of the experiment participants completed a questionnaire. The questionnaire consisted of two parts: a part with user profile questions and a part with questions regarding the user's experience. In the second part, questions concerned the design of the environment, the details, the layout, the positioning of exhibits and the use of input devices for the experiment tasks and concluded with questions evaluating their overall experience. In the majority of questions, users had to rate aspects of the corresponding issue, in some cases they had to note their preferences, while an open-ended question, where the participants could make any comments they liked, also existed. A translated part of the questionnaire appears in the next figure.

Table 2. Questions regarding the overall experience

How would you rate the overall experience in the virtual environment

a.

annoying								pleasing	DK/DA
1	2	3	4	5	6	7	8	9	0

b.

disappointing								enjoyable	DK/DA
1	2	3	4	5	6	7	8	9	0

c.

boring								stimulating	DK/DA
1	2	3	4	5	6	7	8	9	0

d.

difficult/trying								easy	DK/DA
1	2	3	4	5	6	7	8	9	0

Discussion

From the analysis of questionnaires, the notes recorded by the evaluator and after examining the video of participants' interaction a number of issues were identified. These issues fall into three main categories: architectural design issues, navigation/object manipulation issues and input device issues.

Architectural design issues

The evaluators noted that narrow paths hindered significantly the movement of novice users, as they demanded precision in order to enter and move through them without colliding with the surfaces that defined those paths. Users had the same problem with certain curved or tilted surfaces. Especially if curvature was large, a number of participants could not recognise the curve and collided with walls.
Some users also seemed to have problems with semitransparent walls. These walls aimed at providing visitors with views of the museum' exterior space and at alleviating claustrophobic feelings. However, some participants failed to distinguish them from openings. It has to be mentioned though that none of the

participants complained of claustrophobic feelings, while a number of participants liked the sense of transparent surfaces, because they had a chance to "*admire the view*".

Navigation and object manipulation

Users expressed a series of comments on navigation issues. Even though some degrees of movement had already been restricted (roll - rotation on the z-axis) for avoiding disorientation, users still had problems navigating. This is consistent with findings by Bowman et al. [16], which suggest that movement and rotation degrees of freedom should be as restricted as possible in order to reduce cognitive load. Many users expressed negative comments regarding the fact that they could fly and at the same time tilt their viewpoint up and down. They felt that one of the two movements was sufficient for navigation, preferably that of flying.
They also felt that it was preferable to be able to rotate an exhibit only around the vertical axis. Being able to freely rotate an exhibit around all three axes of rotation resulted in a difficulty to position the exhibit in an intended position with accuracy. Finally, since they often found themselves moving too low and hitting the floor, they felt that a “walking” action, where users' movement would follow the surface's slope, always remaining on a course parallel to the floor, would have been helpful.

Input device selection

The experiment did not conclude a clear overall preference for a particular input device. Participants' answers to questionnaires suggest that each input device is preferable for performing certain tasks. This was somehow unexpected since it was assumed that a 3D input device such as the Magellan 3D mouse would have been ideal for the majority of subjects.
A number of reasons may have led to these observations. In the case of navigation-depended tasks users found it easy to understand the notion of “click the button and move” when using the mouse for navigation. On the other hand they had some difficulty with performing the “pull the joystick in the upright position in order to stop moving” action intuitively, while wandering around. Subjects liked both the mouse and the joystick because they could easily achieve an accelerated movement. It was difficult to achieve the same result with the Magellan, since the allowable displacement from the point of equilibrium was far less than in the case of the other two devices. Furthermore, they found it relatively difficult to perform movements and rotations along only one of the axis with the Magellan. With the other two devices it was easier to restrict movement along a certain axis.
When manipulating objects, users did not find the Magellan mouse difficult to use or less precise than the other devices, but felt relatively confused by the actions they had to perform in order to rotate the objects. The instructor also observed that users had problems to get accustomed into using the device. Probably, if object rotation had been restricted to only one or two axes, participants would have found the device as easy to use as the other two. Nevertheless, the Magellan mouse was found to afford a more intuitive interaction experience of manipulating an exhibit, since it gave the impression of holding the object in one’s hand. However, it was felt to be rather ineffective when precise rotations on a specific axis were required.

Conclusions - Future Work

This paper has presented an approach and certain findings from designing and developing a virtual reality museum. Creating such an application to be used by a wide variety of users presents a large number of challenges. The designer has to develop an intuitive, consistent, user-friendly, stimulating virtual environment, with rigid hardware, able to withstand heavy every day use. In the context of this project, a number of design alternatives have been explored. In response to experimental findings, circulation spaces (paths and halls) have been redesigned and the user's ability to move and rotate has been appropriately constrained.
Furthermore, the notion of 'bouncing walls' and 'hit sounds' is currently being investigated for helping users to avoid running into walls where they can get jammed and disoriented. As far as the pointing device is concerned, we are planning to adopt the joystick. This is both due to the fact that most users rated its usability highly, its responsiveness and precision as well as its low cost and ability to endure frequent and hard use. To this end, we are also planning to test gamepad input devices as an alternative to the joystick.

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