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VirtUATX: Incorporating 3D Sound in different Virtual Environment

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Resumen

El uso de herramientas virtuales en un nivel universitario trae grandes beneficios, un ambiente virtual le permite a los estudiantes interactuar con tecnología moderna, aprender con diferentes herramientas, hacer investigación, desarrollar proyectos multidisciplinarios, combinando el taleto de muchos investidores de diferentes áreas. Específcamente, este artículo se enfoca al comportamiento del sonido al combinar navegación, objetos 3D y Sonido en el Laboratorio VirtUATx. VirtUATx es un laboratorio de la carrera de Ingeniería en Computación de la Universidad Autónoma de Tlaxcala. VirtUATx se usa en diferentes materias, por mencionar algunas: Interacción Humano-Computadora, Realidad Virtual, Graficación por Computadora, Redes de Computadoras y Desarrollo de Video Juegos. VirtUATx permite construir diferentes ambientes virtuales debido a que combina el uso de multiples pantallas que pueden ser acomodadas en diferentes posiciones, logrando la visualización de mundos virtuales continuos formados por múltiples objetos 3D, además de que tiene un sistema de navegación completo, diferentes tipos de manipulación, ya que se maneja teclado, rastreador de cabeza, kinects y control remoto. Además, por medio de las pantallas se puede construir estereoscopios gigantes, tal como el estereoscopio de Wheatstone y hacer uso de otras técnicas de estereoscopia.

Palabras claves: *Mundo Virtual, Sonido 3d, interacción.*

Abstract

The use of virtual tools in university level results in a series of benefits, a virtual world allows the students to interact with modern technology, to learn with different tools, to produce research and to develop multi-disciplinary projects on combining the talents of researchers in many areas, etc. Specifically, this paper focuses on the behavior of sound on combining navigation, 3D objects and 3D sound in in a Laboratory called VirtUATx. VirtUATx is built by the program in Computer Engineering at the Autonomous University of Tlaxcala. VirtUATx is used in different courses, such as Interaction Computer-Human, Virtual Reality, Computer Graphics, Networks and development of video games. VirtUATx allows building different virtual environments using multiple screens placed at arbitrary positions and orientations. VirtUATx displays continuous virtual worlds formed with multiple 3d Objects, allows a full navigation system, incorporates different ways of manipulating using keyboard, head tracker, Kinects and remote control. Furthermore, with this project we can also build giant stereoscopes, such as the Wheatstone- type stereoscope and use multiple stereoscopic techniques.

Keywords: *Virtual World, 3D Sound, interaction.*

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1. Introduction

The construction of virtual environments using multiple screens in a public or private University results in a series of benefits. These environments allow producing research and the development of multi-disciplinary projects, combining the talents of researchers in many areas. Furthermore they allow the students to interact with modern technology and to learn with different tools.

The construction of these environments involves the use of different courses, such as: Operative Systems, Computer Networks, Interaction Human-Computer, Computer Graphics, and Mathematics, but these virtual environments can benefit other courses. Currently, this project is being used in two courses at the Bachelor in Computer Engineering at the Autonomous University of Tlaxcala: Interaction Human-Computer and Computer Graphics.

We are surrounded by a lot of sound sources in our daily life, which are produced by different objects, many of these sounds are easy to recognize due to our familiarity with them. Therefore, when it is included in a virtual world undoubtedly improves the realism. The type of sound depends on the virtual world. Specifically, this paper presents an analysis and study of the behavior of sound in different virtual worlds. The first is an art gallery with one sound source (background music); the second is a computing center with nine sound sources with spoken explanation; the third is a depot with ten sound sources, the fourth is an auditory, finally a scene with people. In all these virtual environments the sound sources are used as feedback to some activities, to locate 3D objects, and as background music.

