The experience of the Empty Museum. Displaying cultural contents on an immersive, walkable VR room.

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Abstract

This paper describes the use of an immersive, walkable VR system called The Empty Museum that the authors have developed to allow the users to walk in virtual spaces where they can experience interactive 3D cultural contents. The paper briefly describes the architecture of the system, to focus on the analysis of the modes of interaction between user and content in this hybrid space where the user itself takes the role of the cursor and the physical space constitutes the interface. Finally, it shows several examples of its use on a real exhibition to display contents related to local topics, from traditions to Art.

1. Introduction

During the last decade, Virtual Reality matured and became a powerful tool to display cultural contents, specially those related to the Architectural Heritage. Many examples of VR installations were implemented in exhibitions all over the world, from HMD based applications to Reality Centers and CAVE's.

With the use of those systems, VR proved its potential and clear advantages as a new medium to communicate things that can't be shown otherwise. The aforementioned installations, are excellent in terms of immersiveness and sense of presence, but they have the limitation of the need of the user to stand in a fixed place while the contents move around.

The natural way a person experiences space, i.e. observing while moving in any direction, made it necessary for simulations to use hardly believable metaphors in VR environments [1]. Through a joystick, mouse or other similar type of direction controlling interface, the user is expected to imagine he or she is moving around a virtual setting in a car or by means of other external forms of propulsion.

The necessary use of the imagination to perceive the metaphor of the vehicle as something real takes away naturalness and, consequently, much of the sense of presence to the experience of the exploration. When moving through a space in the real world, the sense of movement a person experiences is not only the motion in itself, but also the kinaesthetic sensation of perceiving his or her own body in movement. The interpretation of our own movement helps us understand the scale of what surrounds us.

The fact of letting the user walk around the VR setting increases the sense of presence of the experience because he or she moves naturally through a real space, without the aid of artificial devices to simulate the movement. This user does not need to practise in order to gain skill in moving around and the sense of motion is real. The absence of wires is also an important factor to facilitate free movement around the virtual/real space.

There are already several wireless systems, i.e. MARS [2][3], Archeoguide [4], that allow the user to walk freely without connection to a workstation, while displaying the 3D contents; they are mainly applied to outdoor Augmented Reality environments. Other systems like VENLab2 [5] allow a wired user to walk inside a room. Our work was instead focused on the application of a wireless immersive system to improve the sense of presence in VR environments to show cultural contents, and to explore the kind of worlds that may be designed to be experienced with that

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technology, adding other capabilities such as multiuser interaction in the virtual world.

This paper first describes the architecture and design issues we worked on to implement a wireless, multiuser, immersive VR system that allows the users to view and interact with multimedia contents, while walking around and sharing three-dimensional environments. This system is equipped with high-resolution graphics and is compliant with authoring tools and a data format for the creation of the multimedia contents.

The idea is to use real space as one of the elements in the motion interface and as part of the actual virtual space. This facilitates experimentation with synthetic architectonic type spaces. The contribution of our work is based on the use of a new form of contents, where the experience of the visit goes further than simple contemplation. Although there is still much to do, we have started to study the parameters associated to the perception of one's own movement and worked on new forms of interaction with the virtual contents and other users, based on the location of the observers.

2. The architecture of the Empty Museum. System design

The system described here was planned as an extension to HMD based systems we had previously developed for different purposes. During the handling of these systems, two significant attitudes were repeatedly observed in the users.

In the first place, there was a tendency of starting to walk with the HMD on, while observing the environments. However, movement was limited by the short cable that connected the user to the station that generated the VR images.

Secondly, we noticed the difficulty of the users to learn to skillfully handle "artificial" systems that simulate movement (i.e. mouse-based) even when very elementary. Certain movements were very complicated; for example, stepping back two paces, ducking, turning around, moving sidewards in a circle or just varying the speed. The simple fact of being able to look in one direction while moving in another was confusing. The alternative of not regarding this possibility, so movement could only take place in the direction looked at, though less confusing, set such limitations to freedom of movement that made the system less natural and quite awkward.

