Chapter 2

Theoretical frame

2. Theoretical frame

2.1 Virtual Reality

The use of Virtual Reality technology is relatively recent. Initially, this technology was almost exclusively used by academic, industrial and military communities. Currently, Virtual Reality is expanding into multidisciplinary areas such as medicine, art, culture, etc. Virtual Reality scientists are always trying hard to improve the interaction with the people using interesting environments and sophisticated tools.

Virtual environments involve graphics, sound and multiple devices in order to achieve a more natural interaction. An immersive virtual environment is characterized by its ability to surround the viewer with a computer-generated environment; this allows the user to have the feeling of being within the virtual world and being part of it, making the interaction particularly easy. The building of virtual environments involves many modules: The modeling module (Virtual Worlds, objects, etc.), the input device module, the communication module, the navigation module, the sound module, the stereoscopy module, the application-specific modules, the interface module, etc. (Zachmann, 1994). See Figure 2.1.

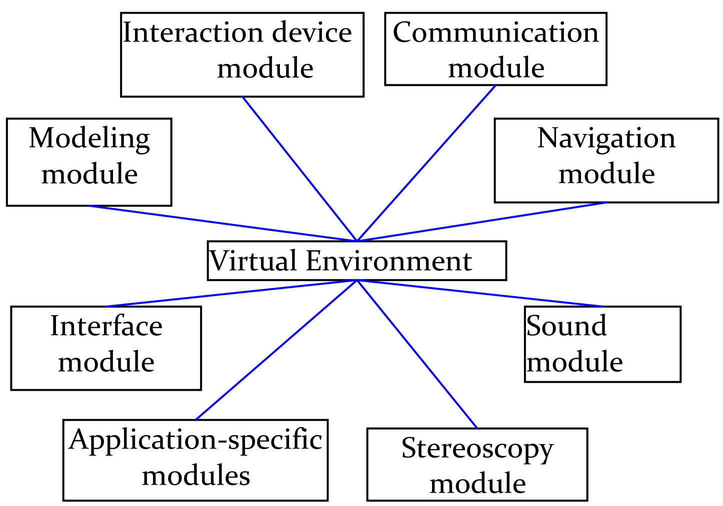

Figure 2.1 Modules used in the building of a virtual environment

This section describes the necessary tools to build different virtual environments.

Section 2.1.1 describes four useful characteristics in the building of virtual environments:

-Virtual and physical aspects
- Immersive and non-immersive environments
-Parallel and perspective projection.
-Interaction

Section 2.1.2 contains a classification of a virtual world.

Section 2.1.3 shows three examples of virtual environments

Section 2.1.4 describes different Virtual Reality applications.

2.1.1 General issues in the design of Virtual Environments

For many years, people have benefited from great advances in computer science. Now, it is not unusual to find applications that make use of different devices and software. Currently, virtual environment visualization can be accomplished using one or more screens depending on the purpose. For instance, an architectonic design can be displayed on a single screen; a Geographic Information System can be displayed on panoramic screen and a training simulator requires a more complex physical environment.

The construction of virtual environments involves many resources, such as equipment, installations, software, hardware and specific applications. Moreover, there are others issues that must be considered such as: the physic and virtual parts, immersion, the levels and type of immersion, the projection types and the user interaction.

2.1.1.1 Physical and Virtual parts in a Virtual Environment

A computer-generated virtual environment system is composed mainly of two parts:

a) The physical part, which includes the user(s) and the hardware (computers, screens, and/or walls and others input and output devices like head-trackers, gloves, loud-speakers, etc.)
b) The virtual part, which includes all the software (solid models like all the non-deformable objects in the scene, volume models for defining clouds, water, etc., main virtual world programs and drivers for all the computer-controlled hardware)

Figure 2.2 shows the physical part of an immersive environment. This environment is built with three screens, four projectors, four mirrors and the floor.

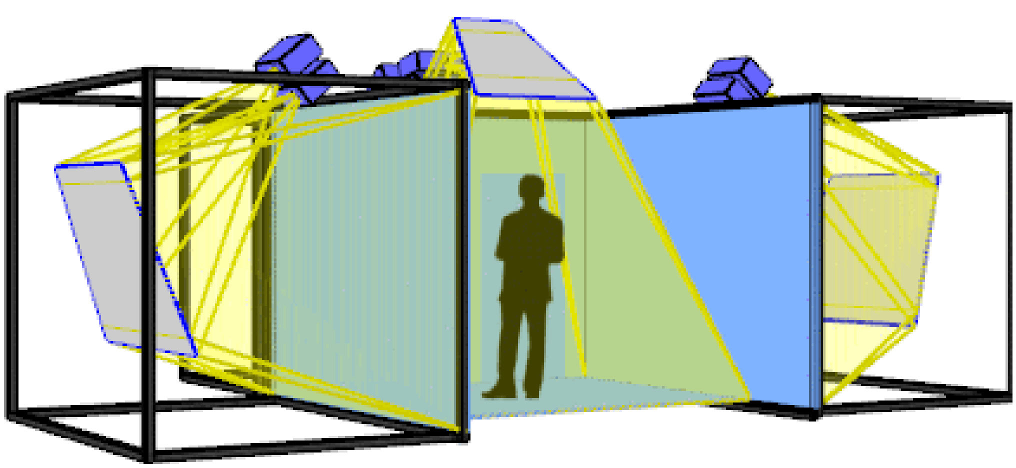

Figure 2.2 CAVE

Figure 2.3 shows a scene of a virtual world, specifically a simulation of the Temple of Zeus at Olympia.

Figure 2.3 Example of a scene of a virtual world

With the physical and virtual parts, it is possible to build different environmental configurations with multiples characteristics.

2.1.1.2 Environments: Immersive and non-Immersive

Immersion is usually defined as the full sensory replacement by artificial means instead of being generated from the real world (Pausch, et al., 1997). Immersion is based on the human senses, mainly sight, which has the ability to process more information than the remaining senses combined. The brain can learn rapidly from the visual data (Jalkanen, 2000). In order to have an effective immersion experience, the viewer has to forget the limitations in the virtual worlds, because it is not yet possible to create fully realistic images in real time. Sound is also very important for an immersive system. Nowadays people can enjoy stereo and 3D sounds; these allow for the improving the quality of a virtual environment. Touch can improve the user experience. Currently, there has been a great evolution in the development of haptic devices. Smell and Taste are still not commonly used in the virtual environments.

In immersive environments such as the CAVE, the viewer is generally surrounded with multiple screens and he can feel that he is inside a virtual world. Figure 2.4 shows an immersive environment built with four projections.

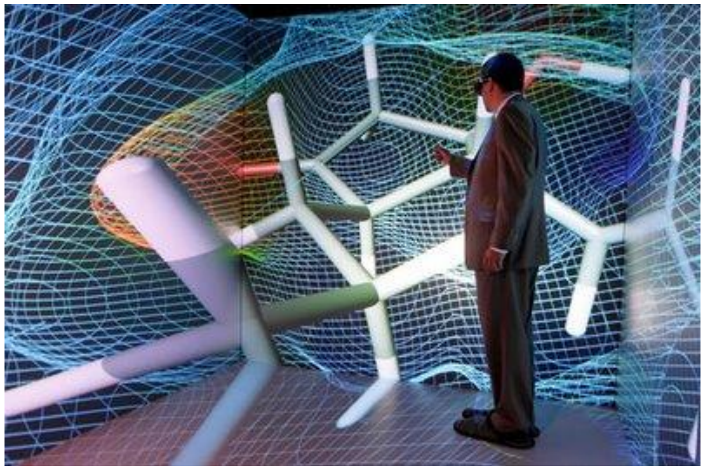

Figure 2.4 An immersive environment

In a non-immersive environment, the virtual world is viewed through one or more monitors that can be lined-up. Its interaction with the user is carried out with the conventional devices: keyboards, mice and trackballs, and on some occasions using 3D interaction devices. The non-immersive environments do not require that the users have any immersion sense and do not consider the viewer position. These environments are the lowest cost Virtual Reality solutions (de Asa Villanueva, 2004). Figure 2.5 shows a non-immersive environment.

Figure 2.5 Non-immersive environment

2.1.1.3 Parallel or Perspective Projection

An objective of computing graphics is the projection of 3D objects in two dimensions. There are two projection types called parallel and perspective. In the perspective projection the distance between the projection center and the projection plane is finite, while in the parallel projection it is infinite (Aguilera, 2007). Figure 2.6.1 shows a house displayed with a parallel projection. Figure 2.6.2 shows the house in perspective projection. The perspective projection is usually used in the building of the virtual environments because it looks more realistic.

