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VirtUATx: A Virtual Reality and Visualization Center

Marva Angélica Mora Lumbreras, Álvaro Jair Martínez Varela, Julio Cesar Calva Plata, Rubén Alfredo Mejorada Lira, Brian Manuel González Contreras, and Alberto Portilla

Abstract—The construction of a Virtual Reality and Visualization Center in a public or private University results in a series of benefits; it allows the students to interact with modern technology, to learn with different tools. Specifically, this paper focuses on a Virtual Reality and Visualization Center built at the Bachelor in Computer Engineering at the Autonomous University of Tlaxcala, this center is called VirtUATx. VirtUATx allows building different virtual environment multi-screen considering the head movements through a professional head tracker, a full navigation system by means of recognition of body movement's using Kinect or manual using keyboard. Furthermore, VirtUATx incorporates 3D object manipulation, anaglyphic and active stereoscopy and 3D sound. This Center is used in different courses, such as Research Seminars, Computer Graphics, Research Methodology, and Interaction Human-Computer, but in the future this center will benefit other bachelors.

Index Terms—Virtual Reality, virtual world, immersion, stereoscopy, 3D sound, manipulation

I. INTRODUCTION

A VIRTUAL Reality and Visualization Center allows producing research and the development of multi-disciplinary projects, combining the talents of researchers in many areas. Furthermore the construction of these environments involves the use of different courses, such as: Operative Systems, Computer Networks, Interaction Human-Computer, Computer Graphics, and Mathematics, so its construction is ideal for Bachelor of Computer Engineering.

Currently there exist several Institutions and Research Centers with their own virtual environments. One of the most popular virtual environments is the CAVE (Cave Automatic Virtual Environment), this concept was developed at the Electronic Visualization Laboratory at the University of Illinois at Chicago since 1992 [1].

In Mexico there are some Universities use Virtual Reality. Universidad Nacional Autónoma de México (UNAM) is an example of this. UNAM has built a visualization observatory called Ixtli, which uses virtual reality tools [2]. Colima University focuses on teaching using virtual reality [3, 4].

II. VIRTUATX

An Advanced Visualization Center involves many resources, such as hardware, software, installations, and specific applications. Moreover, there are others issues that must be considered such as: immersion, projection types and the user interaction.

VirtUATx is composed mainly of two parts:

- The physical part, which includes gaming computers, monitors, three back and front projection screens, four 3D projectors, six loud-speakers and input devices like a head-tracker and two Kinects
- The virtual part, which includes the software for building different flexible virtual environments and virtual worlds.

In order to have an effective immersion experience, VirtUATx allow for the creating of involve virtual environments, when it is cubic the size is 3X2X3 meters.

III. VIRTUATX DESIGN

In this section, we show the general scheme of VirtUATx. The system allows:

- Displaying virtual environments across multiple coplanar and not coplanar screens (monitors and/or projection screens).
- Using three input devices: keyboard, head-tracker and kinect.
- Different virtual environments using OpenGL, 3DS, and Java.
- Anaglyphic and active stereoscopy
- Full Navigation.

VirtUATx uses a client-server structure, which allows for the use of a set of devices connected via net. In Fig. 1 the white squares represent the server and the clients. The gray squares represent the virtual worlds and the manipulation kind. A client is a computer, which display part of a virtual world on a screen or monitor.

The server manages one or more clients (screens) and is responsible for doing a set of tasks. The server obtains the screen configurations, updates the viewer position through an input device, which can be a keyboard or a head-tracker. A user chooses a virtual world through the server.

Each client knows the information about its screen. This information includes the real position, the size, and information about whether the virtual world is stereoscopic or not. The client establishes communication with the server via messages. Then the client sends its screen configuration to the

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server, and the server returns the information necessary to determine the section of the world that corresponds to the display. The client frequently asks the server for the viewer position as well as the camera position to be able to navigate.

