A Virtual World Installation in an Art Exhibition: Providing a Shared Interaction Space for Local and Remote Visitors

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Abstract
Visiting museums and exhibitions represented in multi-user 3D environments can be an efficient way of learning about the exhibits in an interactive manner and socialising with other visitors. The rich educational information presented in the virtual environment and the presence of remote users could also be beneficial for the visitors of the physical exhibition space. In this paper we present the design and implementation of a virtual exhibition that allowed local and remote visitors coexist in the environment, access the interactive content and communicate with each other. The virtual exhibition was accessible to the remote users from the Web and to local visitors through an installation in the physical space. The installation projected the virtual world in the exhibition environment and let users interact with it using a handheld gesture-based device. We performed an evaluation of the 3D environment with the participation of both local and remote visitors. The evaluation results indicate that the virtual world was considered exciting and easy to use by the majority of the participants. Furthermore, according to the evaluation results, virtual museums and exhibitions seem to have significant advantages for remote visitors compared to typical museum web sites, and they can also be an important aid to local visitors and enhance their experience.

1 Introduction

Virtual Museums and exhibitions are considered an effective alternative to an actual visit, especially for people whose physical access to the site is restricted. A virtual museum is a digital representation of an artefact collection presented in a single- or multi-user environment, in which visitors navigate, observe the exhibits, learn related information about them, and in some cases interact with them (Sylaiou et al, 2009). Besides the obvious advantage of serving as information placeholders without time and space limitations, navigating within a virtual museum can generate rich user experiences that may partially satisfy the educational, recreational and social aspects of a museum visiting experience (Dede & Ketelhut, 2003). This holds especially in the case of Virtual Worlds with realistic 3D representations of the space and artefacts and with the ability to view and discuss with other users within the digital environment. People who cannot physically access a museum collection, e.g. for reasons related to distance, cost or kinetic disability, may benefit from the existence of a virtual museum that presents the same collection in a rich, interactive way.

One significant drawback of today's virtual museums is that the virtual space is completely separated from the physical space it represents. Therefore there are two independent social groups that browse the same collection and are not aware of each other: the visitors of the physical museum space, referred in this paper as "local visitors", and the visitors of the virtual museum, referred as "remote visitors". Although virtual

museums may be enhanced with interactive content generated both by the curator and the community, the local visitors are not aware of it. E.g. exhibits may have attached hypermedia information, discussion groups may emerge, comments and tags may be added by the visitors, etc. Furthermore, although visitors of the virtual museum may discuss with each other about the exhibits based on their in-world experience, they cannot exchange opinion with people who have visited the actual museum and have had eye contact with the physical collection.

In this paper we present the design and implementation of a virtual exhibition and its installation in a physical exhibition space, which allowed local and remote visitors be aware of each other and communicate within the 3D environment. The authors have set up a virtual world with a fairly accurate representation of the actual exhibition space enhanced with additional information about the exhibits, which could be accessed by Internet users through their browsers. During the exhibition, remote visitors were able to join the virtual exhibition space, browse the exhibits, view related information, add comments and chat with other visitors. Furthermore, the virtual world was also presented within the actual exhibition space as a wall projection and local visitors had the chance to view the virtual museum users, chat with them and navigate within the environment using a low-cost gesture based interface. Remote visitors were also aware of the presence and motion of the person using the installation in the physical environment, if any, as her avatar representation indicated that she was located the physical exhibition space.

The authors have performed an evaluation of the virtual world and its installation in the physical space in order to assess the usability of the environment and to discover critical issues concerning the shared experience of visitors. The virtual exhibition environment has been evaluated by a number of local and remote visitors using questionnaires and follow-up discussions, where possible. The analysis of the results has revealed that the environment was considered exciting and easy to use by the majority of the participants. Furthermore, the evaluation results have highlighted some strong points of interacting with virtual worlds within the exhibition space or remotely, as well as some issues that need to be further considered.

The rest of the paper is structured as follows. Section 2 presents the related approaches in designing and implementing virtual museums, augmenting museums with virtual worlds, and sharing museum visits through technology. In Section 3 we describe the design and implementation of the virtual exhibition and its installation in the physical space. Section 4 describes the user evaluation process and presents the results. Section 5 presents the implications for design that we have identified based on the evaluation results. Finally, Section 6 presents our conclusions and future work.