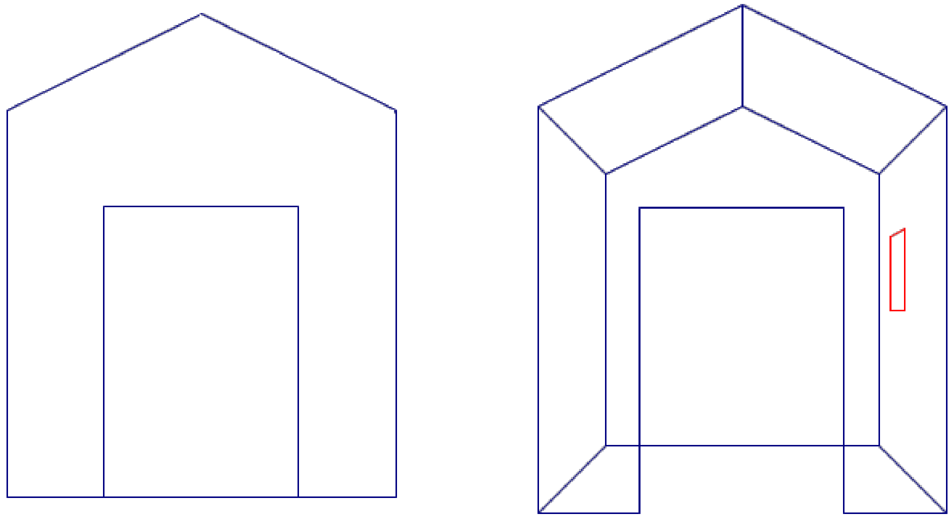

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Figure 2.6 Projections: 1) Parallel. 2)Perspective

2.1.1.4 Interaction in the Virtual Environments

In the previous section some aspects to be considered in the creation of virtual environments have been discussed. This section describes a complementary process- The interaction. The interaction between the system and the user should be natural; for example using the speaking and physical actions with the body. A good interaction helps to get a better immersion sense (Aguilera, 2007). Currently, there are many Virtual Reality devices available for interacting and manipulating virtual environments; besides sensors, cameras and others computer devices to add realism to a virtual environment. Figure 2.7 shows Haptic interaction with a hyper-redundant haptic display. Kinesthetic feedback devices are interfaces allowing force and torque feedback to human operators. These forces and torques are usually measurements from remote teleoperator environments.

Figure 2.7 Haptic interaction with the hyper-redundant haptic display

Another aspect to be considered is the delay. The delay in a virtual environment causes problems in the interaction. Ideally there should be no delay between the input and output devices, that is to say, between the user movement and the system response, because the immersion could be lost. According to (Aguilera, 2007), the response time should be less than 50 milliseconds. The time that the system takes to respond is known as latency. It is more perceptible when the user does fast movements. The latency becomes evident when it is greater than 100 milliseconds. The more complex the environment is, the greater the latency the system will have. For this reason it is necessary to find a balance between complexity and latency.

2.1.2 Virtual Worlds

Although the focus of this work does not include many details about virtual worlds, it is important to know the classification of a virtual world. According to Zachmann (Zachmann, 1994), a virtual world can be classified using several criteria. A virtual world can be: real or unreal, whether they already exist, will exist some time, or existed, or will never exist. Finally, they can be remote or local environments. See Figure 2.8.

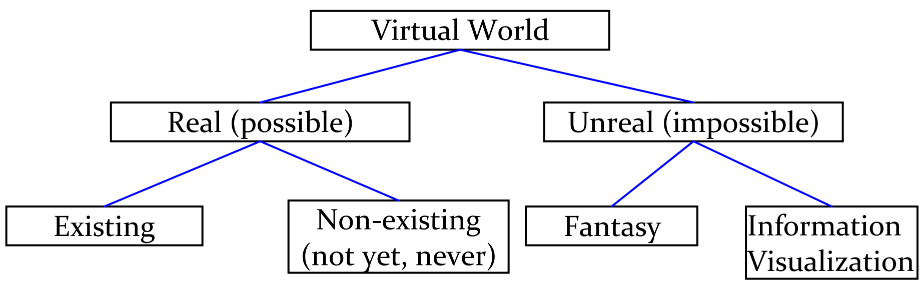

Figure 2.8 Classification of virtual environments

2.1.3 Example of Virtual Environments

There are different models of virtual environments; just three examples are shown below.

-Figure 2.9 shows an immersive virtual environment of the CAVE type, which is built with four projections. This system should react with a minimum response time to the movements of the viewer. Generally these environments require sophisticated equipment, powerful computers and /or PC clusters. Examples of this type of environment can be found in (Cruz-Neira, et al., 1997), (Jalkanen, 2000), (Po-Wei, et al., 2002), etc.

- Figure 2.10 shows a visualization observatory, which has a curved screen. This type of environment has to have a combination of projectors in order to have a correct display. In this particular case, it is possible to use stereoscopic goggles and a dark environment is required. Figure 2.10 shows UNAM's visualization observatory (Universidad Nacional Antónoma de México) (Lucet, 2006).

- Figure 2.11 shows a large display monitor that allows multiple users to look at it at the same time. Users can view the display vertically or tilted horizontally like a table or bench. Users wear special goggles while looking at the workbench. Each user sees the same image projected from the workbench display. An example of this environment is shown in (Strickland Jonathan, 2009)

Figure 2.9 CAVE immersive virtual environment

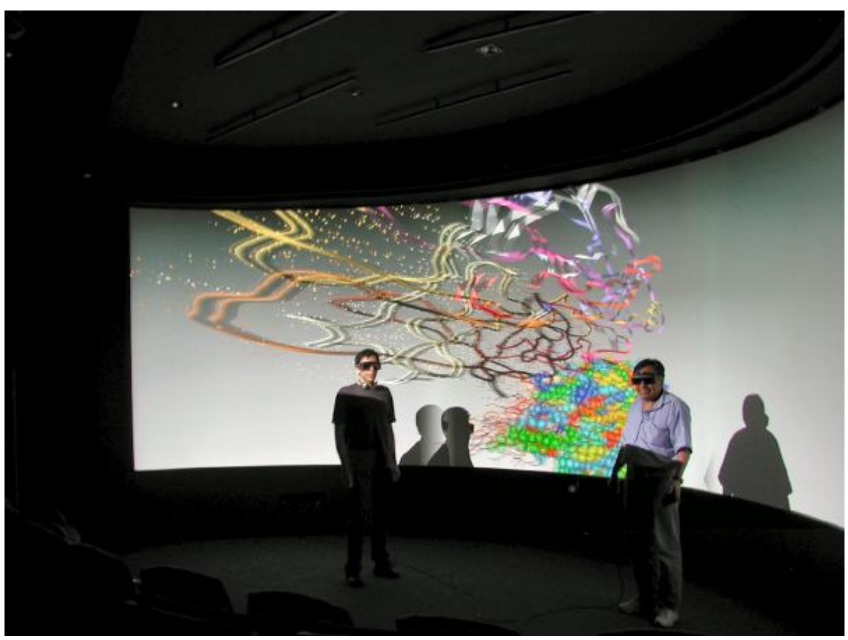

Figure 2.10 IXTLI screen

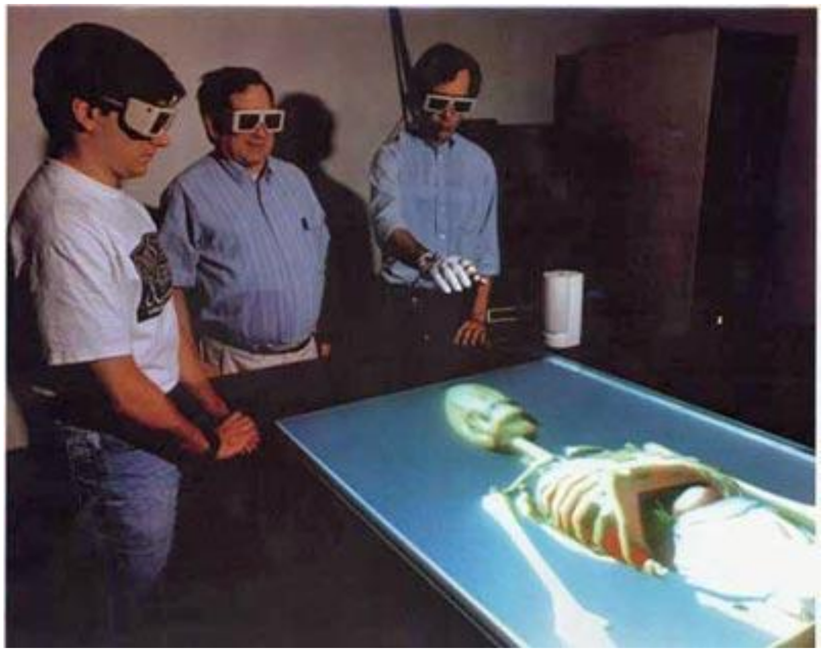

Figure 2.11 Aurally immersive virtual

2.1.4 Virtual Reality Applications

Virtual Reality can be used in many areas; in this document only some applications are mentioned:

- Automobile industries seem to be among the leaders in applying virtual reality. Especially during the product development process. The use of prototypes is essential because they can represent important features of a product which can be investigated, evaluated, and improved (Lamouroux, et al., 2007), (Sherman, 2003), (Henry, 1992).

