Virtual Reality Interfaces for the Broad Public

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SUMMARY

Research in virtual reality (VR) is a relatively young field, which has shown considerable growth in recent years, as the development of new interactive technologies has inevitably impacted the more traditional sciences and arts. This is more evident in the case of novel interactive technologies that fascinate the broad public, as has always been the case with virtual reality. The increasing development of VR technologies has matured enough to expand research from the military and scientific visualization realm into more multidisciplinary areas, such as education, art and entertainment. Consequently, virtual reality interfaces interaction techniques and devices have improved greatly in order to provide more natural and obvious modes of interaction and motivational elements. In spite of various concerns and objections regarding the appropriateness and educational efficacy of virtual reality, there remain compelling reasons for believing that virtual environments warrant serious investigation and can provide strong tools for learning. This paper analyses the direction taken regarding the development of user friendly interfaces and natural modes of interaction for users of varied technical competencies in virtual environments.

KEYWORDS: Virtual Reality, Natural Interfaces, Interaction, Immersion, Virtual Reality Framework.

INTRODUCTION

The Foundation of the Hellenic World (FHW), based in Greece, is a non-profit cultural heritage institution working to preserve and disseminate Hellenic culture, historical memory and tradition through the creative use of state-of-the-art multimedia and technology. To this purpose it uses the best of contemporary museum theory, developments in computer science and audiovisual media for interactive exhibits. It is in this setting that the virtual reality team employs VR technology to create immersive, interactive and photorealistic experiences. Immersion is the illusion of being in the projected world, being surrounded by image and sound in a way, which makes you believe that you are really there. It offers a "better than real life" or "better than being there" experience. Interaction refers to the fact that members of the audience are not merely a viewer of the realistic scenery but can actively participate in the program and determine what their experience will be. Since the graphics displayed in the VR theatre are not predetermined or pre-recorded but generated in "real-time", the audience is able to interact with the programs and define their behavior.

Of particular interest in the use of virtual reality displays and computer generated interactive experiences is the fact that they can allow visitors to travel through space and time without stepping out of the museum building [1]. The potential to transcend the physical location of the built environment and the growing sense of the educative function of the museum juxtaposed with the commercial pressure has lead museums to consider virtual reality as a necessary component in the arsenal of tools to educate, entertain and dazzle [2][3]. Although virtual reality suffers immensely from media hyperbole and thus has not lived up to its promises, the development of VR systems has matured enough to find its way out of the research realm and into public settings. At the Foundation's Cultural center approximately five hundred students visit the VR exhibits daily in groups of ten or less. The duration of their experience in the systems ranges from 10 to 20 minutes. The numbers are large considering the experimental nature of the technology, a fact that proves for a promising technology.

INTERFACES

Virtual Reality hardware has become synonymous to heavy helmets multiple cables and high end computing gear that does not facilitate its sound use with the broad public. The choice of VR equipment that will be used in an exhibitional context is a significant base for making VR technology as accessible to the broad public as possible.

Virtual Reality equipment requires a three dimensional computer graphics system, real-time interactive control and the ability to display the viewer's centered perspective. To this purpose two immersive VR systems have been employed at FHW. The first is an Immersadeskδ (Figure 1) consisting of a 2m x 2.38m back-projected panel tiled at a customizable angle between 0° and 90°. It is powered by a Silicon Graphics® Octane® visual workstation with 2 Mips R10000 processors at 250 MHz.

Figure 1: Children exploring heritage sites on the Magic Screen (Immersadesk™)

The second system is a ReaCTor™, a CAVE® like immersive display (Figure 2) consisting of four 3m x 3m walls, which function also as projection surfaces [4]. A Silicon Graphics® Onyx™ with eight R12000 Mips processors at 300MHz and four InfiniteReality2E™ visualization subsystems power the system.

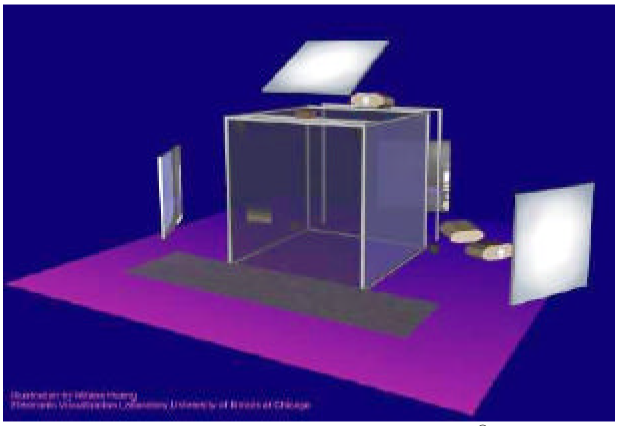

Figure 2: A rendering of the original CAVE® display. Registered trademark of the Board of Trustees of the University of Illinois.

