SHORT PAPER

Title:

Empty Museum. An Inquiry on Autonomous VR Sytems and Hybrid Spaces.

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Abstract

This paper describes a new system for experimentation of three-dimensional, virtual reality (VR) environments, based on the creation of an immersive and walkable space we have named Empty Museum. The user can walk physically and freely around this virtual, three-dimensional space, without any wire connections and while observing multimedia contents included into the same area. Work has consisted on the design of the hardware and controlling software for this immersive space, but also on the creation of an application that allows the user to visualize any type of VRML 2.0 content in this VR hall, enabling us to create various animated and interactive worlds. These experimental worlds have served, on one hand, to analyze the user's response to new forms of interaction occurring in the virtual, walkable space, and on the other, to discern new forms of creating contents that can derive from the use of real space as part of the actual interface.

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1. INTRODUCTION

In recent years, the term "immersive" applied to experimentation with virtual spaces has acquired the meaning of "surrounding" in the sense of "all that surrounds the spectator". For a virtual setting to be considered as such, the user must, at all time, find the expected image that would correspond to the virtual surrounding environment, regardless of the direction looked at.

Until now, "immersion" in an environment of these characteristics has not gone much further. The sensation of three-dimensionality could be increased with the use of stereoscopic image and spatialized sound. However, the natural way of experimenting space as humans know it, i.e. observing while moving through it in any direction, made it necessary to use hardly believable metaphors [Bowman98]. That is, putting into the user's hands a joystick, mouse or other similar type of interface that enabled a control of direction, and asking the person to pretend to be driving around a virtual setting in an imaginary 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 all naturalness and, consequently, much of the reality to the experience of the exploration. To experiment a space in the real world, it is necessary to move through it, understanding by movement not only the motion in itself, but also the kinaesthetic sensation of perceiving one's own body in movement, given that the interpretation of one's own movement facilitates the comprehension of the scale of what surrounds us.

The action of exploring requires a personal rhythm of movement, which differentiates it from the action of travelling. In the latter, the objective is to arrive to a certain point and any variations in the movement are secondary to the perception of the actual journey in itself and, therefore, to the finality of the movement. Yet, in the exploration of space, i.e. when observing a cathedral or a museum, it is necessary for the spectator to decide the rhythm of the movement, the pauses, the accelerations, when to move faster or slower, when to browse or move sidewards, turn or go back. The simulation of all the possible forms of movement by using a metaphor and a device such as a joystick is very difficult, specially considering that movement is usually limited to two modes, i.e. standstill and forward at a constant speed, generally with an abrupt and non gradual transit from one state to the other.

The reason for using the metaphor of the vehicle is no other than the dependence on the physical location of the computer that generates the images, that remains static while simulating the movement. Until now, the complexity of the process of visualizing three-dimensional environments required the use of computers with high graphics performance, which were not very movable. This limitation has been overcome with the arrival of portable computers with high graphics performance. Another technological constraint was occasioned by the volume, weight and power supply needs of the HMD (Head Mounted Display). This is no longer a problem since the existence of small, light-weight, battery operated systems, i.e. Glasstron or similar. Another obstacle to be overcome was the restriction to movement occasioned by the cables that connected the user to the 6 degrees of freedom (DOF) tracking system. This tracking system has a fixed element that acts as a position reference and cannot move around with the user. However, in the market there are now some alternatives i.e. Intersense IS600 Mark2 [Foxlin98] that allow you to obtain the position in space of a small, light-weight, wireless and battery-operated sensor. This makes it possible to finally relieve the user from the eternal umbilical chord that traditionally connected him or her to the VR engine.

We found various systems now using this new approach, with different target applications, i.e. MARS by the Columbia University [Höllerer99] [Feiner97], Cybercompanion [Cybercompanion] or Archeoguide [Didier01].

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, without doubt, facilitates the experimentation of synthetic, architectonic-type spaces. However, the fundamental contribution of this new approach is to open the way to 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, based on the location of the observer.

2. SYSTEM DESIGN

2.1. Hardware Architecture

For the physical construction of the VR system we sought for commercial "off the shelf" elements that could be integrated satisfactorily to meet the requirements observed. This allowed us to build an acceptably light and comfortable system in a short time and with low costs.

The final design of the first Empty Museum prototype placed the rendering computer in the mobile unit carried by the user, and communication with the tracking system was conducted through a wireless network. The diagram of Figure 1 depicts the components and connections between them. This system provides the user with an autonomous system (not limited by the presence of the traditional umbilical cable connected to the VR engine) so he or she can walk freely in a space of up to 8x8 metres, sufficient, as we shall see, to display spaces which are even larger.