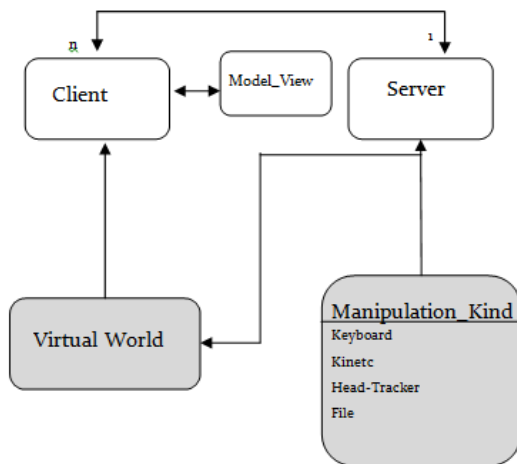


Fig. 1. General Scheme

IV. INTERACTING IN VIRTUATX

Typical interfaces use only keyboard and mouse, which is insufficient to generate immersion because in a virtual environment is important a natural interaction, therefore, a virtual environment requires appropriate devices to interact. VirtUATx uses different interaction methods. The first method consider the viewer position to calculate the vision volume through of generic frustum (described in this section), the second interaction method is the navigation in the world using translations and rotations movements and a virtual camera, finally the specific 3D object manipulation, such as scaling, rotations and translations.

A. Head tracking

A view volume is a perspective projection called *frustum*, *view frustum* and *viewing frustum*. VirtUATx uses frustums to display virtual worlds in multiples screens. *Frustum* determines the region of a virtual world that is going to be displayed on a screen [5]. It is defined by the *near*, *far*, *left*, *right*, *top*, and *bottom* distances between the screen and the viewer position. *Near* and *far* are the planes that cut the frustum and are perpendicular to the Z axis. The *projection center* is the pyramid apex and a projection plane is parallel plane to the pyramid base. The *vision line*, also called *frustum axis*, if this line is perpendicular to the screen center and is spread on Z axis the frustum is symmetric, in any other case is asymmetric.

Frustum uses viewer's and the screens's positions, the viewer position is located in the pyramid apex and every screen is a projection plane, see Fig. 3. Using this method, VirtUATx is dynamic, and every user movement produces different views in the virtual world.

When a *viewing frustum* is miscalculated, the viewer sees the incorrect information, although the *frustum* only differs some millimeters.

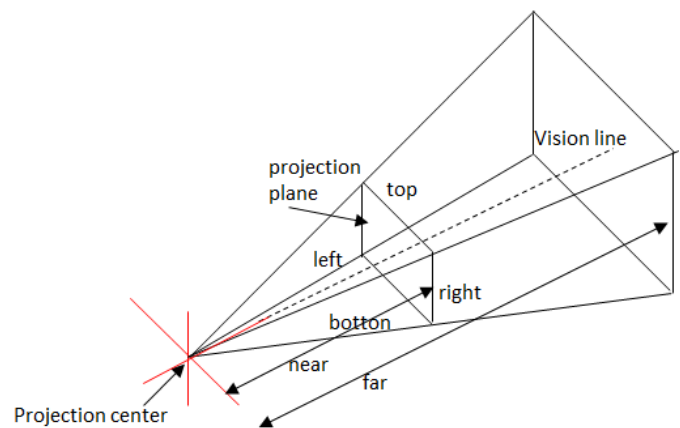


Fig. 2. Frustum

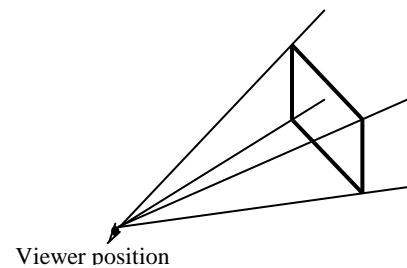


Fig. 3. Viewing Frustum

VirtUATx uses n screens, therefore use n *frustums*. Producing a virtual world divided into regions, these are displayed on individual screens. The projection center for all screens is the viewer position. Fig. 4 shows an example built with four screens and Fig. 5 is other configuration using four screens too.

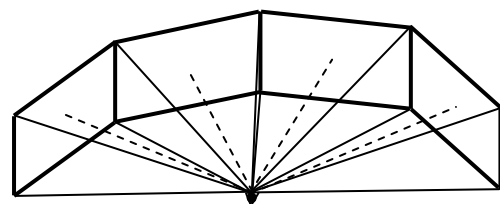


Fig. 4. A virtual environment built with four screens

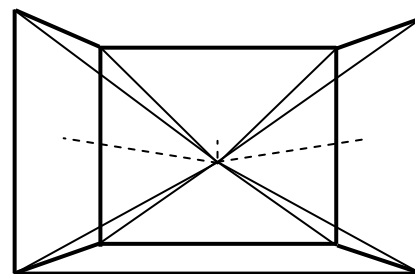


Fig. 5. An involve environment built with four projections

When the frustums are miscalculated in a virtual environment built with n screens, the information does not look continuous, on some occasions the objects can look wider, thinner or even folded. Therefore, it is necessary to

synchronize all measures involved in the environment and take into consideration the screen frames.