2 Background

2.1 Virtual Museums and Exhibitions

The main objectives of exhibitions are to provide a public space for the presentation of artefacts and to serve as a centre of knowledge specialized in a thematic area (Economou,

2004). 2D interfaces (e.g. museum Web sites) limit the user experience to simple page viewing and sequential browsing and leave no room for any immersive experience. On the other hand, a 3D representation of an exhibition environment places the artefacts in a natural-looking setting and may offer a much more realistic and entertaining experience (Lepouras & Vassilakis, 2004). The notion of virtual museums and exhibitions has been introduced by Tsichritzis and Gibbs (1991) as a means to overcome the limitations of the physical space and to provide a vivid experience to remote visitors. A synthetic collection of artefacts, which incorporates multimedia and virtual reality technologies, alleviates the problem of storing, preserving and protecting the real artefacts and allows virtual spaces to contain a limitless number of exhibits, to which users have access at any time and from any place. Furthermore, it may introduce new forms of presentation and interactivity that stand beyond the passive viewing of the artefacts and reading the accompanying legend, which is typically the case with traditional museum and exhibition visits. Digital artefacts may be presented using a combination of various forms of media, such as 3D representations and rich hypermedia annotations and may also let the user interact with them in many intuitive and creative ways in order to learn and entertain themselves.

Various Virtual Exhibitions have been implemented as commercial or research projects during the last decade, taking advantage of the tremendous increase in the efficiency of graphics rendering and processing of modern PCs and of the availability of 3D scanning hardware. In some cases these applications serve as complementary information source to existing exhibitions and they are usually found in the web pages of museums or galleries and contain artefacts that belong to their collection. On the other hand, there are Virtual Exhibitions that host collections of artefacts that may be abstract, imaginary, restorations of damaged objects, hypothetical models of real artefacts that no longer exist, etc. (Ciabatti, 1998). There is a great diversity in terms of visualization and user interactivity in the available approaches, as a multitude of different technologies has been employed. As per the presentation of artefacts, the approaches include simple images, panoramic views, video and hypermedia presentations, and detailed 3D models. In terms of user interface, a variety of systems have been presented, ranging from a sequence of 2D pages containing the artefacts to immersive 3D environments in which users can navigate, explore the virtual space and get haptic feedback from the exhibits (Kim et al, 2006), using specialized hardware. The interaction modalities vary from simply viewing the artefacts to letting users have rich educative interactions with them (Petridis et al, 2005).

Concerning implementation technology, virtual museums have been developed either as standalone multimedia applications or as web-based environments using various standards, such as Flash, Quicktime VR, VRML (Virtual Reality Modeling Language) and X3D. They may run remotely in the users' home computers or in public installations inside existing exhibition spaces. Virtual Exhibitions may also be presented in multi-user environments, where users are represented with avatars and may communicate using text or voice chat. In this case, users can have a collaborative visiting experience by meeting people with similar interests, commenting on the exhibits, exchanging information about the area of interest, making new friends, etc. Virtual Museums and Galleries are also being built inside persistent Virtual Worlds, such as the popular Second Life platform (Marty et al, 2007), thus making the exhibition accessible to a large, already established,

user community, with no need to install any additional software or plug-in. An overview of Virtual Museum technologies is presented in (Sylaiou et al, 2009).

2.2 Augmenting Museums with Virtual Worlds

Virtual museums can provide rich interactive content, from which the visitors of an actual museum may also benefit. The idea of installing a virtual world inside a museum is proposed by Charitos et al (2001) as a means to augment the visitors' experience. According to the authors, this solution would overcome the problem of limited space and would provide rich, lively and multisensory exhibit presentations. Furthermore, it would serve as a navigational aid for visitors inside vast museums, as the virtual representation can provide a good overview of the exhibits and their arrangement in the exhibition space. Kwon et al (2003) propose the architecture of a virtual museum, which will be accessible from the real museum through an information docking station equipped with Mixed and Virtual Reality technology and through handheld PDAs that visitors can carry with them. Robertson et al (2009) describe a museum installation that presents a photorealistic virtual environment in a large wall projection. Museum visitors can collaboratively explore the environment and browse its multimedia content using handheld devices.