The remainder of this paper is organized as follows: section 2 presents the General Objective, section 3 offers the previous work. One of the works is focused on an Augmented Reality environment, the others ones are focused on Virtual Reality Area. Section 4 focuses on 3D sound as an immersive tool in a virtual world. Section 5 presents the room acoustics. Section 6 presents a Virtual Reality and Visualization Center built at the Bachelor in Computer Engineering at the Autonomous University of Tlaxcala, this center is called VirtUATx. In section 7 we present the incorporating 3D Sound into different Virtual Worlds. Section 8 descibes different problems and solutions on incorporating Sound. In section 9 we present our evaluations. Finally in section 10 shows the conclusion and future work

2. General Objective

The General Objective of this project is to do study and analysis of the behavior of sound on combining: "Navigation, 3D objects and 3D sound" and mathematical solutions to problems of coherence of sound

3. Related Work

Different authors present the incorporation of 3D Sound in virtual environments; in this section we describe four works focus on 3d sound. In [1] the authors describe a virtual assembly environment. In their work they carry out an evaluation and a comparison of the use of isolated and combined visual and auditory sense. Their project has some similarity to our work, because we integrate the same senses: visual and auditory. Nevertheless, they focus on a specific environment and our project uses the 3D sound in different virtual environments. [1] describes an evaluation more than an model or an implementation.

In [2] the authors examine the effects of head movement and latency compensation in 3D sound location. They have analyzed that head movement can help in sound location. Although our work does not have as a primary objective a similar evaluation, we combine several ideas-objects with sound sources, navigation in the virtual world and viewer movements to increase realism in the different virtual environments that can be built with our project.

In [3] the authors explore the possibility of location of objects in an environment based on sound and visual cues, in addition in their virtual world several object are too close together producing interference between they, this problem also occur in our project.

[4] the authors deal with the simulation of virtual acoustic spaces using physics-based models, in this work provide with input channels and anechoic sounds, expecting that the spatial features of those models can be modified even during the simulation.

In our project, the different sound sources are used as feedback to some activities, to locate 3D objects, and as background music.

4. Three Dimensional Sound as an Immersive tool in a Virtual World

Digital sound has evolved [5], 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 [6], in addition, sound allows for having a better interface, because indicate the reception of commands or confirm some activities [7]. 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. In this work 3D sound has been incorporated due to the following characteristics [8]:

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. 1, 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 our project these rotations are included.

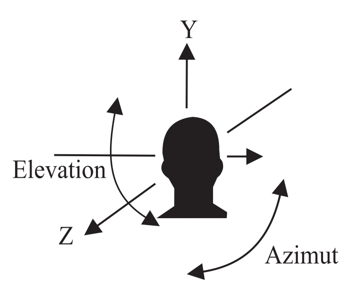

Fig. 1. Elevation and Azimuth rotation.

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

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

$$SourcePosition_n = x_n \; y_n z_n \qquad (1)$$

Where $^{n \geq 1}$

$$\text{LPosition} = \text{L}_{xyz} \qquad (2)$$

$$\text{LOrientation} = \text{R}_x, \text{R}_y \qquad (3)$$

Doppler effect depends on the velocities of source and listener relative to the transmission medium, and the speed of sound propagation in that medium. In this project the sound sources are stationary and the effects of the medium (air, water) moving with respect to listener and source are ignored. Therefore, the speed of sound (v) used for computing Doppler effect is 343 meters per second (in dry air at 20° C).

$$v = 343.3 \; m/s$$

The Doppler Effect is used with the following formula:

$$f' = DF * f * \left[\frac{v - v_l}{v}\right]$$

With

f	original sound pitch
f '	Doppler effect pitch
v_l	velocity of listener
DF	Doppler factor

5. Room Acoustics

A room has specific acoustic characteristics that determine how sound is affected and they depend on many parameters, such as the materials used for the walls, ceiling, and floor; location and type of furniture, windows, curtains, plants, etc. Anything in a room modifies the sound waves. The room size also influences the sound; the height, length and width determine the resonant frequencies of the space. For instance, the longest room dimension, determines the ability of the room to support low frequencies.

In a room or on in a building, there are four areas which need to be taken into consideration: reverberation time (it is affected by the size of the space and the amount of reflective or absorptive surfaces within the space), attenuation (gradual loss in intensity of sound through a medium), the characteristics of frequency of the room, and level of noise in the ambient.

Special rooms where all sound is absorbed by special walls are used for acoustic research and music recording. Such rooms are necessary to listen to or record the unmodified sound of a musician or instrument. Effect processors can simulate many room types or acoustic environments. Any sound can be enhanced to sound like being emitted in a bathroom or in a cathedral.