With the objective of avoiding these limitations, we decided to work on the hardware of a wireless VR multiuser system. It was also desirable for the devices carried by the user to be comfortable, light-weighted and manageable. As HMD we chose Sony's Glasstron, because it is much lighter than other HMD while offering a good image quality. The main disadvantage is its reduced field of view.

The display information is sent to the HMD from a portable computer the user carries in a backpack. The portable computer integrates an nVidia GeForce chip that provides quite powerful graphic performance.

The tracking system needs 6 DOF to detect the position and orientation of the users at all times. The technology commercially available at the beginning of the project led us to use the Intersense InertiaCube2 as orientation tracker and IS-600 as position tracking system. The latter is attached to a workstation that communicates with the users' laptops through a wireless network. With this tracking system, a millimetric resolution for the position can be reached, not possible with other wireless systems (as those based on GPS).

This hardware configuration allowed the system to be wireless, while keeping the user as light and comfortable as possible. The overall design of the system is depicted in figure 1.

The system's software architecture is composed of two applications, corresponding to the fixed-mobile units division shown in figure 1: a controlling application that is run on the workstation that manages the wireless tracking system (base), and a visualization application that is run on the laptop carried by the user (satellite).

The base application monitors the connections of the satellites present in the system and allows the operator to view the condition of these satellites, disconnect them, calibrate their tracking devices, assign virtual worlds to them, etc.

The satellite application continuously receives its position from the base through the wireless network and its orientation from the InertiaCube2. From this data, it generates the images and sounds the user should perceive in each instant, corresponding to the position of his or her head. It also processes the interaction with other users and elements in the virtual world.

A full description of the design of the system can be found in [6].

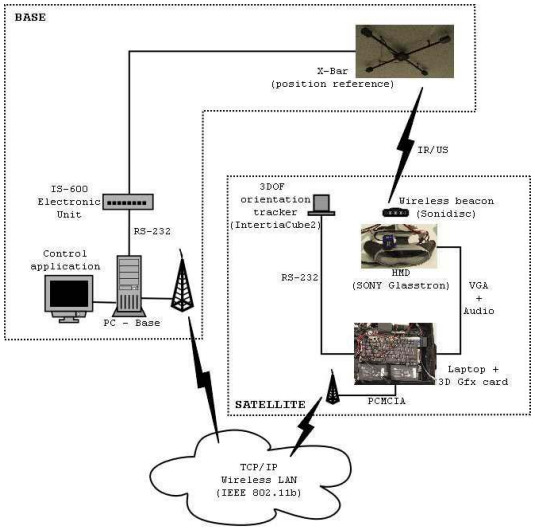

Figure 1. Diagram of the system blocks.

For the construction of the virtual worlds we initially used the VRML 2.0 format, for its versatility. Apart from defining the scenegraph with geometry, materials, textures, lighting, etc., it enables the incorporation of spatialized 3D sound, animations, video and behaviours controlled by sensors of proximity, touch, visibility, etc. In general, it provides a great potential for interaction and combination of multimedia elements.

This system also allows multiple users to visit the same or different virtual worlds at the same time, in the same real/virtual space.

The users can see each other as an avatar, a 3D model (including all the VRML2 dynamic multimedia and interaction posibilities) which moves associated to the corresponding user's position. Also the avatar can be composed of different blocks which move/rotate and behave differently.

This avatar management allows interaction between users and with the elements of the world. It is also possible to interact with users that are in a different physical space (logically mapped to the same virtual space) using a similar facility in distant geographical locations, i.e. for applications involving telepresence.

The Empty Museum is an environment designed to show virtual contents. Thus, avatars must be designed, if possible to be part of the experience of visiting those virtual worlds. The system can assign the behavior of the avatar to any model chosen by the designer of the scenery, so every virtual set can have its own avatars with an appearance according with the content of the world being shown.

