# Chapter 1

# Introduction

# 1. Introduction

## 1.1 Virtual Reality

According to Kalawsky (Kalawsky, 1993) "there are probably as many definitions for virtual reality as there are people in the field". This work uses the following definitions:

- Virtual Reality (VR) is an experience in which a person is surrounded by a three dimensional computer-generated representation and he/she is able to move in the virtual world and see it from different angles, to reach into it, grab it, and reshape it" (Rheingold, 1991).

- Virtual Reality can also be defined as a virtual environment. A virtual environment (VE) is a computer-based simulated environment that intends for its users to inhabit it and interact with it via avatars. These avatars are usually depicted as textual, two-dimensional or three-dimensional graphical representations, although other forms are also possible. Some virtual environments allow for multiple users to participate simultaneously (Biocca, et al., 1995). The perception of these environments can be done via visible, audible, or tactile means.

The technological evolution has resulted in a series of benefits to the Virtual Reality fields. Now it is possible to represent knowledge in an interactive way where visual, haptic, and audible aspects are combined, allowing for the improvement of the user perception, imagination, and manipulation.

Currently exist several Institutions and Research Centers that are already building their own generally complex virtual environments. One of the most popular virtual environments is the CAVE (Cave Automatic Virtual Environment). The CAVE is a system constructed in a room-sized cube using four, five or even six of the walls of the cube. These walls are used as screens where computer-generated images are projected using several projectors. The images are projected either directly or through a set of mirrors strategically placed to save some room space. This concept was originally developed at the Electronic Visualization Laboratory at the University of Illinois at Chicago in 1992 (Cruz-Neira, et al., 1993). The CAVE is a multi-person, high resolution, 3-D video, and audio environment.

## 1.2 Motivation

The construction of a Center of Visualization and Virtual Environments in a public or private University results in a series of benefits. These Laboratories 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, to learn with different tools. Finally, Virtual Reality allows the production of thesis and publications in bachelor, master, and doctoral degrees.

This dissertation is motivated by the needs of two Mexican Universities: Universidad de las Américas, Puebla (UDLAP) and Universidad Autónoma de Tlaxcala (UAT). This work will provide an open road for the research about Virtual Reality to the UDLAP, which is always working in front line themes. Besides, the results of this work will be the basis to start doing research in Virtual Reality at the Bachelor and Master's programs in Computer Engineering at the UAT.

## 1.3 State of the Art

Many works were reviewed for the creation of this dissertation; some of them stand out and are mentioned in this chapter. Due to the fact that this work is organized in a modular fashion every module has its own set of works which are organized into the following sections:

Section 1.3.1 presents the previous work on the Displaying Module; these works focus on the building of multi-screen virtual environments. Some works that use a multi-screen system are mentioned in Table 1.1

Section 1.3.2 describes the previous work on the Projection Module. Some environments that use the mirror and projector technique have been found. This technique allows for reduction in the space requirements. Previous research of this module is mentioned in Table 1.2.

Section 1.4 contains the work related to the Stereoscopy Module. These works focus on projects where basic stereoscopes are used. They are listed in Table 1.3

Section 1.5 offers the previous work about the Sound Module. One of the works is focused on an Augmented Reality environment, the others ones are focused on Virtual Reality Area. They are mentioned in Table 1.4.

### 1.3.1 Previous work of Displaying Module

Multiple-screen systems have been studied by some researchers. Table 1.1 shows four works which contain formulae for displaying an image through multiple non-coplanar screens.

**Table 1.1 Previous work on the Displaying Module**

| Title | Number of screens | Coherence between screens | Structure of the environment | Angles between screens |
|---|---|---|---|---|
| Surround screen projection-based virtual reality: the design and implementation of the CAVE. (Cruz-Neira, et al., 1993) | Fixed (4) | Yes | Fixed (cubic) | Fixed (90 degrees) |

| | | | | |
|---|---|---|---|---|
| Transparently supporting a wide range of VR and stereoscopic display devices (Pape, et al., 1978.) | Variable (n) | Yes | Variable | Variable |
| Use and manipulation of generic Frustums (Granados, 2006) | Variable (n) | Yes | Variable | Variable |
| Implementation of a Low-Cost CAVE system Based on Networked PC (Po-Wei, et al., 2002) | Fixed (4) | No | Fixed (cubic) | Fixed (90 degrees) |