6. VirtUATx

This section presents VirtUATx, which is a Laboratory composed mainly of two parts:

- The physical part
- The virtual part

6.1. The physical part of VirtUATx

The physical part, which includes gaming computers, monitors, three back and front projection screens, four 3D projectors, two loud-speakers and input devices like a head-tracker and two Kinects. The dimensions of the Laboratory are: 9mX8m. VirtUATx is devised for the building of virtual environments, adaptable to different applications and number of resources. Fig. 2 shows the first configuration, it is composed with two aligned screens and other screen forming an angle of 90 degrees.

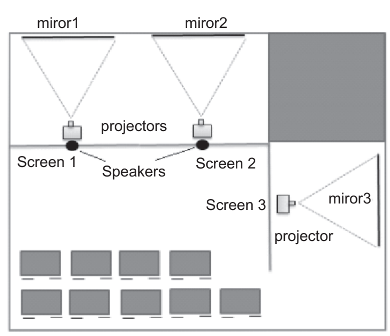

Fig. 2. First Configuration of VirtUATx.

Fig. 3 presents the second configuration of VirtUATx. In order to have an effective immersion experience, VirtUATx allow for the creating of involve virtual environments, when it is composed with three screens forming angles of 90 degrees.

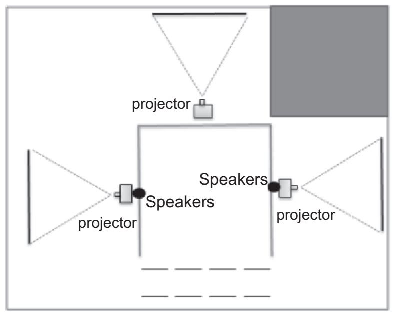

Fig. 3. Second Configuration of VirtUATx.

Fig. 4 presents the second configuration, which is composed with two screens forming an angle of 90 degrees allowing having more chairs and desks that the others configurations.

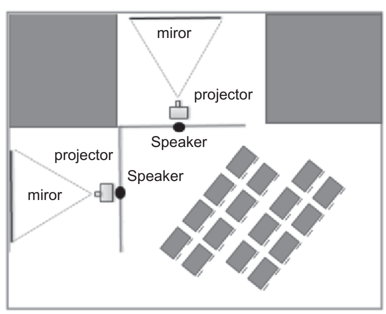

Fig. 4. Third Configuration of VirtUATx.

Reverberation is the persistence of sound in a particular space after the original sound is produced.[9] A reverberation is created when a sound is produced in an enclosed space causing a large number of echoes to build up and then slowly decay as the sound is absorbed by the walls and air.[10].

In VirtUATx, we use curtains as acoustic absorbent in the room and walls isolated from other rooms to avoid noise and interferences, achieving an adequate acoustic.

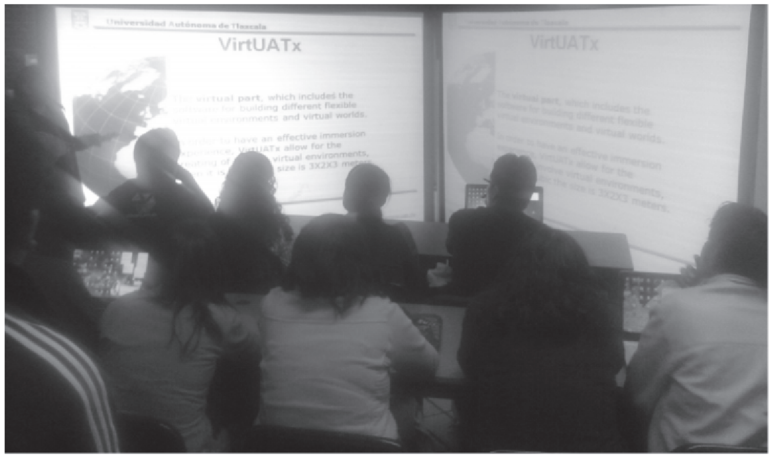

Fig. 5. VirtUATx.

6.2. The virtual part of VirtUATx

The virtual part of VirtUATx includes the software for building different flexible virtual environments and virtual worlds.