- In the Aeronautics industry it is used for designing airplanes, reviewing interiors, aero dynamism and simulating accidents (Aguilera, 2007), (Lucet, et al., 2004)

- Virtual Reality is used in industry in general for modeling during the design process and assembly of parts (Neugebauer, et al., 2007), (Di-Gironimo, et al., 2007), (Drieux, et al., 2007), (Sherman, 2003), (Zachmann, 1998).

- Oil industry uses Virtual Reality to review corresponding information to geological levels, for studying oil accumulation and to determine the optimal method of extraction (Jones, 1995).

- The use of Virtual Reality in architecture is very common, because it allows architects to create detailed and realistic designs (Jones, 1995).

- A major use of Virtual Reality is in the entertainment market. Many companies produce games using Virtual Reality principles (Jones, 1995).

- Artists use Virtual Reality to generate music and to paint applications (Jidong, et al., 2007).

- Virtual Reality has a number of uses in the field of medicine, including sensitive surgical interventions, and training purposes (Jones, 1995).

- Virtual Reality has created more types of interaction between students and computer tutors.

2.2 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.

This section is organized as follow:

In section 2.2.1 there is a description about vision Foundation: Monocular and Binocular depth cues, Binocular Vision and limits of depth perception

Section 2.2.2 offers a brief history of stereoscopy and a description of four basic stereoscopic devices: Wheatstone-type stereoscope, stereoscope of lenses (Brewster and Holmes), Boxed-type stereoscope, and Cazes-type stereoscope, which will be used in chapter 5.

Section 2.2.3 presents different stereoscopic techniques.

2.2.1 Vision Foundation

Human beings can perceive depth when they see objects in a monocular and binocular way. They are able to determine relative position of objects around themselves and their physical relation with them. There are some cues that allow for the interpretation of depth; these are shown in Figure 2.12 (Schwartz, 2004).

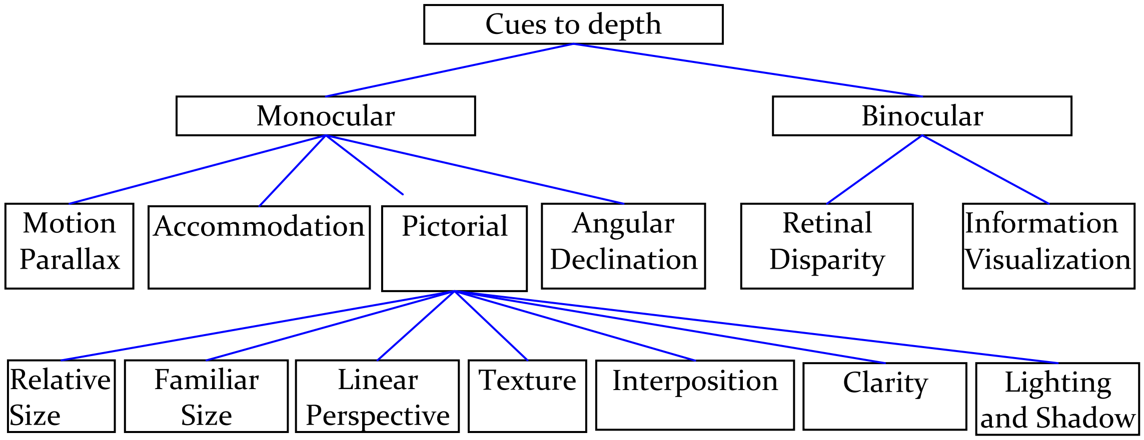

Figure 2.12 Classification of depth cues

In section 2.2.1.1 monocular depth cues are described and in section 2.2.1.2 the binocular depth cues are reviewed.

2.2.1.1 Monocular Depth Cues

Monocular vision is presented when the objects are seen with a single eye and provide most of the depth signal due to the following factors: pictorial, angular declination below the horizon, motion parallax, and accommodation (Lipton, 1997), (Kaufman, 1974).

- **Pictorial depth cues** are the following: size, linear perspective, texture, interposition, clarity, lighting, and shadow. These are used in a two-dimensional representation. Pictorial depth cues are used in photography, painting, TV, etc. (Schwartz, 2004) .

    - **Size**.- human beings perceive distances among objects by the relative size of the retinal images they produce. Additionally, human beings knowledge of object size also has an influence.
    The object size projected on the retina is bigger when the object is nearer to the viewer. Figure 2.13 shows three pitchers which look bigger than the two cabins that are far away. It is possible to understand that the painter wants to give us the sensation that the pitchers are nearer than the cabins.

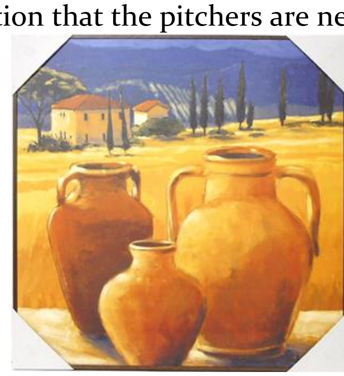

Figure 2.13 The nearest objects look bigger than the farthest objects

- **Linear Perspective**.- Generally, Linear Perspective is represented by parallel lines point directly from us and they seem progressively close together in the distance. This convergence of lines creates a powerful impression of depth in a two-dimensional drawing (Eysenck, et al., 2005). Figure 2.14 shows a scene in linear perspective.

Figure 2.14 A photograph in linear perspective

- **Texture**.- Most objects have texture, which look more real when there is a rate of change in its colors (Boothe, 2002). Figure 2.15 shows an example of texture of sand.

Figure 2.15 Texture of Sand

- **Interposition**.- This occurs when a nearer object hides part of a more distant object. Figure 2.16 shows four examples of interposition.

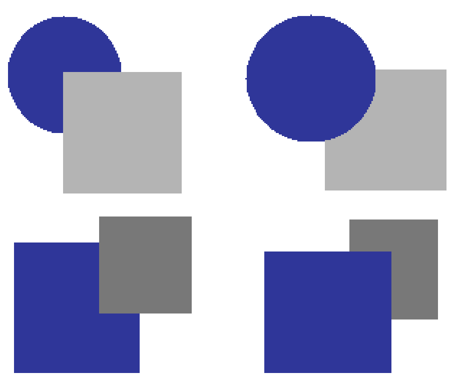

Figure 2.16 Interposition between

- **Clarity**. Different levels of clarity are used to indicate depth. Elements as smoke, rain, and fog darken the objects, which cause an appearance of distance (Schwartz, 2004). Figure 2.17 shows two scenes. In the first scene it is raining and in the second one there is fog.

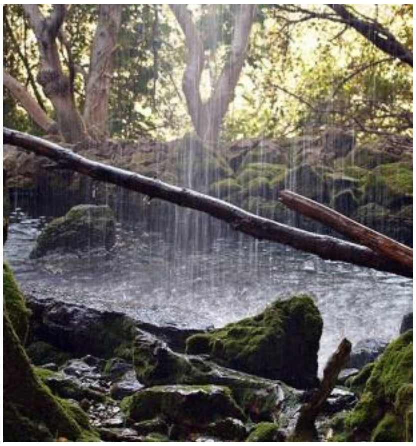

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Figure 2.17 Example of clarity

- **Lighting and shadow** assign different depth levels to parts of the object. Figure 2.18 shows an example of lighting and shadowing.

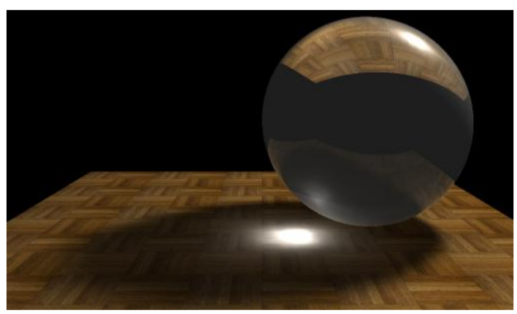

Figure 2.18 Lighting and shadow

- **Angular declination below the horizon**. This is the ability to correctly judge the object distance. See Figure 2.19 (Schwartz, 2004).