Both systems are projection based. A major advantage of projection based VR systems, against other traditional VR systems which use Head Mounted Displays (HMD) or Binocular Omni-Orientational Monitors (BOOM), is the ability of the users to see their own body along with the surrounding virtual environment. The view of the users is not isolated and they are still conscious of the real surroundings and their own body. It has been observed in such a system the problem of disorientation and nausea, which often occurs to novice users and hinders the natural integration into the simulation, is less likely to occur [4]. Furthermore as both systems allow multiple users to experience the simulation (up to 5 people in the Immersadesk™ and up to 10 in the ReaCTor™) [5] they become suitable for shared or guided group experiences. In addition back projected systems have the advantage that most of the equipment is hidden behind the projection screens, which in turn "disappear" when illuminated allowing for seamless immersion and transparency of the underlying equipment.

The eight-inch CRT based RGB projectors are high-resolution, projecting stereo images on alternative fields. They are placed in front or behind the projection surfaces and in many cases mirrors are used in order to minimize the distance between the projector and the projection surface and save physical installation space. Stereo viewing is achieved using lightweight liquid crystal (LCD) stereo shutter glasses, which are worn by viewers to separate the alternate fields to the appropriate eyes. Infrared signals synchronize the glasses to the refresh signal generated by the computer ensuring the correct image display. The use of reliable, high quality, rugged yet lightweight shutter glasses has proven to be essential for the enjoyment of the experience since it is uncomfortable for the user to wear heavy and obtrusive equipment which has to be checked each time thoroughly for problems. To provide a correct perspective of the displayed images, the head position and orientation of one user is tracked with the use of an electromagnetic device, which provides six degrees of freedom. Although only one viewers position is tracked which means that only one person has the correct perspective, additional viewers can wear stereo shutter glasses to experience the same virtual world through the single tracked user's perspective. The tracking sensors are attached to the glasses or a hat worn by the "primary" user (in our case the museum educator) that leads the experience. The use of a familiar to everyone accessory as is the hat has proven to be a successful way to hide technical issues and to help the public get acquainted with the system.

Within the cubic immersive display the user has the ability to move physically in an area of $9m^2$ as well as navigate through the virtual environment. When simulating larger interior, exterior spaces or natural interaction is required, an additional interface is needed. Although a great variety of input devices could be used we chose a device which would combine simplicity and ease of use. The input device chosen was a hand held navigation tool called Wanda™. It features three digital buttons, an analog joystick and a position sensing device which is the same as the one used for head tracking. It resembles the look of a traditional three-button mouse but with the added abilities of a small joystick on top and tracking of its position and direction in space. Its ergonomic qualities facilitate use with only one hand. Visitors, who have used traditional computer devices before, have had no problems adapting to this device.

Employing VR components which are user friendly and easy to use creates an important base for the software developed to use this hardware. The software provides a layer of mediation between the hardware and the final user; it is the part which adapts to the specific needs of an application, hides the difficult to use parts of the hardware and is used to create the features that will enhance the experience.

VR applications are usually developed using object-oriented languages on top of tools such as Silicon Graphics OpenGL Performer™ [6] and OpenGL®. Thus the need for highly trained and specialized engineers in the field of real-time 3D graphics programming, virtual reality and system knowledge is apparent. Such a programming approach, however, would have kept away artists and non-technical users from being able to do much direct work beyond creating raw materials (models and sounds). Furthermore the amount of time and effort needed from the engineers to develop code and tools from scratch each time would be considerable. XP [7], an authoring tool for virtual environment applications was designed to alleviate these problems. The XP framework grew from software developed for the "Multi-MegaBook" [8] project and was further refined during the development of "Mitologies" [9], applications that were both large-scale environments.

The framework was developed using C++ and is based on OpenGL Performer™ and OpenGL® for the graphics, on the CAVElib™ library for transparent access to the virtual reality hardware and stereoscopic rendering and a customary developed sound library for playing audio (Figure 3).

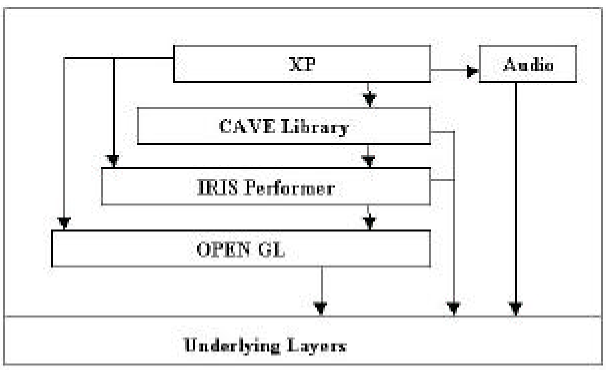

Figure 3: Schematic of the XP framework.