- Cruz-Neira, Sandin, and DeFanti describe the CAVE virtual reality/scientific visualization system in detail and demonstrate that projection technology applied to virtual-reality goals achieves a system that matches the quality of workstation screens in terms of resolution, color, and elimination of flickering. Use of the Silicon graphics' Graphics Library and the off-axis perspective projection techniques are described. Figure 1.1 shows a CAVE diagram of this project. Although this work uses a multi-screen system the mathematical solution is limited to display images correctly only when the screens are put to 90 degrees between them.

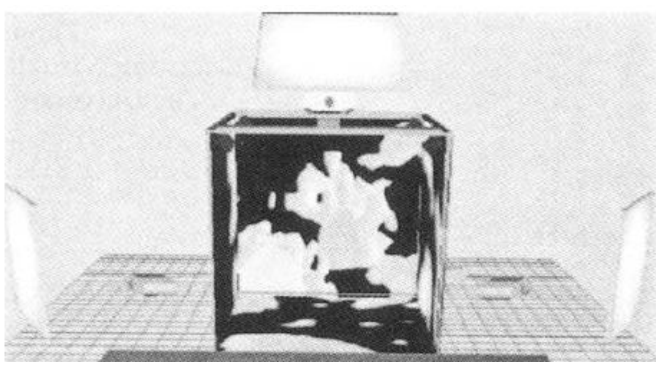

**Figure 1.1 CAVE diagram. Graphics by Milana Huang, University of Illinois at Chicago**

- Pape and his team describe the architecture for virtual reality software which transparently supports a number of physical display systems and stereoscopic methods. They work in systems such as the ImmersaDesk3 and CAVEscope, see Figure 1.2.

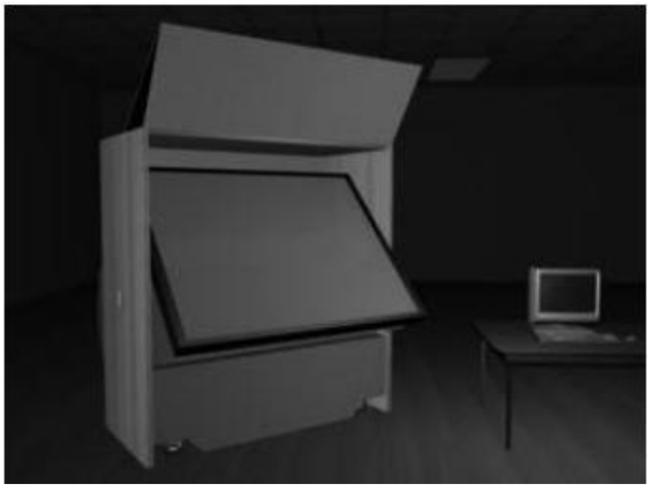

**Figure 1.2 The ImmersaDesk**

- Granados (Granados, 2006) use some formulae found in Pape's work for displaying images on non-coplanar screens. We co-worked with Granados in 2006 and are using the same formulae combined with others that compute the positions of the screens' corners in the real world. Figure 1.3 shows a Granados' work photograph.