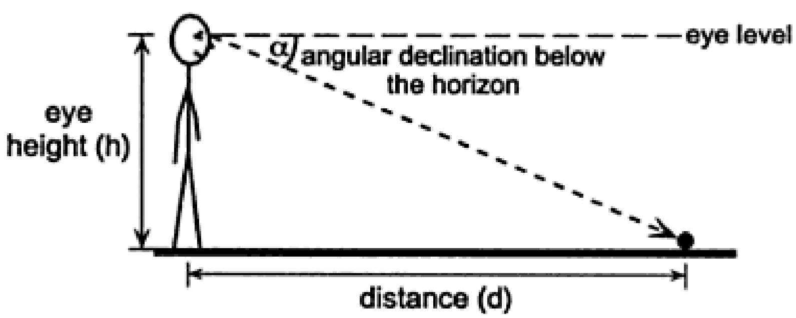

Figure 2.19 Angular declination below the horizon used for determining distance

- **Motion Parallax**. This occurs when there is movement in the position of an object, due to movement of either the object or the viewer. Motion Parallax is a function in which an object position is moved through the retinas. When there are objects in movement the closest ones appear to be faster, although they may have move at the same velocity as objects at a greater distance.

- **Accommodation**. During accommodation, the dioptric power of the crystalline lens increases, allowing the nearer objects to focus more clearly on the retina than the farther ones, see Figure 2.20.

Figure 2.20 The bird appears more in focus than the leaves

2.2.1.2 Binocular Depth Cues

Binocular vision refers to a human being's ability to see the same scene with the retinas of both eyes in slightly different ways. This allows for perception of depth and distance. In stereoscopic vision there are two important concepts: Retinal disparity and Parallax (Steinman, et al., 2000).

- **Retinal disparity** tells that if the images seen on both retinas are compared, we would notice that these images are not in the same position, see Figure 2.21.

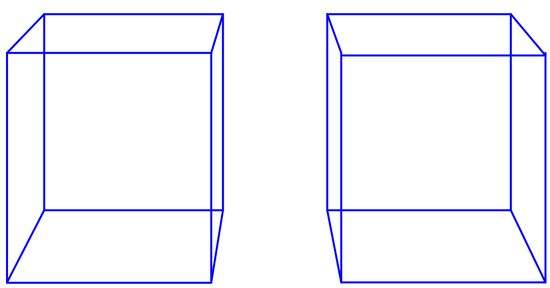

Figure 2.21 Images seen on two retinas

- **Parallax** means disparity, which is caused due to the difference in the position of the eyes. Eyes are separated by a distance referred to an interocular distance. This distance is roughly 60 to 65 mm, depending on the person. Figure 2.22 shows two eyes viewing an object. The respective retinal images are distinct because the eyes are in different locations (Steinman, et al., 2000).

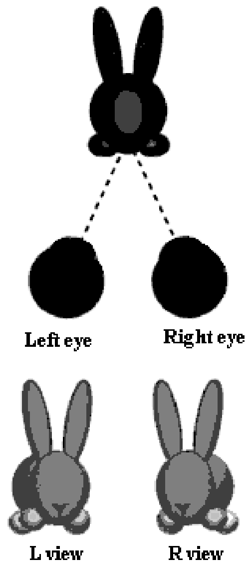

Figure 2.22 Vision Binocular

2.2.1.3 Vision Binocular Foundation

It is understood that binocular vision refers to vision with two eyes. Our perception with binocular vision is richer than it is with monocular vision. Despite the differences in the images in each eye, people can see a singular world.

The building of a 3D image using two images is based on:
-Field of view
- Binocular summation
-Fusion

The field of view is the angular extent of the observable world that is seen at any given moment (Steinman, et al., 2000). A human being has the horizontal field of view of approximately 180 degrees with two eyes. Figure 2.23 shows the human visual field (Steinman, et al., 2000).

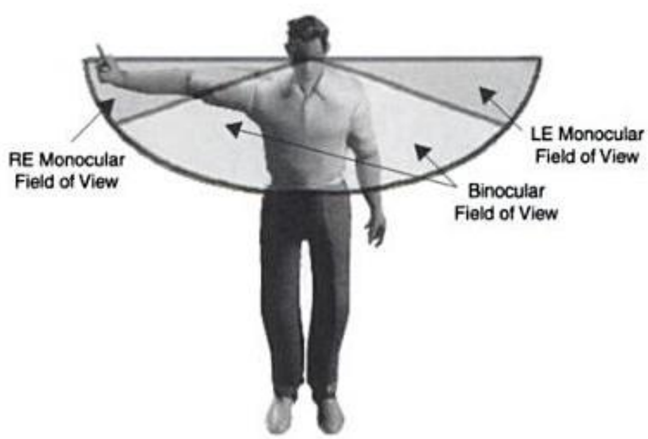

Figure 2.23 Field of view

Binocular summation takes place when fields of view overlap, which results in confusion between the left and right eye image of the same object (Blake, 1973). Two things can occur: one image can be suppressed so that only the other is seen or the two images can be fused. When two images of a single object are seen is known as Double vision or diplopia.

Fusion occurs when a single image is seen despite each eye is having its own image of an object (Wheatstone, 1838). Fusion only occurs with similar images. If the disparity is too big superimposition occurs.

2.2.1.4 Limits ofDepth Perception

Nevertheless on some occasions there are limits of depth perception. Steinman mentions some of them in (Steinman, et al., 2000):

-Stereoacuity is the ability to detect differences in distances. Stereoacuity is a quantitative measure of stereopsis (Kail, et al., 1984).

-Panum´s range is the largest depth before there is loss of fusion (Steinman, et al., 2000).

-Binocular rivalry in when each eye image does not combined fully, but they struggle to win the other eye's image (Alais, et al., 2005).

-Binocular suppression occurs when one eye input is shut off (Steinman, et al., 2000).

2.2.2 A brief history of the Stereoscopy

Stereographs are two photographs or images positioned side by side, one for the left eye and one for the right. This stereo pair is used together with a stereoscope. When they are combined they provide an illusion of depth by allowing us to see three-dimensional views in an artificial way. Stereographs are also known as stereograms, stereoviews, stereo pairs, and stereocards.

Therefore, stereoscopic devices work in the same way that human vision works. Brewster defined a stereoscope as an optical device for representing in apparent relief and solidity, natural objects and groups of objects, by uniting into one image two plane representations of these objects seen by each eye separately (Brewster, 1856). Due to the fact that the stereoscope allows seeing stereographic images (Leyshon, et al., 1996), (McKay, 1953), its task is to make possible the superimposition of both images into a unique 3D image. When each eye sees a different image of a stereo pair, its corresponding image is sent to the brain, which merges their similitude and combines their differences, creating the illusion of a single three-dimensional image (Okoshi, 1976).

There are four basic types of stereoscopes, see Figure 2.24(Parente, 1999):

a) Wheatstone-type stereoscope.
b) Stereoscope of lenses: (Brewster and Holmes)
c) Boxed-type stereoscope.
d) Cazes-type stereoscope

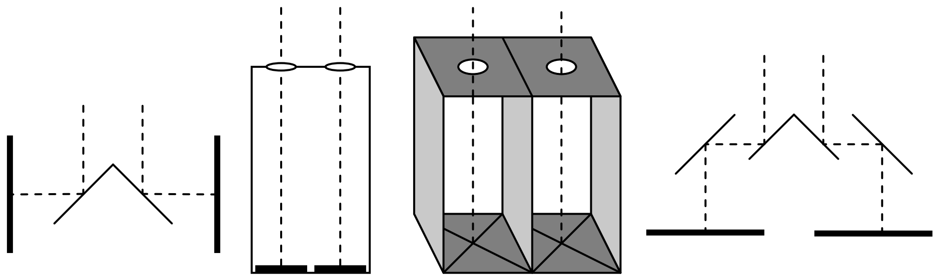

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Figure 2.24 Four types of stereoscopes. The thick lines represent the stereo pairs, the inclined lines represent mirrors, and the dashed lines represent the eyes' lines of sight.