The result on apply frustums is shown in Fig. 6–9. These configurations were built with two computers.



Fig. 6. Two monitors, one rotated 90 degrees

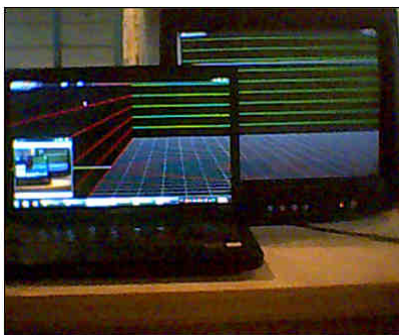


Fig. 7. Two overlapping monitors



Fig. 8. Monitors rotated 90 degrees on z axis



Fig. 9. Two monitors and a Head-Movement-Tracker

B. Navigating a virtual world using a Kinect

VirtUATx displays a virtual world and uses a method for navigating in first and third person [6]. Furthermore, VirtUATx uses a Kinect, which allows navigating the world in six different directions. This device has the advantage of providing full freedom of movement to the viewer.

- If the viewer *turns* his body to his left, right, up or down direction, the virtual environment will turn an opposite angle that the viewer turns.
- The moves in the virtual world are made in accordance with body movements, when the viewer *moves* his body left, right, upward, downward, forward, or backward, see Fig. 10.

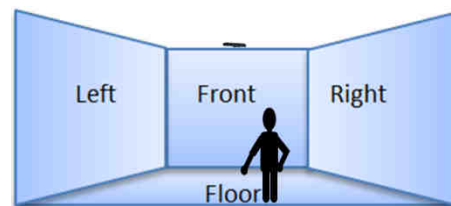


Fig. 10. Navigation using a Kinect

C. Manipulating 3d Objects using gesture recognition

VirtUATx incorporates a better interaction in its virtual world on using a system for manipulating 3D objects through hand movements, the operations used are translation, rotation and scaling. The recognition is done using a Kinect, see Fig. 11.

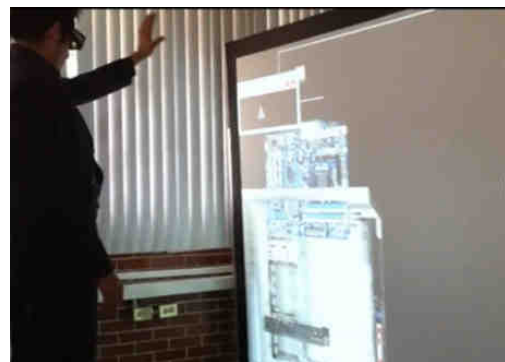


Fig. 11. Manipulating 3d Objects using hand movements

V. 3D SOUND

Digital sound has evolved [7], currently, the use of sound is becoming a more common tool in virtual environments, because it adds a certain level of realism to any virtual environment [8], in addition, sound allows for having a better interface, because indicate the reception of commands or confirm some activities [9]. Even music helps to manipulate user's emotions, including happiness, sadness, nostalgia, peace, etc.

3D sound means that a listener hears sounds from any direction; this sound is generally simulated by a computer. 3D sound has many characteristics that can provide advantages in

virtual environments. VirtUATx incorporates 3D due to the following characteristics:

- 3D Sound provides extra help for the user to find objects when he is navigating, because the hearing system can determine the location of the sound sources.
- The 3D Sound produces a high immersion level in a virtual environment.
- The 3D Sound helps to interpret distances among objects.
- The 3D Sound facilitates a more natural interaction because it is similar to the sound in the real world.
- Sound can provide additional information to a graphic world, by helping users to understand extra information without extra effort.

3D sound is similar to 3D graphics; it uses the positions of the sound sources, besides the listener orientation and position for creating a real effect. The rotations that the listener is permitted to make are called Elevation and Azimuth. See Fig. 12, Elevation is the angle along the vertical plane. Azimuth is the angle along the horizontal plane. With these rotations user is able to see a virtual world in its entirety and perceive the sound from the new positions. In VirtUATx these rotations are included.