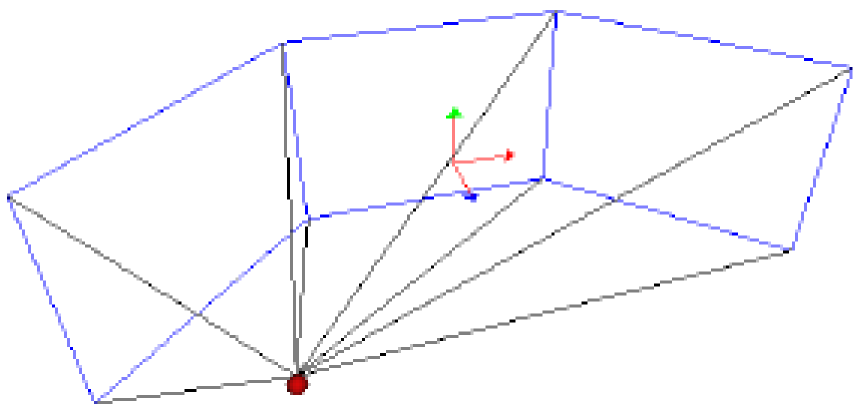

**Figure 1.3 Three non-coplanar screens**

- Po-Wei, Zhi-geng, Jian, and Jiao-ying (Po-Wei, et al., 2002) describe a CAVE system based on four high performance networked PCs. They do a comparison about the performance and the cost between the PC based system and the SGI based CAVE system. There is also a brief description about their Graphics System and the required formulae for the displaying of their virtual world. Although this project is specifically focused on CAVE, it has a similar characteristic to our work, that is, the use of a set of PCs for building a multi-screen virtual environment; Figure 1.4 shows a photograph of this project.

**Figure 1.4 A Campus of Zhejiang University**

### 1.3.2 Previous Work on the Projection Module

In order to build a physical virtual environment, there are some techniques that are often used. These include the technique of mirrors and projectors.- It is used to reduce the requirements of physical space. Some CAVEs have used this technique. The best example of this technique is the CAVE built at the University of Illinois (Cruz-Neira, et al., 1993), (Cruz-Neira, et al., 1997). There are other virtual environments that use this technique; some of them are mentioned in Table 1.2.

**Table 1.2 Previous work on the Projection Module**

| Title | Mirrors and projectors technique | Number of configurations | Equations for determining the room size | Determination of room size |
|---|---|---|---|---|
| Surround screen projection-based virtual reality: the design and implementation of the CAVE (Cruz-Neira, et al., 1993) (Cruz-Neira, et al., 1997) | Yes | 1 | No | No |
| The Fully Immersive CAVE (Ihrén, et al., 1999) | Yes | 1 | No | No |
| Implementation of a Low-Cost CAVE system Based on Networked PC | Yes | 1 | No | No |

| | | | | |
|---|---|---|---|---|
| (Po-Wei, et al., 2002) | | | | |
| Building A Spatially Immersive Display: HUTCAVE (Jalkanen, 2000) | Yes | 1 | Yes | No |
| Sistemas de Multidisplay: Técnicas y Aplicaciones (Aguilera, 2007) | Yes | 4 | No | Yes |

- Cruz-Neira, Sandin, DeFanti, Czernuszenko, Ihrén, Frisch, Po-Wei, Zhi-geng, Jian, & Jiao-ying are some of the researchers that have built complex virtual environments known as CAVEs. These works use the mirrors and projectors technique, but do not specify the minimum space required for the construction of a CAVE. Figure 1.5 shows an example of a CAVE, which uses the mirrors and projectors technique.

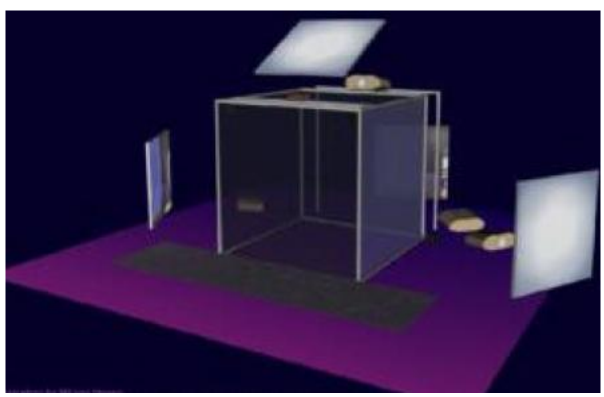

**Figure 1.5 Example of a CAVE using the mirror and projector technique**

Jalkanen offers some mathematical formulae for measuring space when mirrors and projectors are utilized. She also shows in Figure 1.6 the configuration of her work called HUTCAVE, it uses projectors and mirrors. The parameter used in her configuration are shown in Figure 1.7 (Jalkanen, 2000). This work is interesting; nevertheless, some space is wasted.