2.2.2.1 Wheatstone-type Stereoscopic Device

Sir Charles Wheatstone is considered one of the pioneers of the stereoscopy for his article "On some remarkable, and hitherto unobserved, Phenomena of Binocular Vision", which was published in the "Philosophical Transactions" of the Royal Society of London in 1838 (Wheatstone, 1838). In this paper, Wheatstone describes a technique used to create the illusion of depth; he proposes that his development be called Stereoscope. It was built several years before the photography was invented.

Figure 2.25 shows the first stereoscope designed by Wheatstone (Wheatstone, 1838). This stereoscope was built with two flat mirrors, which were placed forming an angle of 90° with each other and placed vertically upon a horizontal board. The stereoscope used two slightly different drawings. The images produced by this stereoscope are shown laterally inverted to the user as a result of mirror use, see Figure 2.26.

After 1838, there were many modifications to the first stereoscope. For instance, Wheatstone built a portable stereoscope in 1852, which is shown in Figure 2.27 (Wheatstone, 1852).

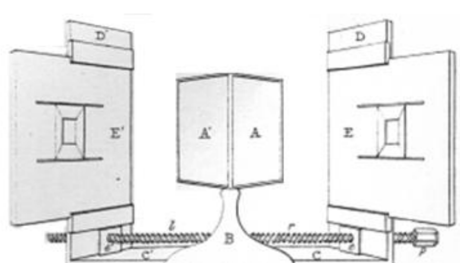

Figure 2.25 First stereoscope designed by Wheatstone

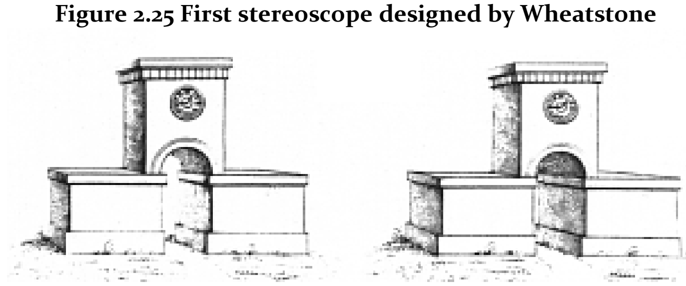

Figure 2.26 An stereoscopic pair made by Wheatstone

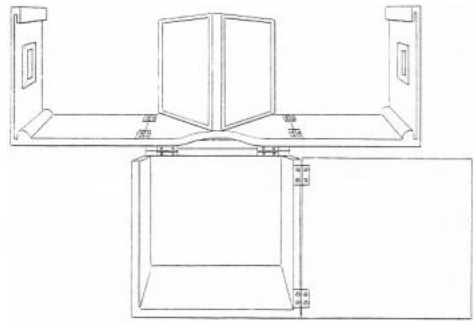

Figure 2.27 A portable stereoscope built by Wheatstone.

From the time of its creation, this stereoscopic device has been both valuable and useful tool for the Vision area and is currently used in some research such as: (Kollin, et al., 2007), (Kollin, et al., 2007-2) and (Ware, et al., 2008).

2.2.2.2 Brewster-type Stereoscopic Device

The Scottish physicist Sir David Brewster designed and built the first stereo camera in 1849. It was a binocular camera which could obtain two synchronized images. This camera stimulated the mass production of stereo photography. Furthermore, Brewster designed a variation of the stereoscope and named it Brewster Stereoscope. He analyzed the theory of stereoscopy and altered it by refractive lenses to his model.

The Brewster-type stereoscope was a box type truncated pyramid. He placed in one extremity at the top of the stereoscope two lenses with an approximate focal distance of 150 mm (6 inch). In the opposite extremity, the stereoscope had a frame that held two photos. The two photos, each approximately 7X7 cm (3X3 inches) are put side by side, see Figure 2.28 (Aguilera, 2007).

This stereoscope was so successful that Brewster said: “It has been estimated that over half a million of these instruments have been sold…” (Kemp, 1859).

Figure 2.28 Brewster type stereoscope

2.2.2.3 *Holmes-type Stereoscopic Device*

In 1862 Olliver Wendel Holmes built another stereoscopic model. This model was considered one of the most popular of the nineteenth century, due mainly to the fact that it was inexpensive and therefore accessible to many people (Aguilera, 2007).

The Holmes stereoscope was hand-held- a vertical base held a horizontal structure on which was assembled a viewer with prismatic lenses in one extremity and in the opposite extremity a stereo pair was held in place using metallic clips. Focal length could be adjusted by sliding the rail of the stereo pair along the structure, see Figure 2.29.

Figure 2.29 Holmes-type stereoscope

2.2.2.4 *Boxed-type Stereoscopic Device*

The boxed-type Stereoscope does not employ any optical element; its work is to hide the corresponding image of each eye from the opposite eye (Aguilera, et al., 2008).

2.2.2.5 *Cazes-type stereoscopic Device*

The first stereoscopes limited the images' size due to the way they were built, with the exception of the Wheatstone-type stereoscope which allows for working with large images. L. Cazes created a stereoscope in 1890, which also allows large images to be seen. This stereoscope uses four mirrors- two for each image. Due to the double reflection, the image can be seen in its original way (Aguilera, 2007), Figure 2.30 show a Cazes-type stereoscope.

Figure 2.30 Caze-Type stereoscope

2.2.2.6 Stereoscopy in the 21st Century

In the 1930´s there was a resurgence of the stereo photography, due to 3D cameras with 35mm tape, such as Realistc or View-Master. The system utilized by these cameras to show the stereo photograph was much simpler those previously discussed. See Figure 2.31.

Figure 2.31 Different View-Master Models

In the 1950's a commercial diffusion of 3D movies was attempted unfortunately, as a result of visual problems due to variety of technical difficulties people rejected these types of movies. Some painters used stereoscopic representation in their work. For instance Salvador Dali applied the ideas of Wheatstone-type stereoscope to showcase some of his works.

In the 1980´s stereoscopy had better results with the IMAX system. The IMAX system has the capacity to display images of far greater size and with much higher quality.

In the 1990's the technological evolution and the 3D monitor's development allowed for stereoscopy to be used in many areas such as medicine, art, etc.

Currently, there are new stereoscopic techniques, tools and graphics libraries in many languages, which increase people's accessibility to stereoscopic technology.

2.2.3 Stereoscopic Techniques

There are other techniques that allow for seeing stereo images correctly, which are described in this section.

2.2.3.1 Parallel Viewing or Wall Eyed

Parallel viewing requires a left and right image. First, the left eye sees the left image and the right eye sees the right image, then the viewer sees each image moving toward the other one until they are overlapped which produces a 3D effect. Using this technique the user can see images without any optical device; nevertheless parallel viewing is limited to images about 2.5 inches wide, the space of the typical human eye (which averages 65 mm), see Figure 2.32.

Figure 2.32 stereo pair

2.2.3.2 Crossed-Eye Viewing

Crossed-Eye Viewing consists of the left eye seeing the right image and the right eye seeing the left image. As a result, the viewer obtains a three dimensional illusion in the center of the images. This technique does not require any equipment; however, crossed-eye viewing can be somewhat stressful, requires patience and practice because the eyes must do the work of a stereo viewer. See Figure 2.33.

Figure 2.33 Inverted Stereo pair

2.2.3.3 *View-Master*

The View-Master is a variation of Parallel viewing but the stereo pair is printed on a translucent film. The film is mounted on the edges of a cardboard disk; this device allows viewing seven colorful images per disc is easy to use and is an economical device. See Figure 2.34.

Figure 2.34 View-Master

2.2.3.4 *Head-Mounted Displays*

Head-mounted display (HMD) is very common in games and stereo films and is sometimes used together with a head-tracking device. The three dimensional effect is produced when the viewer wears a helmet or glasses and sees the stereo pair on two small LCD displays with magnifiers. Due to the proximity between the eyes and the HMD the images look bigger than those displayed on normal screens. Besides, when using a head-tracker and a HMD the user can see a computer-generated image which takes into consideration the viewer position, improving the feeling of immersion. Currently, HMD provides good color and quality image; however, HMD is wear on the user head and its weight of around 1.2 kilograms is still considered excessive. Figure 2.35 shows a HMD

Figure 2.35 Head mounted display

2.2.3.5 LCD Shutter Glasses

This method requires eyeglasses with liquid Crystal; the glass of the eyeglasses has the ability to darken with voltage and be translucent without voltage. These eyeglasses are connected to a video card, and then they alternate darkness and translucent in lapses of time on each eye. These glasses are used together with a monitor or projector. The number of colors seen in the images depends on the monitor or projector. Many virtual environments use this technique. However, this technology has problems such as difficulty in synchronization, ghosting, and flickering. Figure 2.36 .