VirtUATx has a client-server structure, which allows for the use of a set of devices connected via net. The server manages one or more clients (screens), updates the viewer position, indicates to the client(s) what virtual world should be displayed and turns on the 3D sound. Each client knows the screen position and the viewer position.

3D sound is included in this project, besides a navigation system, a multi-screen system, and a stereoscopic environment. In addition, some virtual worlds have been created; each one has a set of objects with at least one sound source.

Therefore, 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.

7. Incorporating 3D Sound into different Virtual Worlds

The first world is an anaglyphic gallery. This gallery shows a collection of anaglyphic photographs, this implies that 3D objects, 3D sound and stereoscopy are involved in the same world, see Fig. 6. This gallery does not require many sound sources and therefore it only contains a loudspeaker placed on the ceiling. The spatial effect is perceived when the virtual world is navigated and the sound is heard from the loudspeaker.

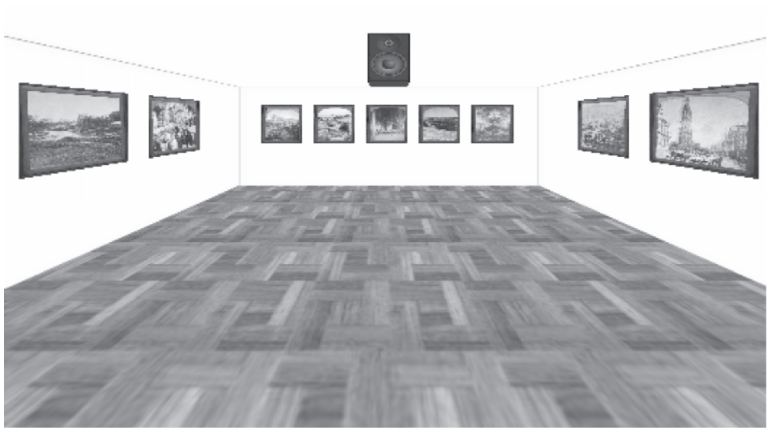

Fig. 6. Anaglyphic gallery.

The second virtual world that was programmed is a computing center containing nine computers, each one with a sound source, see Fig. 7. In this case, the 3D sound provides the user with some complementary information about the world. Each computer speaks out using a pre-recorded sound clip, specifying details about a planet of the Solar System. As our project is dynamic, when the user navigates through the virtual world, the sounds change too according to the movement made.

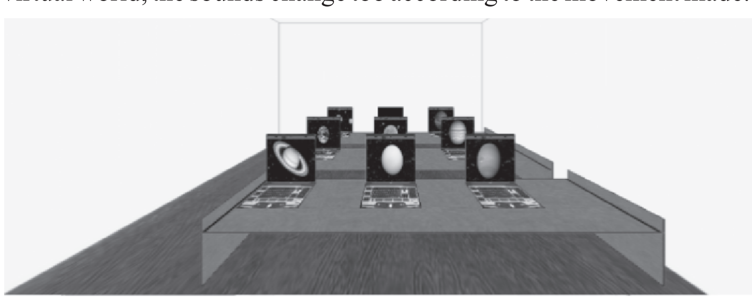

Fig. 7. Computation center with nine computers, each computer has its sound source.

Fig. 8 shows the position of the sound sources of the computing center pointed with red points.

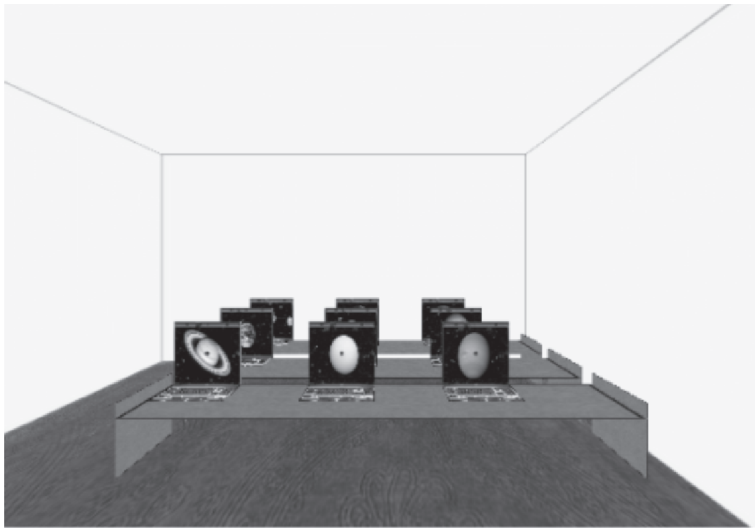

Fig. 8. Sound source of the computing center.