A number of installations try to go beyond the simple projection of a 3D environment on a flat surface by generating more immersive experiences. Immersion in virtual worlds is supported through the use of wearable devices that provide high fidelity visualization with stereo vision, and more natural interactivity of the environment, e.g. using head tracking, hand and arm gestures, etc. (Biocca & Delaney, 1995). A number of immersive virtual reality applications have been installed in the Foundation of Hellenic World (Roussou, 2001) for educational and recreational purposes. They present reconstructions of historical cities and buildings, which visitors can explore using special handheld devices and wearing stereo glasses. A classification for immersive virtual reality installations on the basis of the hardware used for displaying and interacting with the environment is proposed in (Carrozzino & Bergamasco, 2010). The authors present a number of existing approaches and classify them using their proposed scheme. Finally, Papagiannakis et al (2005) propose the use of Augmented Reality technology to mix real and virtual scenes in the site of ancient Pompeii. Their system can generate a 3D storytelling environment with virtual actors superimposed in the real site, provided that the visitors are wearing the appropriate display devices. Immersive and augmented reality may be a promising technology for museum installations. However, it has been criticized for the feeling of nausea often caused to visitors in the extensive use of such environments, a symptom also called cybersickness (LaViola, 2000).

2.2 Shared Museum Visits

The museum visit is also a social encounter and technology can serve as a communication medium between visitors. Falk and Dierking (1992) claim that the visitors' perspective is strongly influenced by the social context and they consider it as one of the major aspects that shape the visiting experience. Additionally, one of the four

museum visitor types identified by Umiker-Sebeok (1994) is the Utopian, who is interpreting the exhibition as an encounter session and her main goal is the social interaction. In a study of the motivational factors of exhibition visitors using questionnaires in three different sites, the results showed that a significant percentage of visitors had social interaction as one of their goals (Parker & Ballantyne, 2002). Paolini et al (2000) identified the need for interaction and collaboration between museum visitors and propose a number of cooperation metaphors that can be applied in virtual museums. These metaphors involve the distribution of the shared state, the grouping mechanism, the flow of information, the user and scene visualization, the user movement and the avatar representation.

Various systems have been developed to support synchronous or asynchronous communication between museum visitors. Sotto Voce (Grinter et al, 2002) was a handheld guide that supported shared listening of audio descriptions; groups of visitors could use it to listen to each other's guidebook. An installation presented by Fraser et al (2004) allowed users to record their opinion about the exhibits and listen to other users' opinions, thus serving an asynchronous communication mechanism between visitors. Cosley et al (2009) present a system for social tagging of museum exhibits using a handheld mechanism. Visitors can read each others' tags, vote about them or add new tags to the exhibits. Dini et al (2007) propose the use of synchronous collaborative games to facilitate interaction between museum visitors. They present five games played on handheld devices that are relevant to the museum content. The games support mutual awareness and can be played collaboratively. Finally, Brown et al (2003) present a system that allows local and remote visitors of a museum share their visit in real time and communicate with each other. Local visitors use a handheld device, whilst remote visitors are using either a Web or a Virtual Reality interface. This co-visiting system shares some similarities to the installation presented in this paper, in the sense that both systems allow local and remote visitors communicate with each other, and that remote visitors are immersed in a VR environment. However, there are also a number of significant differences: a) our approach is not using an immersive VR technology, but a Desktop VR environment which is multi-user and accessible to remote users via the WWW. On the other hand, the system of Brown et al allows only one visitor to be immersed in the VR environment, who has to use special equipment, and Web visitors are interacting using a non-VR interface (Web page browsing). b) Our approach does not provide voice communication channel and does not track the actual position of the local visitors. However, it is a low-cost solution that provides a natural interaction with the environment. c) Our study has been set up during an actual exhibition and has been evaluated by the exhibition's visitors, whilst the system of Brown et al has been tested using a series of trial sessions with three concurrent visitors per session.

3 The Virtual World Installation

The authors designed and implemented a virtual world accessible by local and remote visitors of an art exhibition in order to facilitate visitor communication and to augment the exhibition with interactive content. The aim of this research was to provide a space in which local visitors can be aware of the activity taking place in the virtual world and to

take active part in it. This perception of how live remote visitors are moving and experiencing the space that local visitors have just visited or are about to visit is expected to give them additional social navigation cues (Cosley et al, 2009) and enhance their sense of co-presence. This will also allow them to acquire extra information about the exhibits and to exchange opinions about them with the remote visitors. The communication between local and remote visitors taking place both synchronously as live discussions and asynchronously as commentary is expected to facilitate the sharing of the visiting experience and to widen the social context of the exhibition visit.