3. Hybrid space

The users of the Empty Museum experience space in a double manner. On one hand, the space is what he or she knows as such, with known dimensions, a real area the person is conscious of being in (figure 2). On the other hand, in that same space there are virtual objects. Not only does the user see and accept these as inserted in the space, but is also able to identify their size and position in relation to him or herself through parallax when moving around, nearer and further from them. The virtual space (not the objects inserted in it) is, therefore, as genuine as the real space, inasmuch as it has its same properties. As a user, you see yourself immerse in a hybrid space in which it is easy to move around and observe the objects. The real space thus becomes part of the interface.

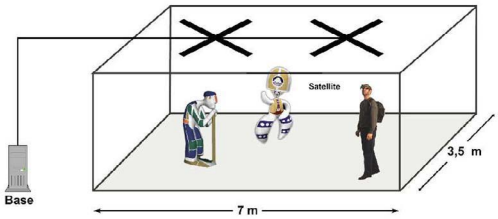

Figure 2. Empty Museum for three users. Every user sees the others as avatars.

As a multiuser system, there can be various users at the same time in the same hybrid space. However, the system also enables various users to share the same virtual space without being in the same physical space or be in the same physical space, but in different virtual worlds [7].

The dimensions of virtual and real spaces can, however, be different in size, and this difference can be manipulated by introducing a scale factor in the movement. This way, we can fit a large virtual space into a much smaller dimensioned physical space. The user moves around, taking steps that can cover various metres of the virtual space, giving a sensation of very fast movement that is surprisingly not unpleasant. On the contrary, the testers described it as natural and flowing. This allows us to display great virtual spaces in a small room. When experimenting with an example of architectonic space, we displayed the inside of a more than 30m long building in an Empty Museum of only 8m long.

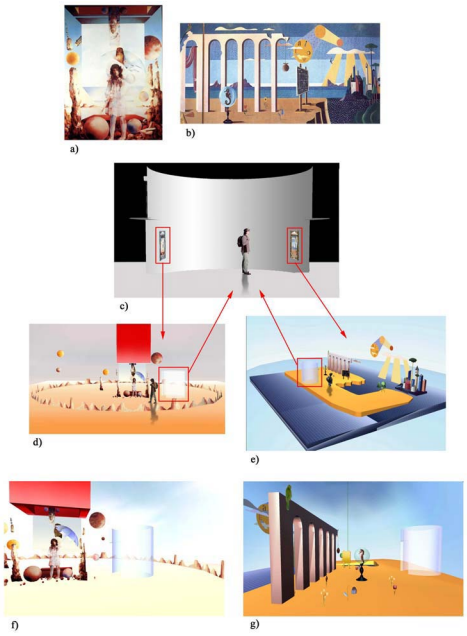

Figure 3. The Art Gallery: a) and b) Original paintings c) Art gallery with the paintings exhibited. (The arrows indicate the location of the teleport elements and their destination). d), e) The user inside a 3D version of painting. f), g) User's view

For worlds that are much larger or complex, we have also experimented with the "teleport chamber", a metaphor well accepted by the users. This metaphor consists of placing a special element in the virtual world, such a bright cylinder, that, once the user steps into it, switch to another virtual world, behaving as a transfer system that will take him or her to other locations in the same, or in another different virtual place. Figure 3 illustrates the application of this concept in "The Art Gallery", one of the contents made to test the system.

4. The contents of the Empty Museum. Worlds for test bed and exhibition.

We initially designed several worlds to serve as a test bed for the system in order to check the functionality of the hardware and software and the behavior of the users during the experience. Most of these worlds were found suitable for exhibit so they compose together with other worlds made on-demand a catalog of virtual experiences that gives variety to the permanent exhibition in which the Empty Museum takes part.