In Fig. 9 the first view is the frontal, two laptops are shown. One of them shows the planet Earth and the other one shows Jupiter. Therefore, the explanation heard about Earth is emitted from the left side of the virtual world and about Jupiter from the right side. If the same laptops are seen from back, see Fig. 9, the explanations would be listened to from reverse sides; that is, now the explanation about Jupiter will be emitted from the left side and, about Earth, from the right side.

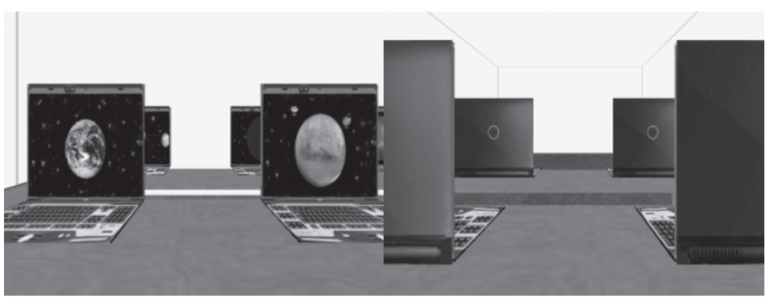

Fig. 9. Frontal and posterior view.

In Fig. 10, the first view there are two nearby laptops. The first one shows Jupiter, the other one shows the posterior side of a Laptop

(Neptune). When this scene is seen, the explanation about Jupiter is heard on the left side and about Neptune on the right side. In the second view a rotation of 180° is done and an approaching to two computers. The posterior side of a Laptop (Uranus) is shown as well as the Laptop of Earth and explanations of the planets are heard. The explanation of Uranus is heard from the left side and of Earth is heard from the right side.

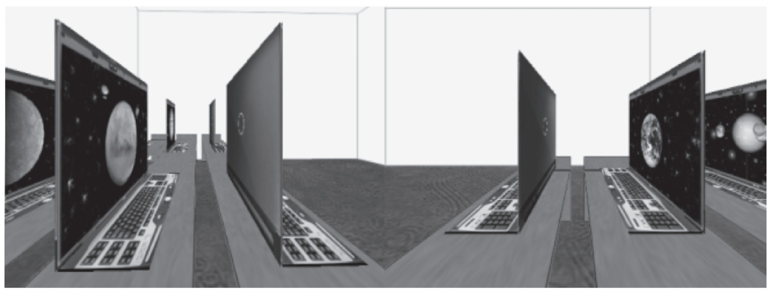

Fig. 10. Computing center with nine computers, each computer has its right and left view.

The third virtual world is a depot; this world contains ten sound sources hidden to the viewer in some boxes. Fig. 11 shows a set of boxes. Although the sound sources are hidden, when the virtual world is navigated the user can find them.

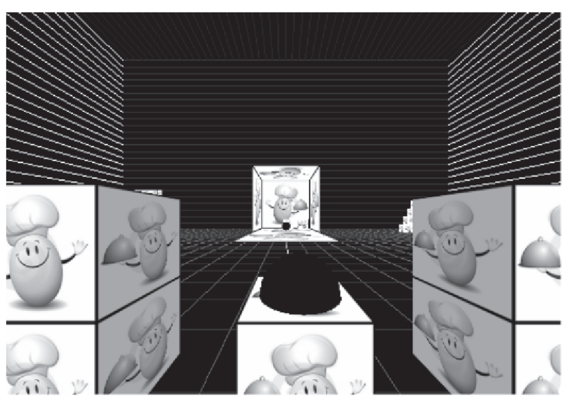

Fig. 11. Depot and some sound sources.

The fourth virtual world is an auditorium; this world contains four sound sources in the different instruments, see Fig. 12, this case combine the four sound sources and resulting a melody

Fig. 12. Stage using four sound sources.