2.2. Software Design

The system's software architecture is composed of two applications, corresponding to the fixed-mobile division explained in the previous section (see Figure 1): a controlling application that is run on the fixed PC, that manages the wireless tracking system (*base*), and a visualization application that is run on the laptop carried by the user (*satellite*).

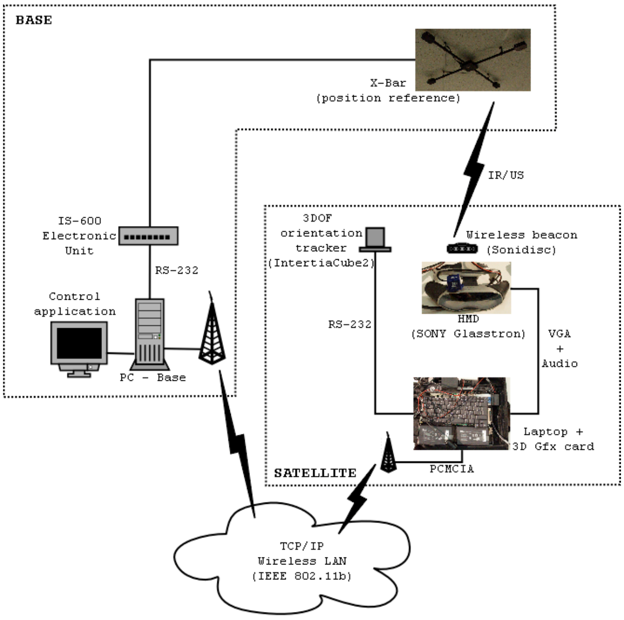

Figure 1. Hardware Architecture

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 data of its position from the base through the wireless network and of its orientation from the gyroscopic/inertial/magnetic system. From this data, it generates, in every moment, the image corresponding to the position of the user's head. This image is displayed on the HMD screen.

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

Using this format also makes it possible to build worlds with authoring tools i.e. CosmoWorlds. To interpret the VRML 2.0 information, a viewer was developed based on the kernel of the open source library OpenVRML

[OpenVRML], which was adapted to this specific application and new features were added.

The software was written in C++ language and OpenGL as the API for the graphics hardware. Spatialized sound was implemented using the OpenAL library [OpenAL]. For the development of the controlling application's interface, we used the GTK+ library [GTK].

Even when the actual implementation of the system uses a specific hardware, the software has been designed and developed in a modular way and is thus completely configurable. It could be adapted to use combinations of different devices without making changes in the programs. The configuration files used are defined in a XML language and we developed graphical tools to generate them. The software architecture of the system is illustrated in Figure 2.

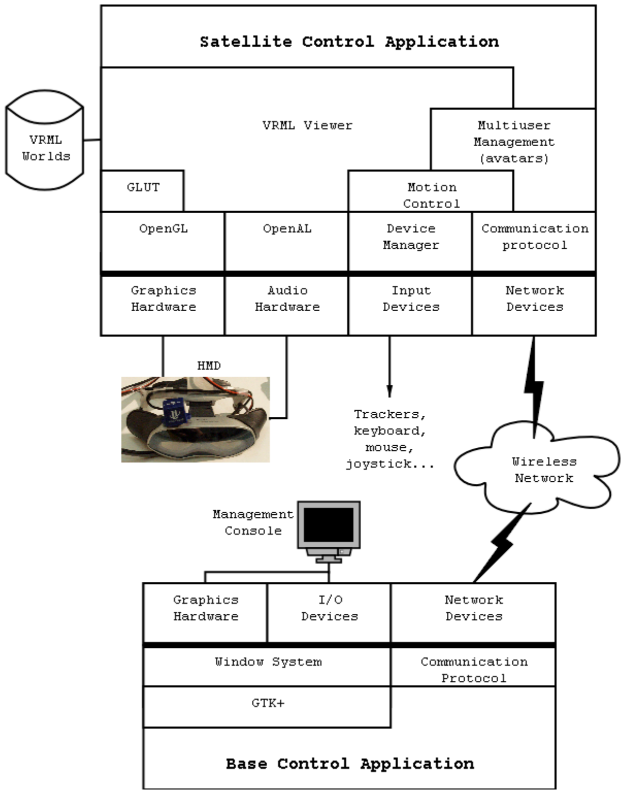

Figure 2. Software architecture.

The software was developed so that various users could visit the same or different virtual worlds at the same time, in the same real/virtual space. The users can optionally see each other as an avatar, which is a VRML model included in the definition of the virtual world and which moves associated to the corresponding user's position. The protocol used in the communications system is based on TCP/IP.