The system is divided into two major components: the scripting language, which describes the scene as a collection of nodes and their connection via events and messages and the low level core C++ classes that implement the features and interpret the scripting language commands. Thus the authors have to mostly create scene files (simple text), where a description of the world using the scripting language is stored. The framework includes many of the features common to virtual environments and allows engineers to reuse tools and code between various applications and at the same time incorporate new features. Artists can participate more actively or even develop entire applications on their own adjusting, the final virtual environment to their needs.

The framework allows for multithreaded execution, which is essential for interaction in a multiprocessor system like such as the ones used normally in VR where each projection surface has its own Graphics/Raster Engine. Because of the size of the databases used for the applications it is not possible to load the data all at once without degradation of performance. In order to switch between applications without needing to stop an existing application and run another one, introducing additional loading time and burden the user with knowledge of how to execute an application on the VR system, a dynamic loading feature was implemented. Dynamic loading/unloading enables the applications to be loaded and unloaded at run time using a menu or when triggered by some event, thus providing seamless transition from one application to another.

By tracking the head and hand movement of the user and monitoring the buttons and joystick, it is possible to know exactly where the user is positioned and where he is looking at. The applications and events are synchronized or triggered by these parameters to provide a more natural flow of events. The main mode of navigation uses the wand with which it is possible to navigate freely around the 3D world and interact with it. The user has to push the joystick on the wand to move into the direction the wand is pointing at, or turn to the left or right side. Interaction with an object is possible either by pointing at it, bringing the wand near it or using either of the above actions pushing any of the three buttons available. Consistency in methods of interaction between different projects is achieved because the wand buttons are almost always used in the same way. Button 2 for picking and dragging and button 3 for flying mode or gravity mode. The device is also color coded, for simplicity, something the users appreciate. Instead of giving instructions like "Press Button 1" they respond more positive with instructions like "Press the red Button". Other modes of navigation include teleporting to a specific location, following a path or attaching to a moving object of the scene.

To preserve a natural way of navigation a user expects from the environment to respond more or less like in the real world. For this reason physics and collision detection have been implemented. Collision detection is used to locate collisions of the user with objects either for interaction purposes or to prevent moving through walls. Physics are employed to mimic gravity so a user stays attached to the ground. There is also a fly mode, which enables free navigation in all directions. Keeping a high and constant frame rate throughout the simulation is essential in real time VR applications. Techniques have been developed to decrease the high polygon count many models have without loosing visual quality. Billboards, level of detail, view frustum culling and selective in/out switching of objects are techniques which when employed carefully can provide high and constant frame rates. Providing a smooth simulation by not sacrificing visual detail helps visitors and users of the VR system to get a better understanding of the world they are projected in and also facilitate easier interaction. In order to keep the engagement of a user undiminished and to provide an interesting environment various effects are implemented such as particle systems, morphing, dynamic texturing. These effects are used to mimic representations found in nature such as fire, water, smoke and incorporate movement and animation, thus producing a dynamic and lively environment.

Although a lot of features have already been implemented, each new project and application yields its own challenges and often missing features that might be needed are added by the programmers. Once added the new features can be reused many times in other projects. Thus the framework is constantly being extended to become more user friendly and more feature rich.

APPLICATIONS

The above choices in both VR hardware and software are reflected in the creation of a number of educational and cultural programs targeted at wide public audiences on many levels. The major projects undertaken by the VR team at FHW include among others the reconstruction and virtual journey through the ancient city of Miletus by the coast of Asia Minor, an interactive educational environment that brings to life the magical world of Byzantine costume, the reconstruction of the Temple of Zeus at Olympia and an interactive exhibit about pottery depicting Olympic games. Other programs under development include productions to complement or highlight important events that shape our time, culture, or everyday life, as well as experimental environments and innovative collaborations with scientists, universities and artists, that allow to gain insights on the creative use of technology.

The premiere program, "A Journey through Ancient Miletus" (Figure 4), propels visitors on a voyage of discovery to the city of Miletus as it was two thousand years ago; the temple of Apollo Delphinius, the Council House, the Hellenistic Gymnasium, the Ionic Stoa and the North Agora are some of the public buildings that can be experienced. Participants can "walk" through or fly over the accurate three-dimensional reconstruction, "dive" into the harbor of ancient Miletus, explore the city as it unfolds through time and experience the life of its architectural glory, its people and their customs, habits and way of life. With the use of the navigational device, visitors of all ages are free to choose their own path in visiting important public buildings. They can examine the architectural details and landscape from many different perspectives, practice their orientation skills and get to understand the sense of scale, proportion and space as defined by their ancestors. If they choose to fly close up to the columns, the architectural elements of the 3-D models fade into layers of higher detail, enabling the participants to experience an accurate reconstruction. Our next step in enhancing the educational experience is to add construction ability, where the visitors can switch between elements and compare the evolution of style through the evolution of time in the city.