3.1 System Overview

The virtual world was accessible during the exhibition of the artist Ioannis Xenakis[1], which took place between the 14th and 23rd of August 2010 in the Cultural Center of Hermoupolis in Syros island. Remote visitors could access the virtual exhibition through the artists' Web page, in which a hyperlink to the client application was provided. The virtual world was also projected in the actual exhibition space and visitors could browse the activity in real time and use the facility provided, i.e. a handheld device and a keyboard, to interact with the environment. The installation actually attracted the majority of the exhibition visitors and a significant percentage of them interacted with it. Furthermore, a lot of remote visitors joined the virtual world, especially people familiar with the artist's work who could not physically access the exhibition. Figure 1 shows a visitor using the handheld device to navigate in the virtual world.

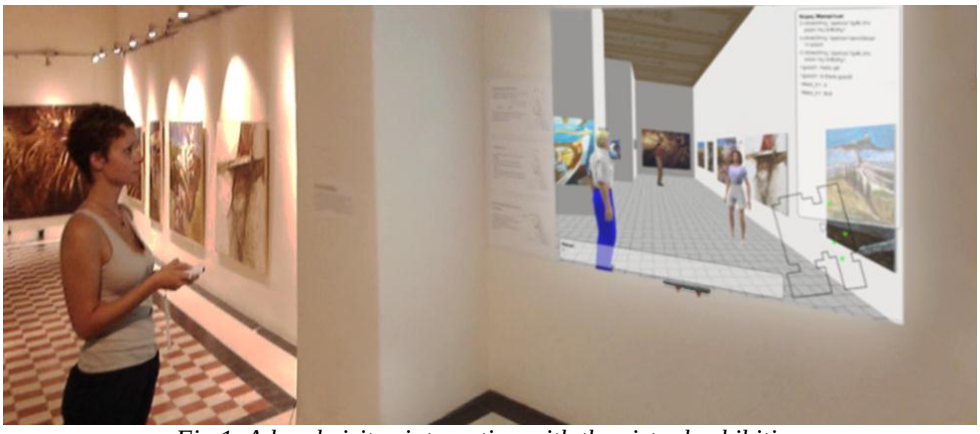

Fig 1. A local visitor interacting with the virtual exhibition

The key design choices of the virtual exhibition installation are the following:

- *Exact representation of the actual exhibition*. Although a lot of 3D virtual museums use larger virtual exhibition spaces and include more exhibits that the actual exhibition, the authors decided to design the virtual world as a copy of the physical space. One reason for this choice was that remote visitors could get a better understanding of the actual exhibition space and exhibit arrangement. The other was that the instant mapping between physical and virtual space would be beneficial to local visitors; they would easily recall the exhibits they had just

[1] http://www.syros.aegean.gr/users/ixen/

visited when they navigate in the 3D space, and they would be able to instantly re-visit a physical exhibit that captured their attention or has been referred by others in the virtual world.

- *Additional exhibit information.* All exhibits are enhanced with additional content that provides important information to visitors, especially the ones wishing to get further insight into the artist's work and related artistic movements. The content provided may also help visitors to better understand the context of the works of art and get richer interpretations of them.
- *Avatar-based user representations, discussion and comments*. Fostering visitor communication was one of the main goals of the installation. The virtual world uses human-like avatar representations of users that move in real time so that other viewers are aware of their position and point of view. Furthermore, local and remote visitors can communicate with each other using text chat and they can exchange opinions about the exhibits by reading each others' comments and adding new ones.
- *Natural user interface for local visitors.* The traditional desktop user interface, i.e. mouse and keyboard, requires from the user to be in a sitting position, or at least to use a supporting surface, which novice computer users may need to frequently look at. We decided to let local visitors navigate and interact with the virtual world in a more natural way and intuitive way using a handheld device and minimise the use of keyboard only in case she needs to post a comment or talk to the remote visitors.
- *Internet-based, cross platform application*. We wanted the virtual world to be accessible to the majority of the Web visitors without any need for additional installations. Therefore, we selected an implementation platform that allowed the 3D environment to be installed and executed directly from the Web browser and could run successfully in various platforms including Windows, MacOS and Linux.