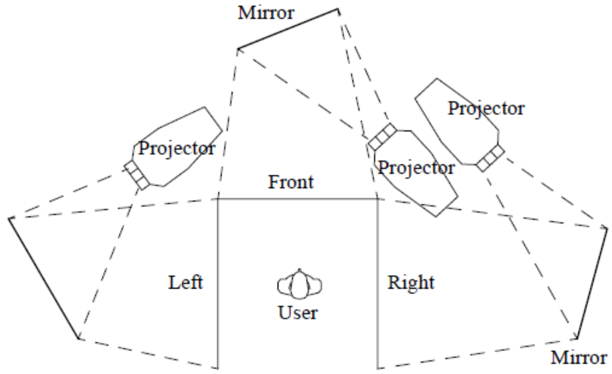


**Figure 1.6 CAVE layout, top view. Projectors on the sides.**

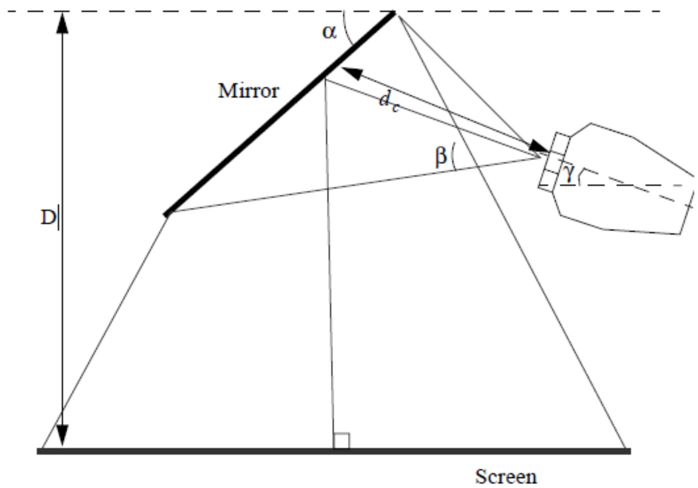


**Figure 1.7 Single-mirror configuration and parameters**

- Aguilera shows the design for building CAVEs using specific measurements. He shows the results of his work using a system, but he does not provide details about his technique, see Figure 1.8.

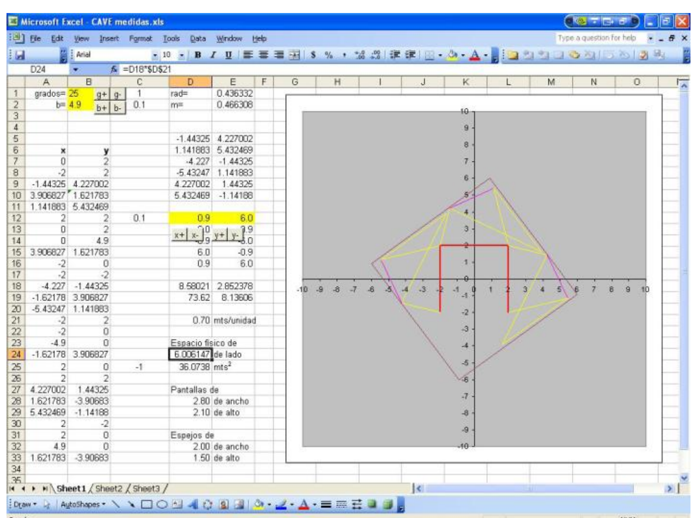


**Figure 1.8 Configuration of Aguilera**

## 1.4 Previous work on the Stereoscopy Module

There are different methods to see stereo graphics. One of these methods is using stereoscopic devices, see chapter 5. In this work, three stereoscopes have been adapted using electronic devices. Table 1.3 shows some works where digital stereoscopes have been used.

**Table 1.3 Previous work on the Stereoscopy Module**

| Title | Stereoscope | Static /Dynamic | Displaying device | Images kind |
|---|---|---|---|---|
| http://astronomy.swin.edu.au/pbourke/stereographics (Bourke, 2005) | Holmes-type digital stereocope | Static | iPod | Photographs |
| Reevaluating stereo and motion cues for visualizing graphs in three dimensions (Ware, et al., 2008) Visualizing graphs in three dimensions (Ware, et al., 2005) | Wheatstone-type digital stereoscope | Dynamic | Monitors | Graphs |
| Re-engineering the Wheatstone stereoscope (Kollin, et al., 2007) Re-engineering the stereoscope for the 21st century (Kollin, et al., 2007-2) | Wheatstone-type digital stereoscope | Dynamic | Monitors | No specified |

- Paul Bourke builds a digital stereoscope based on the Holmes-type stereoscope. He uses two iPods for displaying the stereo images (Bourke, 2005). Figure 1.9 shows the digital stereoscope of Bourke. Although in this work the Holmes-type stereoscope is not used, there is some similarity in the concept of adapting an antique stereoscope.