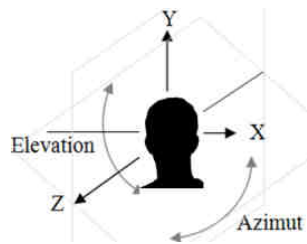


Fig. 12. Elevation and Azimuth rotation.

The allowed translations in the navigation of this work include *left, right, upward, downward, forward, and backward*.

Three important coordinates are used in virtUATx: the positions of the sound sources see (1); the listener position, see (2); and the orientation, see (3).

$$\text{SourcePosition}_n = x_n y_n z_n, \quad (1)$$

where $n \geq 1$,

$$L\text{Position} = L_{xyz} \quad (2)$$

$$L\text{Orientation} = R_x, R_y, \quad (3)$$

VI. STEREOSCOPY

Although the human beings are able to see with depth in a natural way, some scientists have worked on the artificial simulation of this perception since the nineteenth century. Sir Charles Wheatstone who built the first stereoscope in 1838 is considered one of the pioneers in stereoscopy [10].

The stereoscopy consists in using two photographs or images, one for the left eye and one for the right. When they are combined they provide an illusion of depth by allowing us to see three-dimensional views in an artificial way. There are different stereoscopic techniques such as Parallel Viewing or

Wall Eyed, Crossed-Eye Viewing, View-Master, Head-Mounted Displays, active stereoscopy, passive stereoscopy, Two-color Anaglyph, Wiggle Stereoscopy, Autostereograms, Pulfrich Effect, Displays with Filter Arrays, etc.

VirtUATx includes active and Two-color Anaglyph stereoscopy, both techniques allows for seeing stereoscopy in giant virtual environments.

Fig. 13 shows the assembly of a computer using active stereoscopy. Fig. 14 shows Research Center of the College of Engineering and Technology using anaglyphic technique.



Fig. 13. Computer with stereoscopic view

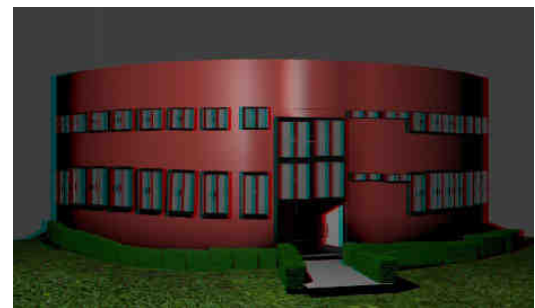


Fig. 14. Research Center of the College of Engineering and Technology

VII. RESULTS

In this paper VirtUATx is presented, VirtUATx is used with undergraduate students; furthermore it has been presented events of different academic levels such as high schools, bachelors and masters in the Tlaxcala city.

Every technique has been tested in the courses and in the academic events from manipulation, stereoscopy, sound, continuity and coherence between screens, including immersion level, etc.

Fig. 15 shows VirtUATx in the Computer Graphics course.

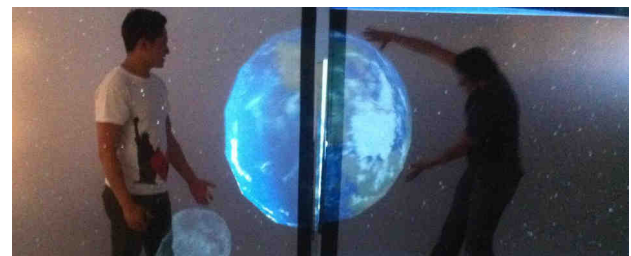


Fig. 15. VirtUATx built with two screens, a class demonstration

Fig. 16 shows a section of VirtUATx presented in a high school.



Fig. 16. A section of VirtUATx presented in a high school

VIII. CONCLUSIONS

This paper presented a Virtual Reality and Visualization Center built at the Bachelor in Computer Engineering at the Autonomous University of Tlaxcala. VirtUATx can change in size, shape (angle between screens), monitors, projections, etc., it is totally flexible, allowing it to be employed in varied projects.

Different students have used VirtUATx in courses such as Research Seminars, Computer Graphics, Research Methodology, and Interaction Human-Computer, furthermore academic events, with satisfactory results. VirtUATx allows the students to interact with modern technology; in addition, it allows working in research complex projects, although the construction of virtual environments is a complex work.

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