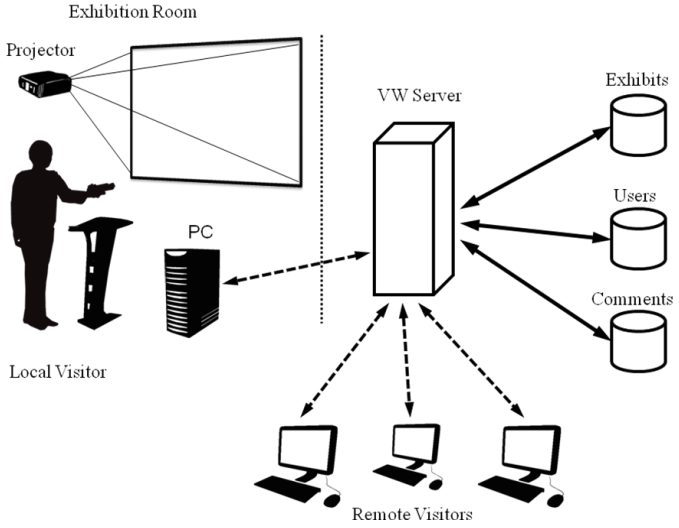

Fig 2.System architecture

The implementation of the virtual world is based on a client-server architecture. A virtual world server is responsible for the storage and update of the environment's data. It loads

the models of the exhibits, their associated information and their position and orientation in the 3D environment. It also maintains a list of the online users and their actions, e.g. navigation, communication, interaction with exhibits, and records the user comments on the exhibits. Remote visitors are connected to the virtual exhibition using a client application which is downloaded and running from their browser. The virtual world server communicates with the clients via TCP/IP and transmits all changes in the environment so that all users view a consistent version of the environment. On the exhibition room there was a computer with a slightly different client application running; the difference was that the user input was adjusted to communicate with the handheld controller and interpret its actions. The virtual world was projected in the exhibition room and users could navigate using the handheld device, which communicated with the computer via Bluetooth, and send messages and comments using a wireless keyboard placed on a surface in front of them. Figure 2 presents the architecture of the system.

3.2 Virtual World Interface and Functionality

The client interface is a desktop multi-user virtual environment. Each remote visitor initially enters a user name and selects his avatar. There are six human-like avatars available: three male and three female. The virtual world is rendered from a first person perspective and, therefore, users don't see their own avatar. Although it is common in virtual worlds to use a third person perspective, e.g. in Second Life, we preferred to use the first person view, because we wanted users to be able to observe the works of art without their avatar model blocking the view. Remote users can navigate freely in the environment with the keyboard or the mouse using a navigation technique, which is common in 3D environments and first-person computer games. During their navigation they can observe the exhibits and view the motion and actions of other users in real time. As a navigation aid we have added a mini-map, which presents a small top-down view of the environment and is always rotated towards the direction the user is looking at. The location and orientation of the users in the environment are marked on the mini-map.

Users can get more information about each exhibit by clicking on it. The environment checks the position and orientation of the user with respect to the exhibit she clicked and, if she is not standing close enough, it automatically moves the user towards the exhibit to an appropriate viewing position. Then, the user can select from a menu-based interface the type of content she wishes to view. The information associated with each exhibit in the virtual world is: a) background information about the content, artistic movement and materials used, b) related artwork of the artist not included in the exhibition, c) related artists and their indicative works (Figure 3a) and d) links to similar works in the exhibition. The latter is visualized in the environment as follows: routes are drawn on the ground from the user's current position to the target exhibits, the exhibits are labelled as 'similar' and their location is also marked on the mini-map (Figure 3b). Finally, users can browse other users' comments on the exhibit they selected and post their own ones.

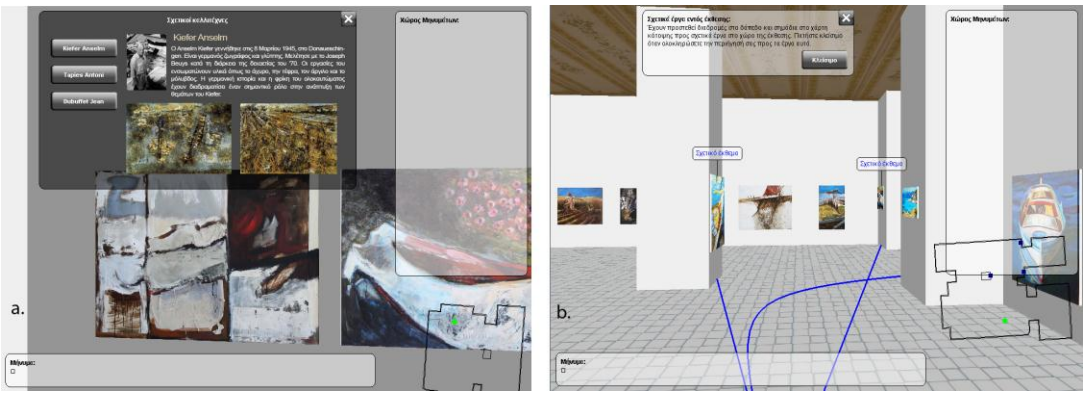

Fig 3. Screenshots of the virtual world. a.Information about relevant artists b.Routes to similar exhibits