Figure 2.36 Shutter glasses

2.2.3.6 Polarized Glasses

This method uses two projectors, a filter in front of the lens of each projector, a depolarizing screen, and polarized glasses. Each filter only passes light when the polarization between the projection filter and the glasses is similar and blocks it when it is different; therefore each eye only sees one of the images and in this way the 3D effect is achieved. Using this technique a group of people can see the stereoscopic images at the same time, see Figure 2.37. However, there is a problem, the light reflected from a screen tends to lose a bit of its polarization, and therefore a special screen is required, which increase the cost of resources.

Figure 2.37 Polarized glasses

2.2.3.7 Two-color Anaglyph

Anaglyphic 3D is a technique that was discovered by two Frenchmen; Joseph D'Almeida and Louis Du Hauron in the 1950's. This technique consists of two images of different colors; both images are overlapped to create a single image, see Figure 2.38.1. In order to be able to see the depth effect, it is necessary to use anaglyph glasses. The colors used for the images and the glasses are: red/green, red/blue or red/cyan. The left eye uses the red glass and right eye can use the cyan, blue or green glass, see Figure 2.38.2. The use of a specific monitor or projector is unnecessary, making the anaglyph technique an economical option for users. However, this technique has some disadvantages such as: ghosting, retinal rivalry (it occurs when the brightness of the two images is not the same in each eye), and loss of color.

1 2

Figure 2.38 1) Anaglyph image. 2) Anaglyph glasses

2.2.3.8 Wiggle Stereoscopy

Wiggle stereoscopy does not require any special material, the 3D effect is obtained with an animated gif image that alternates between the left and right image of a stereo pair. The viewer receives the information contained in the stereo pair assembles it in his brain and later interprets depth in the image. This method can be used by people with limited or no vision in one eye. Nevertheless, it is difficult to appreciate some details in images due to a constant wiggling, which can become annoying.

2.2.3.9 Autostereograms

An autostereogram is created using a repetitive pattern on a page. The eyes are looking at the same image, due to the fact the pattern is distorted slightly on each repetition the 3D effect can be achieved. This technique does not require any special device; however, autostereograms can be tiring for the eyes. See Figure 2.39

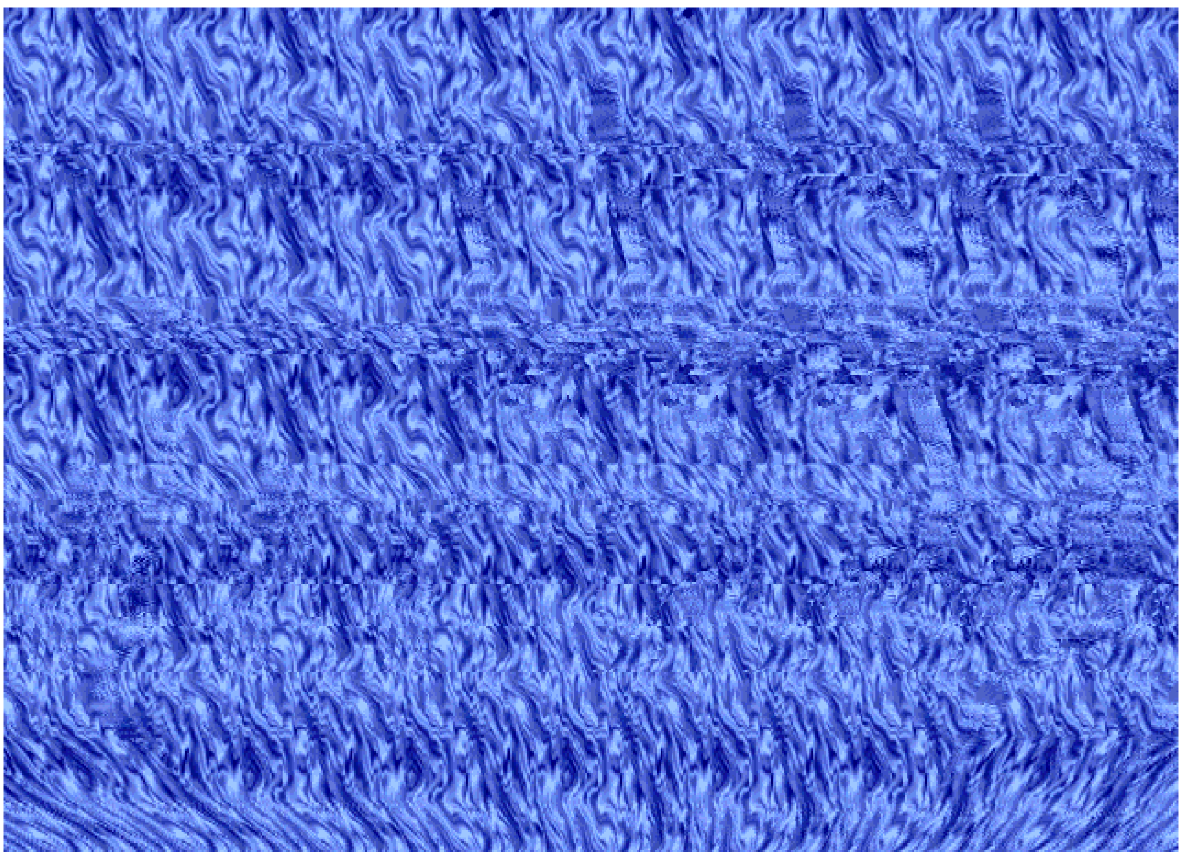

Figure 2.39 Autostereograms

2.2.3.10 Pulfrich Effect

The Pulfrich effect consists of the eyes seeing an object that is moving on a parallel plane toward the viewer forehead. This method is based on understanding that the response of the brain to low light is slower than the response to bright light. Therefore, an eye can be covered with a dark filter and the brain perceives the same image as having as a difference in the horizontal position, which produces a depth effect. This technique does not require special devices, but it cannot be used to show a stationary object; besides, the objects moving vertically will not be seen as moving in depth.

2.2.3.11 Displays with Filter Arrays

The LCD display is covered with an array of prisms that divert the light from odd and even pixel columns to the left and right eye respectively. This technique is typically used in medical and scientific research.

2.3 Sound

The use of sound is currently becoming a more common tool in virtual environments, because it adds a certain level of realism to any virtual environment. When a virtual environment is going to be built, it is possible to take into consideration some advantages of the human hearing system. For example, human beings have the ability to localize different sounds in an environment where there is a set of objects (Greenebaum, et al., 2004). Furthermore sound can play different roles in a Virtual Reality System; these are described in the following points (Gutiérrez, et al., 2008).

- **Complementary information**: sound can help to provide additional information in a virtual environment.
  - When the objects of a virtual world have a sound source, these sounds provide spatial information such as directions and positions.
  - Sound can also indicate to the listener information about the environment size using echoes.

- **Alternative feedback:** sound allows for having a better interface, because a set of sounds can indicate the reception of commands or confirm some activities (Greenebaum, et al., 2004).

- **Alternative interaction modality:** in the form of voice, sound can be an efficient communication method, because this allows for the provision of additional information in a graphic world.
  Currently, there are sound displays which are computer interfaces that provide synthetic sound to the listener interacting in a virtual world (Burdea, et al., 2003).

The use of sound in a virtual environment has unique properties that make it interesting. A human being is able to associate objects with sounds due to his experience in the real world. As a result, when there are sounds in a virtual environment, the user interaction and his immersion improve.

Historically digital sound has been evolved from monophonic to conventional stereophonic and later to multichannel surround (Gröhn, 2006).

- **Monophonic system**. In this system, the listener hears one or more sound sources from one point.

- **Stereophonic system** is characterized by a division in sound sources between a left and right receiver.
- In **multichannel surround systems**, sound sources can be heard from different speakers even behind the listener.
- In **3D sound**, the listener perceives the position of the sound sources.

Nevertheless, according to (Greenebaum, et al., 2004), the use of sound as feedback or information has disadvantages. When the audio becomes viable online, the listener could react in an innate way to the sounds. Additionally the sounds could become annoying after extended use of the program.

This section is organized as follow:

In section 2.3.1 there is a description about the acoustical fundamentals.

Section 2.3.2 describes the monophonic sound.

Section 2.3.3 contains a description about the stereophonic sound.

Section 2.3.4 contains a description about 3D sound.

Section 2.3.5 presents different configuration of surround sounds.