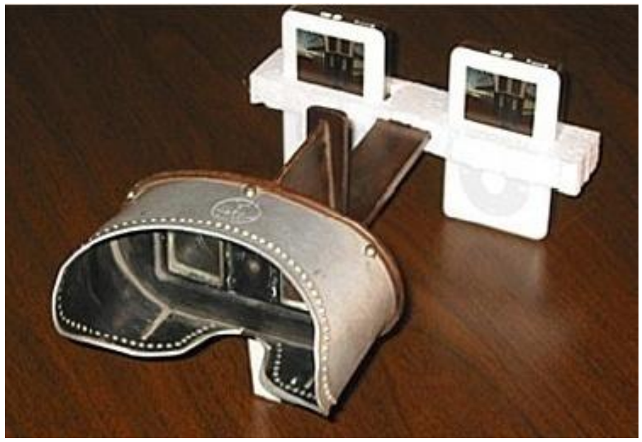

**Figure 1.9 Holmes-type digital stereoscope built with two iPods**

- Researchers Colin Ware and Peter Mitchell of the New Hampshire University build a digital stereoscope based on the Wheatstone-type stereoscope to display graphs in 3D. They used two monitors for displaying graphs (Ware, et al., 2005), (Ware, et al., 2008). Figure 1.10 shows the digital stereoscope of Ware and Mitchell. The Wheatstone-type stereoscope is used in Chapter 5 to build virtual environments in different sizes.

**Figure 1.10 Wheatstone-type digital stereoscope built with two monitors**

- Joel Kollin and Ari Hollander of the Washington University build a digital stereoscope based on the Wheatstone-type stereoscope. To display the stereo images two monitors are used. Additionally they have worked in the re-engineering of this stereoscope (Kollin, et al., 2007) and (Kollin, et al., 2007-2). shows the digital stereoscope of Kollin and Hollander with different rotations angles between the mirrors and monitors.

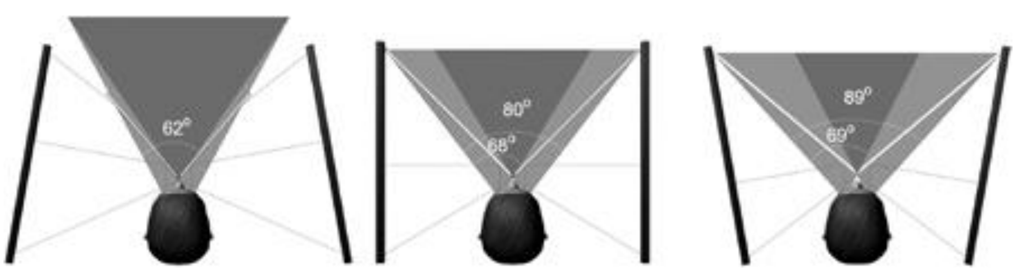


**Figure 1.11 Re-engineering of Wheatstone-type stereoscope**

In our research, three stereoscopes were adapted including the Cazes, the Wheatstone and the box type, which are described in the chapter 5.

## 1.5 Previous Work on the Sound Module

Table 1.4 mentions different work related to sound in Virtual Reality.

**Table 1.4 Previous work on the Sound Module**

| Title | Kind of world | Kind of sound | Sound is used: |
|---|---|---|---|
| The Use of Visual and Auditory Feedback for Assembly (Ying, et al., 2005) | Virtual assembly environment | Sounds of a specific object | As feedback to some activities |
| Head motion and latency compensation on localization of 3D sound in virtual reality (Wu, et al., 1997) | No specified | Sound | To locate objects 3D |
| Spatial sound localization in an augmented reality environment (Sodnik, et al., 2006) | Virtual scene with airplanes | Sound of airplanes | To locate objects 3D |

- Ying Zhang, Reza Sotudeh, and Terrence Fernando (Ying, et al., 2005) 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 dissertation uses the 3D sound in different virtual environments. This reference (Ying, et al., 2005) describes an evaluation more than an model or an implementation. See Figure 1.12.