Communication is taking place in the environment using text messages. Whenever a user sends a message, it pops up and stays visible for a few seconds above his avatar's head. User messages are also permanently displayed on a message window allowing users to keep track of the chat history. The message window additionally displays other user actions such as a user entering or leaving the environment, the posting of a comment, etc. Finally, if a user is using the exhibit menus to view further information or comments, a status message is displayed on his avatar so that other users can be aware of her activity.

3.3 Installation Interface

Local exhibition visitors view the same multi-user 3D environment and can perform all available actions. Their avatar appears in the environment with a status message that the user is "located in the physical interaction space". They can interact with the environment using a Nintendo Wiimote, i.e. the controller of the Wii game console which is capable of sensing motion and acceleration, and a keyboard for sending messages and comments.

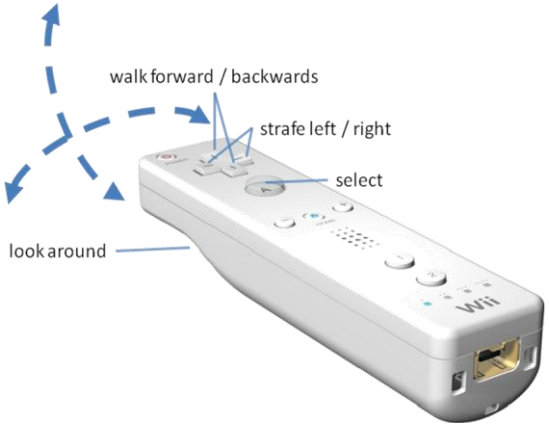

Fig 4. User interactions with Nintendo WiiMote

The Wiimote can be used in the following interaction modes:

- *Mouse mode*. This mode can be used for clicking on the exhibits and interacting with the menus. If the user points the Wiimote on the screen and moves his arm,

the mouse pointer is positioned accordingly. Pressing the "A" button is the equivalent of a left mouse click.

- *Look around mode*. If the user presses and holds the "B" button of the Wiimote and slowly moves his arm to any direction, her viewpoint in the 3D environment will rotate accordingly. This mode is useful for observing the environment from a fixed position.
- *Walking mode*. If the user presses and holds the "Up" direction arrow, her avatar will move forward in the environment. Moving the device to the left or right while holding the button will change the walking direction accordingly, thus allowing the user to steer her motion. The "Down" direction arrow causes the user avatar to move backwards and can be steered as well. Finally the "Left" and "Right" direction buttons make the avatar walk sideways to the left or right side accordingly, a technique known in first-person computer games as *strafing*.

Figure 4 presents all available user interactions in the virtual world using the Wiimote controller.

3.4 Implementation Details

The implemented system is integrating a number of technologies. The client applications have been implemented in Java and run over the Web using the Java Web Start technology. They utilise the Java3D library for the construction, visualization and real-time interaction of the virtual environment. The 3D models of the exhibits have been built in VRML format using high resolution photographs of the actual exhibits and the exhibition space has been modelled based on its ground plan and using photographs as textures in some parts of the space for added realism. We intentionally avoided putting too much detail on the surrounding environment because we wanted the application to run in adequate refresh rates even in older computers. User avatars have been built using low-resolution models of Curiouslabs Poser and are also stored in VRML format. The VRML models are imported in the client applications with the use of the java3d-vrml97 loaders. The virtual world server is a Java application that communicates with the clients using standard TCP/IP sockets and a dedicated communication protocol that supports the message exchange between them. Finally, the Wiimote interface with the client application running at the exhibition room is supported by the WiiUseJ library.

4 Evaluation

We performed a user evaluation of the virtual world and its installation in the exhibition in order to assess the usability of the proposed system, to gain empirical observations and to discover critical issues concerning its usage. Our evaluation method included monitoring of the visitors' behaviour during their interaction with the environment, follow up questionnaires and discussion. Remote visitors were also asked to fill the same questionnaires via a Web form. 43 people participated in the evaluation, out of which 25 were local visitors (11 male and 14 female) and 18 were remote (12 male and 6 female). Concerning the age distribution the majority of the participants were between 18 and 35 (39.5% aged 18-25 and 32.6% aged 26-35). Six users were under 18, five users were between 36 and 45, and only one user was over 45. The questionnaire asked users to rate

their experience with 3D environments (e.g. 1st person games) using a 1-5 scale (1: not at all - 5: very experienced) and the average was 3.23.