Finally, the last virtual world is a place with people; this world contains voices, due to the sound sources are placed near each other it can result in interference and confusion between them, see Fig. 13.

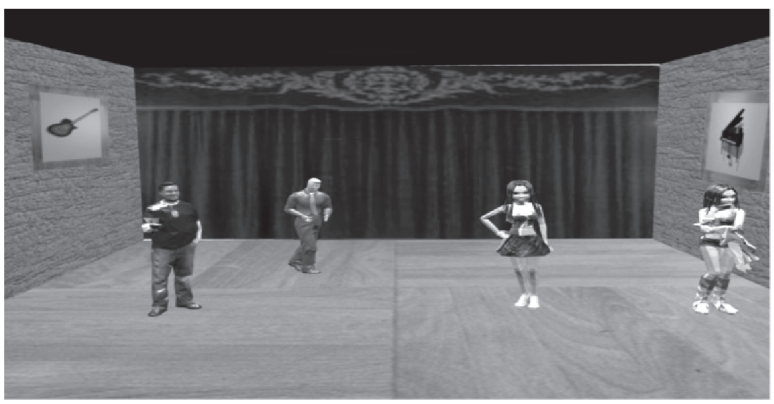

Fig. 13. People producing interference.

8. Problems and solutions on incorporating Sound

Different problems were presented when sound was included in this project. They are mentioned in the following points [11]:

When different sound sources are used in a virtual world, we should have taken some precautions when placing them. If sound sources are placed near each other it can result in interference and confusion between sounds. However, it also depends on the kind of sound. Music and some other sound source do not have problems, but when the sound is a spoken explanation; they can be mixed and therefore not understood, resulting an annoying noise. This problem was found in the computing center, see Fig. 7, since the size of this virtual world is small and the computers are near, the difference in the sound volume between computers was minimum resulting interference and confusion between dialogues. Therefore an adjustment in the volume of the objects was made, limiting the maximum volume reached in the virtual world.

The volume of each object (in this case each computer) is V_{obj} and was adjusted with the following equation:

$$V_{obj} = 1 - \frac{d_{obj}}{d_{max}} \qquad (6)$$

Where d_{obj} is the distance between the viewer position and the object position, d_{max} is the reached maximum distance to hear an object and to avoid interference.

Every virtual world shown in this document can be used with any virtual environment built with one or more screens. Due to the fact that every environment can display virtual worlds without any modification, this project did not experience any problem when the sound units were included in them. This was true except with the Wheatstone-type digital stereoscope. We adapt a stereoscope in our project. In 1838 Charles Wheatstone described a technique used to create the illusion of depth, he built a stereoscope using two plane mirrors and two slightly different drawings, the two plane mirrors were inclined 90° against each other and set vertically upon a horizontal board [12], our idea was to adapt the stereoscope using two monitors or projectors set one in front the other one and a pair of mirrors set in the middle of two monitors for seeing a stereo environment; nevertheless, it produces a laterally inverted virtual world, see Fig. 14. When the viewer eyes are set in front of the mirrors the virtual world is seen stereoscopically. If the 3D sound is not used, there is no problem seeing the inverted virtual world. When spatial sound was incorporated we had to invert the world beforehand so that it could be seen correctly and coincide with the sounds. This stereoscope can be built using the screens of VirtUATx.

Fig. 14. Wheatstone-type digital stereoscope.

9. Evaluation

This project was tested by 40 students of the Autonomous University of Tlaxcala. Two aspects were tested: 3D sound and interaction in the different virtual worlds.

The first test was focused on 3D sound; every virtual world was tested with and without sound sources to determinate the effect in the users. The users navigated in the worlds, found specific objects with o with sound sources. The results were the following: 95% of the users considered an important improvement on using 3D sound in the different virtual worlds. 95% of the users could perceive that the sound sources were emitted from different 3D objects and notice an improvement in the location of 3D objects when the sound sources were incorporated. All the users considered that the sound can be used as feedback and provides spatial information.

The second test was focused on interaction, the result of the interaction module was excellent, all of the users considered easy to utilize the manipulations and the input devices, furthermore, the users considerate, the incorporation of 3D sound in a virtual world produce in a general way a better interaction.