4.1 The Museum of Sacred Art

This world is inspired in the Romanesque music, sculpture and architecture. The user appears in a hall where there are signs that make reference to certain medieval instruments portrayed in the Portico of Glory of the Cathedral of Santiago de Compostela. When drawing near to any of the signs, an image of the sculpture of the musician corresponding to the instrument named in the label descends towards the user and a three-dimensional model of the actual instrument emerges from the previous image and its music begins to sound. This allows the user to contemplate the instrument while listening to its sound.

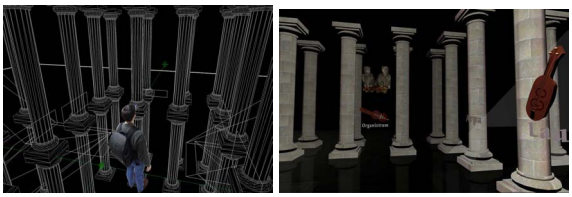

Figure 4. Museum of Sacred Art. Location and view of the user.

The user walks around all the world's areas of exhibition, observing the different instruments that, once displayed, remain visible or "already activated". The persistence of the changes provides more realism to the experience, given that it is an attribute of the things in the real world.

4.2 The world of the Galician sea.

The Galician region has a strong relationship with the sea. It has many traditions, legends and traditional fishing industries related to the ocean. This world displays some of the marine life, traditional fishing arts, shipwrecks and the sounds related to the maritime atmosphere.

The user appears in a marine setting, just above the water surface. There are seagulls in the air, crying out and flying around in circles, boats sailing, traditional mussels farms, dolphins swimming and jumping out of the water. The user can dive underwater to see more objects.

When the user ducks, he or she can then see the submarine world. There is a certain surprise when the user finds what he or she would expect to see: shoals of fish, seaweed, the mussels growing in the wires of the farms, a shipwreck... Vision becomes misty and the echoes of the sea depths can be heard, together with the sounds of the dolphins that swim past nearby.

It is a much more dynamic world that in the previous case, as it includes spatialized sound and animations that the user can discover by exploring the different corners of this world. The user passes from the surface to the underwater world in a natural way, as would happen if he or she were really in that space at a giant scale.

Figure 5. Sea Museum. Surface and immersion. The real images correspond to the laboratory, before is was ported to the final location.

4.3 The storm

Shipwrecks are a recurrent topic in people's memories in this region. It is not in vain that part of the Galician coast is called "Coast of the Death".

In this virtual world, we tried to transmit to the user the feelings of a shipwrecked sailor in the middle of a violent storm in the sea. To achieve this, the user is placed in the middle of the room, while in the virtual world he or she can see a calm scene over the surface of the ocean. An island appears in distance, seagulls songs over his or her head are passing by. Then wind suddenly starts to blow, the sky begins to cover with dark clouds, and rain begins as the waves begin to raise progressively higher and wilder and the fog surrounds the user. The sounds of the tempest get louder; and remains of a ship float on the wavy surface. The user has to walk and reach one of them to get the calm again.

The use of spatialized sound, particle systems for the rain, fog, a realistic simulation of waves and foam, together with the activation of air fans during this simulation make it a very vivid experience for the user.

Figure 6. The Storm. Two moments of the experience.

4.4 The Paint Gallery. Worlds in other worlds

The user starts out in a paint gallery that displays two works of surrealist art made by two galician painters of the beginning of the 20th century (Figure 3). When walking through any of them, as Alice through the looking glass, the user appears in a moving, three-dimensional version of the painting, as if looking into the artist's mind. In one of the corners of this dream world there is a white cylinder that metaphorically represents a teleport cabin. When the user has finished examining the imaginary world, he or she can walk into the cylinder and be teleported back to the paint gallery, where the experience can be repeated with the other art piece.

This world includes a new characteristic, i.e. the inclusion of various worlds inside one same world. The user can be teleported from one to another very easily, based on a concept between hyperlink, since it acts as a link between two elements of information, and teleport chamber, given that it is perceived and works as such. The users accept this type of movement between worlds as natural and very easy.