The majority of the users found the virtual world exciting and easy to use. In a question asking users to rate how stimulating was their experience from the use of the application in a 1-5 scale (1: very boring – 5: very exciting), the average value was 4.4 (local visitors: 4.48, remote visitors: 4.29). The average visitor rating of how easy was their navigation in the 3D environment (1: impossible – 5: very easy) was 4.35 (local visitors: 4.4, remote visitors: 4.29). An interesting observation is that the local visitors navigating with the Wiimote, which they probably used for the first time, did not have significant difficulties using it. Furthermore, all users that reported having little or no experience with 3D environments rated the ease of navigation with 4 (easy) or 5 (very easy). Finally, the users were asked to rate their awareness of the presence of other users in the environment (1: not at all, 5: very aware). The average value was 4.16 (local visitors: 4.13, remote visitors: 4.22). The evaluation results concerning the visitors' experience of the virtual world are summarised in Table 1.

	Local Visitors	**Remote Visitors**	**Total**
Stimulation (1 very boring – 5 very exciting)	4.48	4.29	4.4
Ease of navigation (1 impossible – 5 very easy)	4.4	4.29	4.35
Awareness of other users (1 not at all – 5 very aware)	4.13	4.22	4.16

Table 1. User rating of their experience with the virtual world

Users were also asked about the advantages of 3D virtual exhibitions compared to typical exhibition Web sites. They could select more than one answers from the following: a) the presence of other users and the ability to chat with them, b) the presence of visitors from the physical exhibition space, c) the placement of the exhibits in a representation of the physical space, d) a more natural way of navigating and browsing the exhibits. Respectively, they were asked about the disadvantages of virtual museums compared to Web sites and the possible answers were: a) worse presentation quality of the exhibits, b) less chances to present extra information about the exhibits, c) difficulties in navigation, d) incompatibility with some platforms (e.g. cell phones, older computers, etc.). The results are presented in Figure 5. One may note that the advantage of browsing the exhibition in a more natural way has been selected by over 70% of the local visitors, a percentage significantly higher compared to remote visitors. This could be related to the fact that local visitors were using a gesture based interaction device instead of the typical mouse / keyboard input of the remote visitors and the environment was projected in a significantly larger area compared to a typical computer monitor. One user (remote visitor, male, 26-35) added the advantage that the natural size of an exhibit is easier to understand in virtual museums, because the user can see its analogy with the other exhibits and the room. Regarding disadvantages of virtual worlds, the navigation difficulties and the limited information about the exhibits were selected by only a few visitors. On the other hand, the presentation quality of the exhibits and the

incompatibility with some platforms seem to be considered important drawbacks by the visitors.

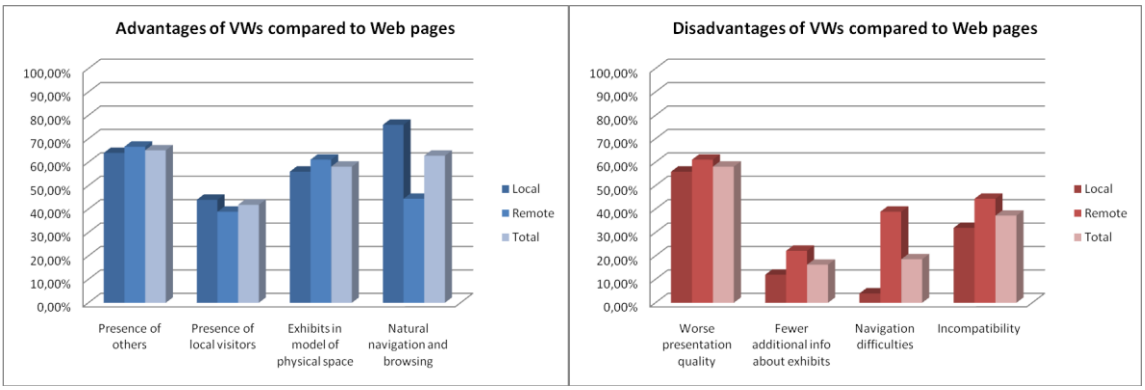

Fig 5. Advantages (left) and disadvantages (right) of virtual museums and exhibitions compared to museum web pages

There were also a couple of questions addressed only to local visitors, who had the experience of visiting both the physical and the virtual space. We asked them how similar was the visual representation of the exhibition presented in the virtual world compared to the physical exhibition space (1: not at all, 5: very similar) and the average value was 4.62. Another question was whether they the additional information presented in the virtual world was useful for their interpretation of the works of art (1: not at all, 5: very useful) and the average value was 3.93.