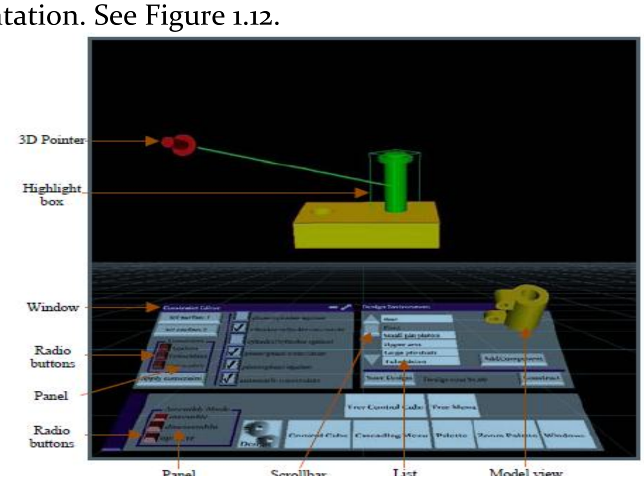


**Figure 1.12 User Interface of the virtual assembly environment**

- Jiann-Rong Wu, Cha-Dong Duh, Ming Ouhyoung, and Jei-Tun Wu (Wu, et al., 1997) 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 their work Jaka Sodnik, Saso Tomazic, Raphael Grasset, and Andreas Duenserand Mark Billinghurst explore the possibility of location of objects in an environment based on sound and visual cues, see Figure 1.13. In addition in their virtual world several object are too close together producing interference between they, this problem also occur in our project,