4.5 The Museum of the Galician Arts. A Multiuser experience in the virtual environment.

It was necessary to design some specific contents in order to test the functioning of the system in the multi-user mode, so as to make the most of its full set of features. Thus, when designing this world, it was intended that the contents to be shown would include:

1.- Spatial elements. An architecture designed on intent following a (virtual) universe rules where gravity, lighting, and material costs parameters are different from those of the real world. The architecture of the virtual gallery itself is part of the exhibition, and it has a realistic side, while it shows unreal elements such as

floating walls, exhibition areas which activate with the user's approach, etc. Walls and partitions exist only to serve as a spatial reference for locating the interactive points, and also to help the user know which parts are walkable and which ones are not. This method enables users to walk only on the precinct occupied by the real space controlled by the system, and to visit it in a natural way, knowing where the interesting areas are located.

2.- Volumetric elements. *Empty Museum* allows users to turn around virtual three-dimensional objects which are found in the application's hybrid space. Not only the elements in the exhibition are three-dimensional, but also the users' avatars themselves are part of the exhibition, in the shape of traditional Galician pottery designs.

3.- Spatial sound. Sound is constantly present in the experience. Not only as atmospheric music, but also by means of sentences uttered by a guide-character (a butterfly) tells the user from time to time encouraging him to watch this or that element. Some of the arts in the exhibition also use spatial 3D sound (cinema, music, literature).

4.- Texts. It was interesting to check the capacity for reading texts in the virtual environment, to the extent of being able to read a poem written on a real-size book.

5.- Multimedia. Together with texts, images and audio, video is present among the contents, showing a cinema example created in Galicia as another work of art.

This is what the visiting experience feels like: When entering the world, the user is immersed in a singular architectural scenario composed of stone and concrete elements within an open space. After a welcome voice message, he/she may see that some semi-transparent blue objects surround him/her. These blue areas tell them where the action is. Each one of them corresponds to a different art. As the user approaches, an event takes place setting in motion a series of behaviours related with that specific art.

At one end of the walkable space there is a balcony surrounded by two walls from which a stone wall can be observed in the distance. When the user reaches the balcony, a cinema screen is displayed on the far wall which shows an extract of the film "El Bosque Animado" ("The Living Forest") (Fig. 7).

At the other end a blue crystal gangway may be seen, where a sculpture by Francisco Leiro comes out of the blue as the user passes by (Fig. 8).

A painting by Jaime Quessada may be observed next to the sculpture, which appears as the user approaches the area (Fig. 9).

With regard to literature, there is a blue backdrop behind a stone pillar. When the user comes close, a 3D Rosalía de Castro book opens before him/her, and a voice starts reciting a poem by the author. A series of images related to the writer's life are shown on the blue backdrop (Fig. 10).

The music scenario is similar to that of literature, but in this instance it is not a book but a bagpipe that appears on the pillar. Galician music sounds as a series of images related to the topic are shown on the backdrop (Fig. 11).

Between the literature and music areas there is a semi-transparent blue sphere floating in the air at eyesight height (Fig. 12). A voice will tell the user passing by that he/she must walk into the sphere in order to visit the architecture area. When this happens, the space where the user was suddenly disappears, and they find themselves inside Santiago de Compostela cathedral, which is generated from a spherical and panoramic image. As they leave the sphere, they return to the original scenario.

Apart from these six arts shown at different museum areas, users have been represented as part of the world, examples of a seventh art which is always present in the experience, i.e. pottery. Thus, users are perfectly integrated within the scenario, turning from mere watchers to being part of the exhibition content.

Therefore, users are represented by avatars in the shape of Sargadelos pottery figures (Fig. 13) that will move following their movements. Besides, the pottery figure's head follows every movement of the user's head, improving the presential feeling of the user inside the world, together with the perception of the other users, instead of being mere decorative elements. We could go as far as saying that this movement makes the rest of users more expressive. For instance, it is curious to see a user located inside the sphere looking up and down and turning around in order to watch the cathedral's interior. This leads the other users to believe that there is something interesting to be seen in that place. Another interesting scene is the one where

the avatars in a circle chat with one another, which becomes natural in the virtual world.