The observation of local visitors' behavior, the discussions with them and their free text answers in the questionnaire comply with the aforementioned results and reveal some interesting points for further consideration. Visitors were curious to watch and use the installation and needed little or no assistance using the Wiimote. They were especially excited when remote visitors were present and they could communicate with them. The most common communication utterances were about their opinions of the exhibition and of specific exhibits. In several cases people moved their avatars in front of exhibits to highlight the ones they were referring to, e.g. in discussions about which they liked most. In some cases remote visitors were asking general questions about aspects of the exhibition that they could not observe through the virtual world, such as the number of local visitors, the 'feeling' of the actual exhibition space, the general impression of visitors, etc. Finally, there were also cases in which users were asking for assistance on the use of the virtual world interface or were starting more generic conversations with each other.

Concerning their general impression of the installation, some users wrote that they would like to see more information about the artist and his works within the environment, e.g. to see his artistic evolution, his sources of inspiration, etc. One user (local visitor, male, 18-25) specifically noted that it would be interesting to include more information for users without significant background in the history of arts to assist them in interpreting the works. One local visitor and two remote would like the environment to offer additional navigation techniques usually found in computer games. Another local visitor (female,

<18) wrote that “it is amazing that Wii is being used for moving in the 3D world”. There were a number of participants that highlighted the expected benefits of using virtual representations of museums and exhibition. They mentioned that they would be especially useful for people with kinetic difficulties and for people who do not have the time or money to visit all the museums they would like to. They also noted that the use of a virtual world inside a large exhibition space would be useful for visitors to see a preview of the environment and plan the route of their visit. Finally, there were a couple of visitors who said that the actual visit to the exhibition generates much stronger emotions compared to a virtual visit and expressed their concern whether virtual worlds would reduce museum visits in the future.

5 Implications for Design

Individuals differ in how they construct their aesthetic experience, and visitors without significant background knowledge in art history usually require a lot of care or feeding in an exhibition (Smith & Wolf, 1996). Virtual worlds can help towards that way by augmenting the works of art with further information addressed to various visitor types, as same participants suggested. Considering that virtual worlds offer a more natural and intuitive way of presenting and interacting with the environment, a challenge for the interaction design community would be to discover novel metaphors for enhancing virtual museums with rich, interactive and adaptive information.

A significant drawback for designing and developing interactive 3D environments is the notable lack of protocols and standards, a fact, which prevents their reusability and interconnectedness. The popular virtual world of Second Life may help towards that direction as it has a very large user base and a lot of content has already been developed in its worlds. However, its user interface is not customizable, one cannot install a private server, and the land ownership requires monthly subscription. Another critical issue regarding virtual worlds is that they require high processing power to be rendered in acceptable frame rates and, therefore, they are not suitable for computers with less capabilities, such as smartphones and netbooks, which are nowadays being used for browsing the Internet. On the other hand, visitors of virtual museums expect as much realism as possible. Therefore, designers should reach a good balance between visual quality and minimum system requirements.

The interaction of exhibition visitors with a virtual world is expected to give further insight about the motion and preferences of visitors, e.g. whether they they prefer a linear organization in exhibitions, or a more holistic or global presentation (Veron and Levasseur, 1983), and may aid the development of adaptive content presentation (Bonis et al, 2009) targeted to various visitor types.

6 Conclusions and Future Work

This paper presented the design implementation and evaluation of a virtual world that allows local and remote visitors of an art exhibition co-exist in a shared 3D environment, access additional information about the exhibits and communicate with each other. The

evaluation results were promising. The virtual world installation captured the attention of visitors and they were quite excited from using it despite the fact that it was based on low-cost hardware. Furthermore, the evaluation revealed some important advantages and drawbacks of virtual worlds, as well as some issues that need to be considered by the research community.

In the future we are planning to expand our implemented system to a generic platform for designing virtual museums and use it to build a network of interconnected museum environments. Furthermore, we aim to experiment with mixed reality environments that will enhance the communication between local and remote visitors with voice and real-time video in order to offer more rich and vivid co-visiting experiences.

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