**Figure 1.13 Localization test in an augmented reality environment**

## 1.6 Research Design

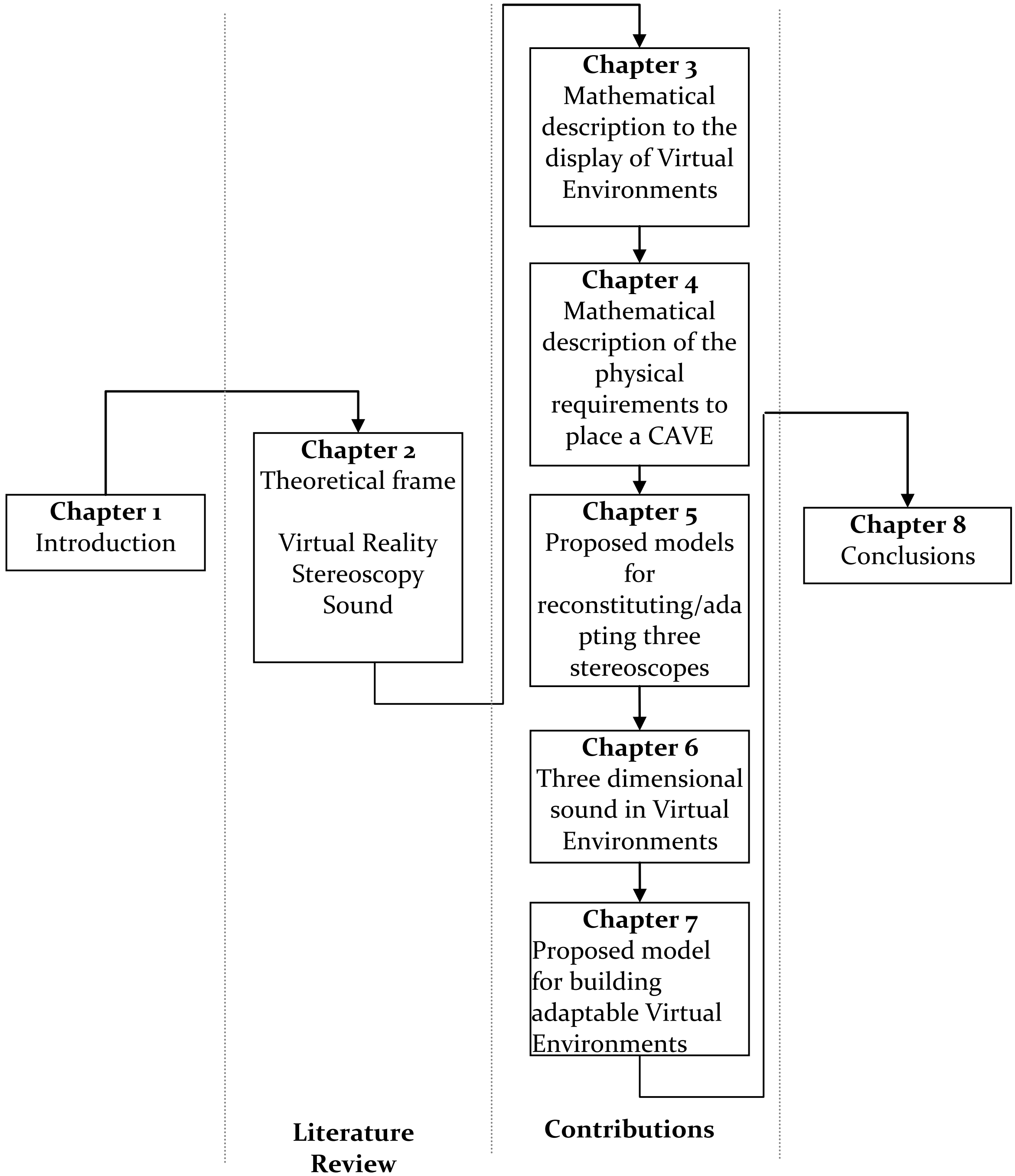


**Figure 1.14 Dissertation Organization**

The remaining chapters of this dissertation are organized as follows:

### Chapter 2 Theoretical frame:

This chapter provides a description of the fundamental characteristics for building virtual environments. Besides, this chapter presents the foundation of stereoscopy and different stereoscopic techniques. Finally, the last section offers the fundamentals of acoustics and techniques of sound.

### Chapter 3. Mathematical description to the display of Virtual Environments:

This chapter provides some characteristics of the *frustum* and the required formulae to display different virtual worlds through multiple screens. The result of this research is published in the 1st International Conference on Computer Science -CICOMP 2006 (Mora, et al., 2006).

### Chapter 4.Mathematical description of the physical requirements to place a CAVE:

This chapter is focused on the development of equations for computing the room size where a CAVE will be built. This research is published in the Journal of Research in Computing Science (Mora, et al., 2008-4).

### Chapter 5. Proposed models for reconstituting/adapting three stereoscopes:

This chapter presents three contributions to stereoscopy: The first one is a method for obtaining Stereographics using a two-monitor system and four mirrors published in the 18th International Conference on Electronics, Communications and Computers -CONIELECOMP 2008 (Aguilera, et al., 2008) and in the Virtual Concept Conference (Aguilera, et al., 2006). The second contribution is the creation of a virtual environment, which is formed by using two parallel walls published in the journal "Iberoamericana de Computación. -Computación y Sistemas", (Mora, et al., 2009) and finally the third contribution is the building of a boxed-type stereoscope published in the journal CiBIyT (Mora, et al., 2008-2).

### Chapter 6. Three dimensional sound in Virtual Environments:

This chapter discusses the incorporation of sound into different virtual worlds and shows some of the navigation effects when sound is used. The result of this research is published in the 20th International Conference on Electronics, Communications and Computers -CONIELECOMP 2010 (Mora, et al., 2010).

### Chapter 7. Proposed model for building adaptable Virtual Environments:

This chapter contains the general scheme of the system and three virtual environments with different input devices published in the 19th International Conference on Electronics, Communications and Computers -CONIELECOMP 2009 (Mora, et al., 2009-2) and in the journal CiBIyT (Mora, et al., 2009-1).

## Chapter 8. Conclusions:

This chapter contains a discussion of the contributions of this work and some suggestions for future research and development.

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### Index B. List of Tables

This index contains the list of tables of this work.

### Index C. List of Equations

This index contains the list of equations of this work.

### References

This section presents the list of references of this work.