2.3.1 Acoustic Fundamentals

2.3.1.1 Sound Waves

Sound can be defined as fluctuations, or variations transmitted through a solid, liquid, or gas composed of frequencies within the range of hearing and of a intensity level sufficiently strong to be heard (Eargle, et al., 2002), (Robertson, et al., 2003). If the contraction and release of a medium happens repeatedly; it will vibrate with a certain frequency and emit sound waves. The propagation speed of these sound waves in the air depends on the density and the temperature of the transmission medium. The speed of sound in dry air at 20 °C is 343 meters per second. At higher temperatures the speed of sound increases slightly, while at lower temperatures the speed decreases. The exact value is given by the equation:

Eq. 2.1 $$SS = 331.4 + 0.607\,°C$$

Where SS is the speed of sound in the air and the temperature is given in Celsius.

Generally a sound source emits sound waves into all directions, but these waves are affected by interference, reflection, diffraction, refraction, Doppler Effect, etc.

1. The process of **interference** that results from linear superposition of wave disturbances underlies many commonly encountered acoustic phenomena.

Superposition applies to any lineal sound field, whether continuous or transient; whether generated by discrete compact sources, such as a small sparks, or by complex sound sources that are extended in space, such as vibrating machines; or created by the sound field radiated by a source together with reflections of that field by surrounding obstacles. Interference occurs even if sources are random in time and broadband in frequency, but interference is only evident if the sound field is analyzed into many finely resolved frequencies (Frank, 2003).

2. **Reflection** refers to sound that when strikes the wall goes in several directions. Most of it is reflected back into the room where the sound originates. Some of it is absorbed in the wall structure and converted to heat, and a relatively small portion is transmitted through to the other side. The reflection of sound from a wall normally involves some degree of scattering. See Figure 2.40.

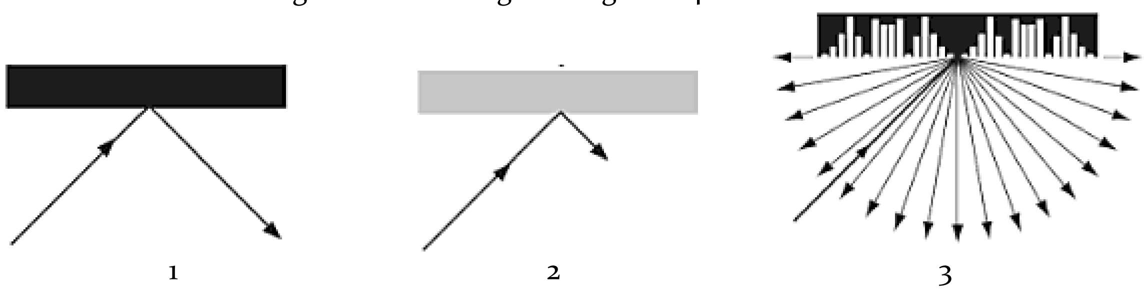

Figure 2.40 1)Reflection. 2) Absorption. 3) Diffusion

3. **Difraction** describes the bending of sound around obstacles in the path. If the obstacle is small relative to the wavelength of the sound, the sound bends around the obstacle as if it was not there. If the frequency of the incident sound is increased, the wavelength is reduced. The bulk of the sound will progress around the obstacle, but there will be some degree of reradiation or back-scattering from the obstacle. If the frequency of the incident sound increases further, producing even shorter wavelengths, then more sound will be reflected from the obstacle, and there will be a clear shadow zone behind it. See Figure 2.41.

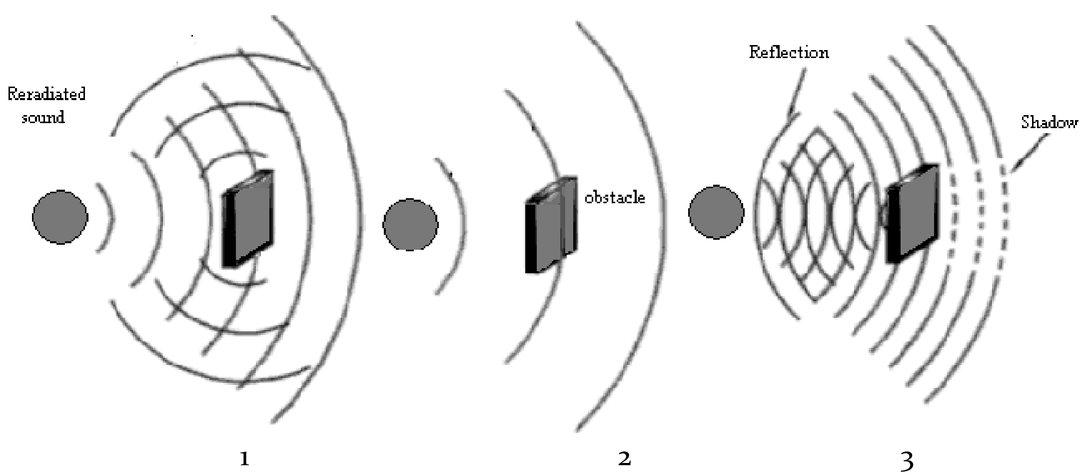

Figure 2.41 1)Small obstacle. 2) obstacle. 3)Shadow

4. **Refraction** refers to the change in the speed of sound as it progresses from one medium to another, or as it encounters a temperature or velocity change (or gradient) in the air outdoors. (Frank, 2003).

5. **Doppler Effect** is the change in frequency of a wave produced when an observer is moving relatively to the source of the wave. With the waves closer together, an observer perceives a higher frequency. Behind the source the waves are spread out, and with an increase in wavelength, a lower frequency is heard. If the source is stationary and the listener moves toward and passes the source, the shifts in frequency are also perceived. The total Doppler effect depends on the source motion, the observer motion, and/or the medium motion. Each of these effects is analyzed separately. The Doppler effect occurs for all kinds of waves, including water waves, and light waves.

   In classical physics, where the speeds of source and the listener relative to the medium are much lower compared to the speed of light, the relationship between observed frequency f and emitted frequency f_0 is given by:

Eq. 2.2 $$f = \left[\frac{v + v_l}{v + vs}\right] f_o$$

   Where:

   v is the velocity of waves in the medium
   v_l is the velocity of the listener relative to the medium; positive if the receiver is moving towards the source.
   v_s is the velocity of the source relative to the medium; positive if the source is moving away from the listener.

2.3.1.2 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.

2.3.1.3 Psychoacoustics

Psychoacoustics is the study of subjective human perception of sounds. Human beings detect sounds through vibrations which come to the brain via the ear canal (Burdea, et al., 2003). Human beings have two ears located on opposite sides of the head, due to separation the arrival time of a signal to each ear varies. Thus, human beings are able to indentify sound and its location. He associates a sound to a direction and distance. In other words, he expects most of the sound sources have a defined position (Gröhn, 2006). Nevertheless, there are sounds in our environment that do not have a position, such as the wind and the rain.

There is an important characteristic in the hearing system: The auditory field- An important difference between hearing and vision is that vision is limited by the field of view (see section 2.2.1.3), but hearing has no directional limitations. A human being can hear a sound that is out of his/her field of view. The auditory field of the human being is 360 degrees around him (Greenebaum, et al., 2004). In addition, the hearing system is unique because of its permanently open channel. That is, even when human beings sleep they hear sounds (Greenebaum, et al., 2004). Nevertheless, the sounds heard by a listener are seldom the same as the sound sources have generated. Air absorption affects the signal, ground reflects sound, and inside buildings walls, ceiling, and the floor generate reflections (Blauert, 1997).

In the hearing system there are two important planes, which are the median and horizontal plane (Gröhn, 2006), see Figure 2.42

- The median plane symmetrically divides the space of a listener into left and right sections. When a sound is located in the median plane, both ears hear the same thing.
- The horizontal plane divides space into upper and lower sections. Each point in the horizontal plane has the same height.
- Azimuth angle is the angular difference from the median plane.
- Elevation angle is the angular difference from horizontal plane.
- Yaw, pitch, and roll are rotation angles around the z, y, and x axes respectively.

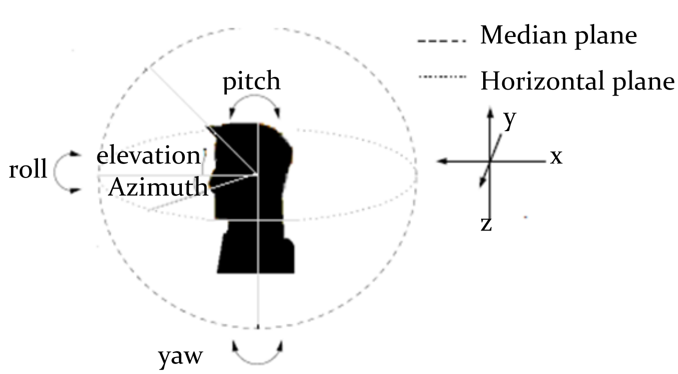

Figure 2.42 Coordinate system for hearing system

In the hearing system the listener uses different types of cues (Wightman, et al., 1997), such as: monaural, binocular, and range.