Figure 4: View of the Bouleuterion; a public building of Miletus.

The use of architectural detail in immersive real-time virtual reality systems is difficult due to the technical and performance restrictions placed by the real-time image generator. Hence, increase in detail and interactivity results in performance decrease that in turn creates a less believable experience. We are technically trying to achieve better performance without compromising quality and detail before we can add the ability for a more constructionist and interactive perspective. As the amount of data for this exhibit is in the order of hundreds of megabytes different techniques had to be developed so that the increase in detail would not result in performance decrease, which in turn creates a less believable experience. The visitors must believe that they are entering a real environment that the computer simulates. The simulation must flow without visible interruptions otherwise the visitor will become disoriented and confused. A constant frame rate must be kept at all times. Since more geometry exists than the real-time image generator can handle at one time, levels of detail are employed through the software; a technique that displays lower resolution geometry for distant objects. Big chunks of the data can be removed from the database when their actual geometric projection is too small or when they are not visible. Another factor that must be considered as the user moves freely around the environment is the case of "getting trapped", or falling in a "hole". A special mechanism is then employed which can disable collision detection so that the user can move out of the hole or even more drastically move the user to a specified location in the environment.

An even more interactive exhibit, "The Magical World of Byzantine Costume" is the second immersive world created and the first in a series of educational virtual reality programs related to the exhibition on the 4000 years of Hellenic costume. The focus in this program is different from the one above in that an accurate reconstruction is not sought; rather an interactive, magical experience with less detail and more interactivity is attempted. It brings to life aspects of the Hellenic culture through an experiential educational world created for young children. Here the visitors are transferred to a multicolored virtual garden where they meet with figures from the emperor's escort. The scenario prompts students to search the garden for missing accessories of their clothing. The children must pick up the object using the 3D mouse and find the appropriate virtual character it belongs to. As in a game the user interacts with the environment while asking questions and actively participating in the learning process. Through the narrative nature of the program and with the assistance of the museum guide the children learn the different aspects of costume during this particular historic period.

In the "Temple of Zeus at Olympia" the visitors have the opportunity to admire the splendid temple itself as well as the sheer glory of the famous statue of Zeus, one of the seven wonders of the ancient world, of which nothing remains today. On the east pediment of the temple the myth of the origins of the Olympic Games is depicted, the chariot race between two kings. As the visitor approaches the temple the metopes come into view, portraying the twelve labors of Hercules, the famous hero son of Zeus. Walking on the backside of the temple on the west pediment, the visitor can marvel the battle between the people of Lapithes and Centaurs; the fight between Reason and Instinct. In order to highlight places of interest in the virtual environment, an alternate navigation model was also employed. Eventhough the users have the freedom to move freely in the environment they also have the choice of a predefined path navigation model that assists them in making the experience more meaningful as the path highlights points of historic significance.

In the "Olympic pottery puzzle" exhibit (Figure 5) the users must reconstruct an ancient vase putting together clay pieces. A highly interactive exhibit, different object selection mechanisms had to be employed to make the process as natural and simple to use. The users are presented with a color-coded skeleton of the pottery with the different colors showing the correct position of the parts. They then try to select a piece at a time and place it in the correct position on the vase. When they finish the puzzle, the depiction becomes alive presenting an animation of one of the ancient Olympic contests.

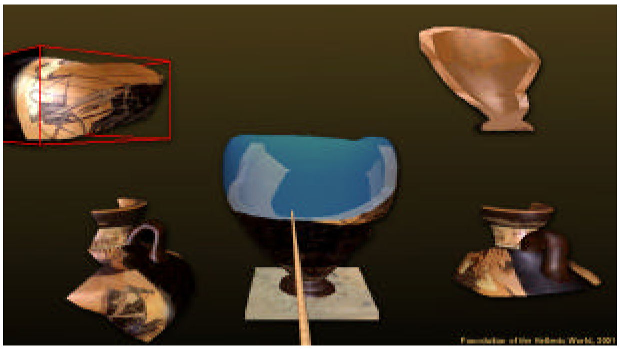

Figure 5: View from the Olympic pottery puzzle.

CONCLUSION

We are still at the early stages of using immersive virtual reality systems for public access. Virtual environments, such as the ones we are developing, can provide rewarding aesthetic and learning experiences that would otherwise be difficult to obtain. Despite the high cost and restrictive format of these installations we believe that it is well worth investigating the added value and potential that virtual reality can bring in the public domain. In order to keep VR technology as accessible as possible to the broad public it has to become transparent and provide natural, consistent and seamless modes of interaction and interfaces. Both the hardware and the software employed have to become as human friendly as possible. Encouraged from our visitors' numbers and their comments, we are working towards further development of cultural and educational experiences.

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