Figure 7. Cinema

Figure 8. Sculpture

Figure 9. Painting

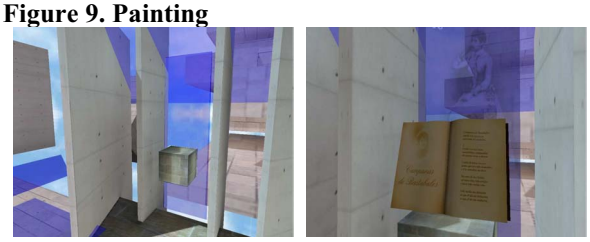

Figure 10. Literature

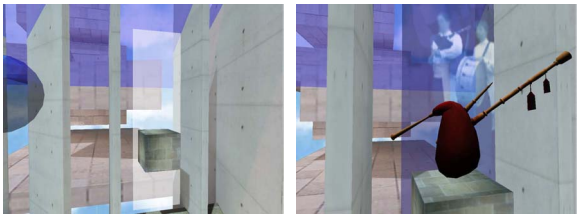

Figure 11. Music

Figure 12. Architecture

Figure 13. Multi-user. Real world view (in the lab), virtual and subjective view

5. The Empty Museum in *the Galicia Dixital* exhibition.

The system is actually running as one of the attractions of a permanent exhibition called *Galicia Dixital,* located in Santiago de Compostela (Spain). This exhibition is devoted to show the Galician culture, history, traditions and art by means of the use of new technologies. Hence, the visitors can acquire knowledge of cultural and technological topics at the same time. Figure 14 shows the installation of the system.

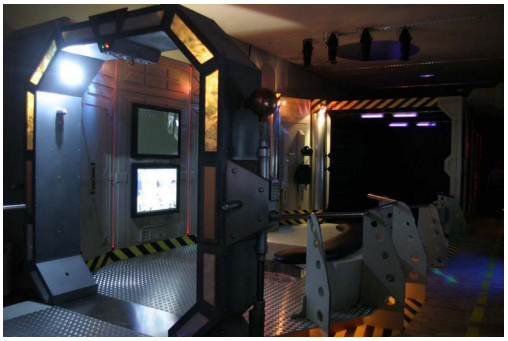

Figure 14. The final installation of the Empty Museum at the permanent exhibition *Galicia Dixital.*

6.- Conclusions

The use of an immersive, walkable virtual reality space has proved to be useful to show cultural contents in a way that can't be achieved by other existing VR systems. To make it possible, it has been necessary on one hand, to design and develop a hardware and software architecture, and on the other hand to explore the characteristics of the worlds that should fit more adequately the paradigm of the hybrid space that emerges by the use of this system.

The restrictions of previous paradigms of movement in three-dimensional environments (clumsiness, slowness, impossibility of certain movements, etc.) disappear, offering the user good movement abilities and a capacity of reaction incomparable with any other device or metaphor for simulating movement. Some limitations related to the size of the walkable area can be avoided, with the possibility of scaling the movement. This allows us to walk around spaces that are much larger than the real physical space available, with acceptably good perceptual results. For larger, more complex spaces, we have also successfully tried out the "teleport chamber" metaphor as a means of transition between different worlds or between areas in one same world.

The experience achieved from the users' observation and their comments make us believe that this system is particularly suitable for showing any kind of three-dimensional and multimedia contents in a spatial environment. The usage of avatars has evidenced the easy passage within the space; no collisions between users have been reported, in spite of them walking blindfolded through a confined space. Experiencing the space has become a social act on every occasion, where users comment on what they see, chat, and have fun together in the virtual worlds.

This points towards the adequacy of walkable systems for multi-user experimentation of virtual contents of any kind, being those related to cultural topics specially suitable for this purpose. The Empty Museum has proved its utility in this field by disseminating the Galician cultural heritage among the numerous people that visit the *Galicia Dixital* exhibition every day.

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