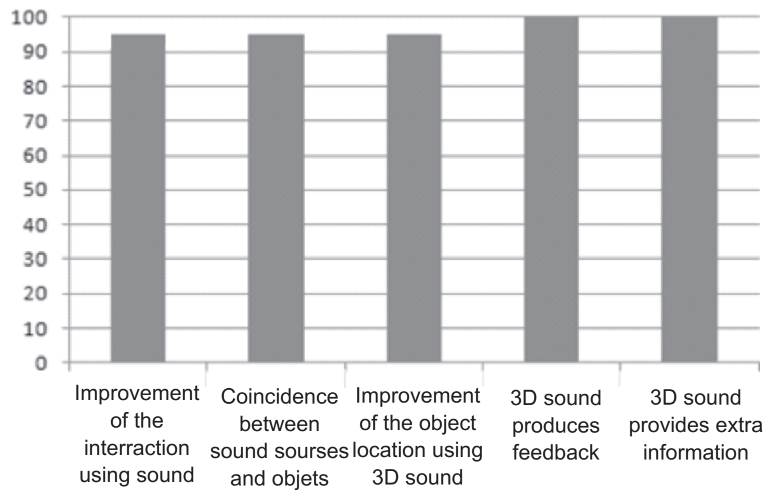

Fig. 15. Results of the evaluation of sound.

Table 1 shows a comparative analysis between previous work about sound module and the work described in this document.

- Ying detects collisions between a specific object and the surrounding objects. Ying designs a system for providing visual feedback, and/or 3D auditory feedback during the manipulation.

- Wu uses one sound source changing its position for evaluating the improvement of the location of sound using dynamic movement of the human head.

- Sodnik evaluates the perception and location of 3D sound in a tabletop augmented reality environment. He uses nine sound sources corresponding to airplanes within a small virtual world.

- Jiann deals with the simulation of virtual acoustic spaces using physics-based models.

Our work presents different virtual worlds. The first is an anaglyphic gallery, which with one sound sources as background music. The second is a computing center with nine sound sources with spoken explanation, the third is a depot with n sound sources, The fourth virtual world is an auditorium with different musical instruments, finally, the last virtual world is a place with people and voices of them. In all these virtual environments the sound sources are used as feedback to some activities, to locate 3D objects, and as background music.

Title	Number sound sources	Kind of sound	3D sound	Sound is used:
The Use of Visual and Auditory Feedback for Assembly [1]	No specified	Sounds of a specific object	Yes	As feedback to some activities
Head motion and latency compensation on localization of 3D sound in virtual reality [2].	1	Sound	Yes	To locate objects 3D
Spatial sound localization in an augmented reality environment [3]	Variable	Sound of airplanes	Yes	To locate objects 3D
Phisics-based models for the acoustic representation of space in virtual environments [4]	Variable	Sound	Yes	To locate objects 3D and to calculate latency
VirtUATx	Variable	Spoken explanation, sounds, music	Yes	As feedback to some activities To locate 3D objects To background music

Table 1. Comparative analysis between previous work.

10. Conclusion and Future Work

In this paper a description about how to combine 3D objects and sound sources was described. The 3D sound in our project was specifically used in two ways:

- As supplement to visual information through: Spatial Information and Spoken explanation
- As background sound in a gallery of art.

The incorporation of 3D sound was done in different virtual worlds; they were shown and tested. When 3D sound was incorporated in the project two problems were found:

- When different sound sources are placed near each other it produces interference and confusion between sounds. Therefore an adjustment in the volume of the objects was made, limiting the maximum volume reached in the virtual world. The solution was the volume adjustment of each object using the Eq. 6. In this equation the maximum distance to hear an object is limited.

- The second problem was detected on incorporating 3D sound in the Wheatstone-type digital stereoscope, because it produces a laterally inverted virtual world, the solution was to invert the world beforehand so that it could be seen correctly and coincide with the sounds.

Finally, a future work could present an analysis of latency between 3D objects and sound, the second future work is the Incorporation of techniques of Artificial intelligence and finally we propose incorporate different sound effects.

11. Acknowledgment

This research project would not have been possible without the support of PROMEP (Programa de Mejoramiento del Profesorado)

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