3. HYBRID SPACE

The user of the Empty Museum experiments space in a double manner. On one hand, the space as what he or she knows as such, with known dimensions, in a real area the person is conscience of being in. 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, as happens in the augmented reality systems, but is also able to experiment their size in relation to him or herself through parallax and movement around, nearer and away from them. The actual virtual space (not the objects inserted in it) is, therefore, as genuine as the actual 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.

The dimensions of both 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 lodge a large virtual space into a much smaller dimensioned real 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 fluent. 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 building more than 30m long in an Empty Museum of only 8m long. For worlds that are much larger or complex, we have also experimented with the "teleport chamber" metaphor.

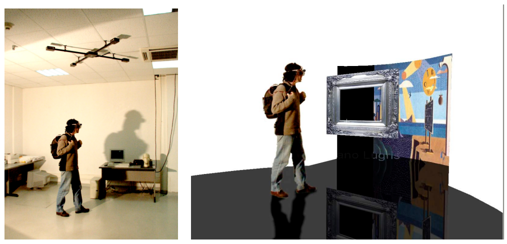

Figure 3. Real Space and Virtual Space

4. PERCEPTION IN THE WALKABLE VIRTUAL SPACE

We can define reality as the cognitive interpretation of what we perceive, that is, the interpretation of the information an individual receives from the surrounding environment through his or her senses. Therefore, to make a person feel immerse in a reality that is different from the real, physical world, you must fill that person's senses with information of the virtual world you want to introduce him or her into. If you only stimulate some of the senses in this direction, the user will be receiving information from two different environments simultaneously, allowing him or her to distinguish which one is real and which virtual. The more senses you artificially stimulate, the more the user becomes immersed in the virtual world.

The major difference between this and previously described systems of virtual space experimentation is the extraordinary contribution that real movement inside the room has to the sense of realism of the virtual space. This is because, when you move, your own kinaesthetic and vestibular systems provide you with information that corresponds to what you are seeing, and to this we add the traditional stimulation of visual and auditory senses.

During the testing and evaluation of the Empty Museum we did a poll to several users with different skill levels. This poll confirmed that the sense of immersion achieved was greater than that obtained by any other traditional VR system, including CAVE.

This sensation can be observed from the outside, through the expressions and gestures of the user who is exploring the worlds. It is frequent to see the person moving to avoid obstacles, even though these are virtual and do not present any physical adversity or obstruction, i.e. the pillars of a virtual building. Backward movements can also be observed before animations of objects that are potentially dangerous, i.e. to avoid collision with a virtual toy car that is chasing around the floor, or a startled jump back in surprise (Figure 4).

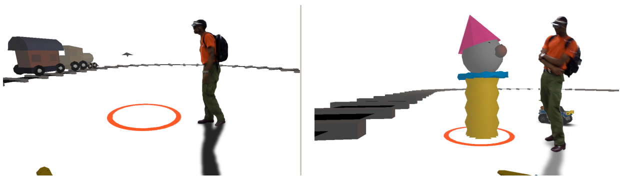

Figure 4. Interaction with the virtual objects.

A shared comment among people observing Empty Museum users is that part of the entertainment is to watch the users' reactions, seeing to what point he or she becomes involved in the virtual world.

Sound plays an important role, given that the spatialization of the different noises generates a sound landscape inside the room, which changes according to the user's position. This way, the user can locate objects of interest through their sounds or produce emotions of anxiety or alarm before threatening noises. In this sense, we must point out the enormous potentiality of the Empty Museum as an audio-based spatial training system.

5. CONCLUSIONS

We have described how we built a wireless, multi-user VR system using "off the shelf" elements. This system solves great part of the constraints found in the conventional VR systems in which the user is connected to a computer through a cable. We have also outlined the characteristics of a new paradigm for three-dimensional navigation through virtual worlds and started to study this paradigm's potentiality.

The system has been tested and assessed by users with and without technical knowledge on VR. From the results of these tests we can conclude that the users' approval has been very good.

The sense of immersion is clearly superior to that reached in preceding systems with reduced mobility. The fact of being able to move and interact as in the real world allows the users to explore the space immediately, without technical skills and without receiving previous instruction on how the system works. Moreover, feedback through the kinaesthetic and vestibular senses introduces the user into the world with a level of immersion that cannot be achieved in any other way. This avoids rejection from the users and makes them very efficient in the use of the system, with a practically null learning curve.

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. The possible size restriction owing to real space dimensions is reduced, if not eliminated, 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 described system not only improves the way of exploring conventional 3D worlds, but is also a new way of focussing the design of virtual spaces and VR applications. It opens a new field of research in spatial perception and interaction through the user's own movement, position or viewpoint.

The integration of the Empty Museum with the VRML 2.0 format enables the generation of new multimedia contents. The result of this union of walkability with multimedia is a further advance in VR systems.

6. ACKNOWLEDGEMENTS

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