1) Monaural Cues

Monaural localization mostly depends on the filtered effects of external structures. The external filters include the head, shoulders, torso, and outer ear or pinna (the visible part of the ear), and can be summarized as the head-related transfer functions (HRTFs) (Blauert, 1997), (Wightman, et al., 1997).

2) Binaural Cues

There are two main directional binaural cues that are derived from differences in ear canal signals (Blauert, 1997):

- Interaural time difference (ITD) is the difference in arrival time of a sound between the two ears. This difference helps the listener to determine the location of sounds.

- Interaural level differences (ILD), sometimes called interaural intensity differences (IID), are differences in the sound pressure level arriving to the two ears; which human being uses to localize higher frequency sounds.

3) Range Cues

In addition there are range cues, which are described in the following points:

- **Sound intensity.** A human being can determine the distance of a sound source due to his previous knowledge of this sound and the volume (Burdea, et al., 2003). Figure 2.43 shows a listener, who listens to a loud siren of an ambulance; then he knows that the ambulance is near.

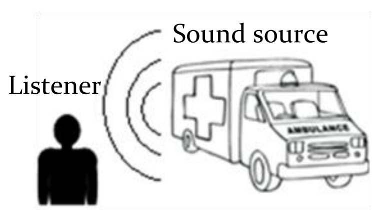

Figure 2.43 Near sound source

Figure 2.44 shows the same listener, but now he hears a low sound of a siren. The listener interprets that the sound source is far. He knows that this source is an ambulance because has previous knowledge of the sound.

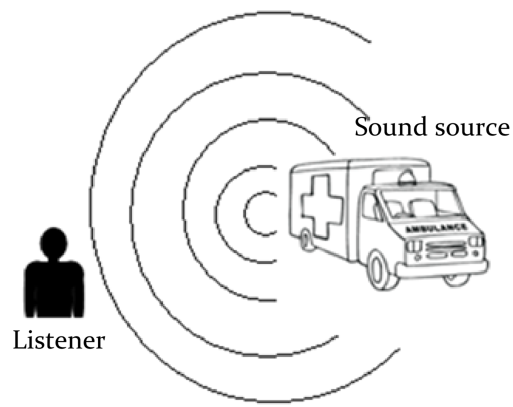

Figure 2.44 Far sound source

- **Motion parallax or change in sound source azimuth** is the generated change in the sound source when the listener changes his head position (Burdea, et al., 2003). Large motion parallax indicates a source nearby (small range). Sources that are far away will have no change in the azimuth rotation. Figure 2.45 and Figure 2.46 show a man listening to music. In Figure 2.45 the man is near the tape recorder, when he moves his head there will be changes in the sound according to his movements.

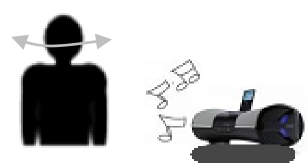

Figure 2.45 Motion parallax: The listener is near the sound source

In Figure 2.46 the man has changed his position and he is farther from the tape recorder, when he moves his head the sound intensity is the same.

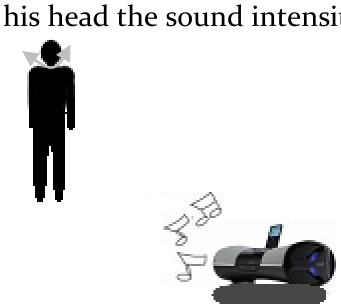

Figure 2.46 Motion parallax: The listener is moving

- **Ratio of sound**. Sometimes a sound goes from its source to the objects that surround the listener such as walls, furniture, floor, etc., and from these objects to the listener (Burdea, et al., 2003). See Figure 2.47

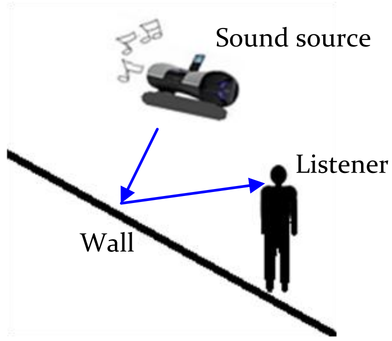

Figure 2.47 Reflected sound

2.3.2 Monophonic Sound

In Monophonic, or "mono" sound, the audio is in the form of one channel. Typically there is only one microphone, one loudspeaker, or in the case of headphones or multiple loudspeakers channels are fed from a common signal path. With this technique, the volume can be modulated to emphasize when a sound source moves away or comes closer, but the user cannot obtain spatial information from a sound source. See Figure 2.48

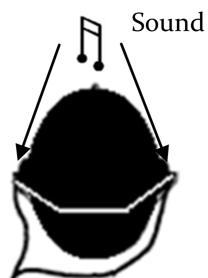

Figure 2.48 Monophonic sound

2.3.3 Stereophonic Sound

Stereophonic sound or stereo sound is the reproduction of sound using two independent audio channels through a symmetrical configuration of loudspeakers in such a way as to create the impression of heard sound from various directions as in a natural environment. This was developed in the early 1950's.

Stereo sound can use different intensities between the ears; these intensities allow for the listener to feel a movement and position sense of sound. The perceived movement is along a line between the two loudspeakers or inside the head between the listener's ears when headphones are used. (Jacko, et al., 2003). In stereo sound the listener's movements are not taken into consideration. Figure 2.49.1 shows a man listening to a sound source in the right ear, if the man turns his head some degrees, the sound source seems to turn too, see Figure 2.49.2.

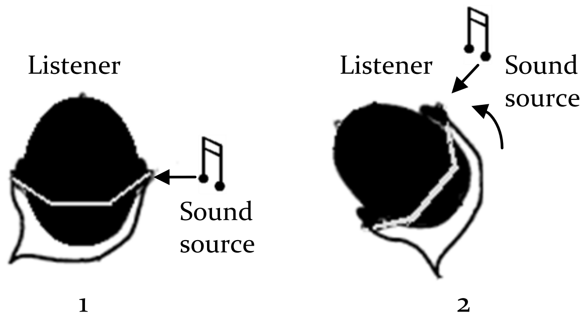

Figure 2.49 Stereo sound

This technique can give us useful spatial cues in a virtual environment (Jacko, et al., 2003).

2.3.4 Three Dimensional Sound

The 3D sound technique allows using binaural spatial audio in a 3D environment (Gutiérrez, et al., 2008). 3D sound links objects and sounds; therefore the sounds should be processed based on their positions. Headphones can be used to hear the 3D sound effect because they take the listener position, sensed by a head-tracker, into consideration. In Figure 2.50 there is a user who is listening to a sound, if the user turned his head he would notice that the sound remains in the same position. The 3D sound systems are used for complementing, modifying, or replacing sound attributes and have control over the spatial perception.

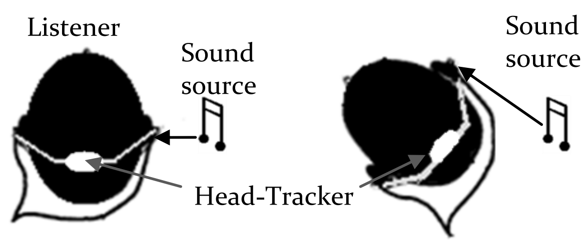

Figure 2.50 3D sound

Some characteristics taken into consideration for use of 3D sound in a virtual environment are described in the following points (Gutiérrez, et al., 2008):

- **3D position:** A sound source is linked with an object; both should have the same position in the virtual environment, see Figure 2.51.

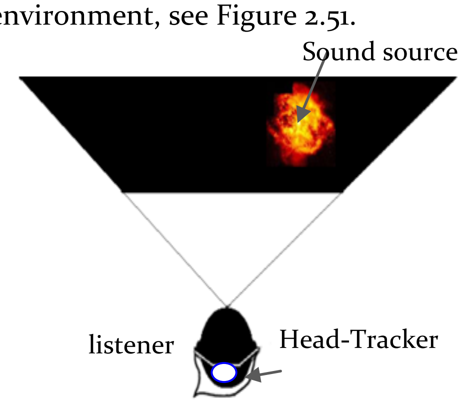

Figure 2.51 An object and its sound source are linked

- **Acoustics simulation:** 3D sound allows for the consideration of acoustics in a 3D environment, which is essential for recognizing spatial properties. For instance, the reflection properties among the objects of a virtual environment can be considered, see Figure 2.52.

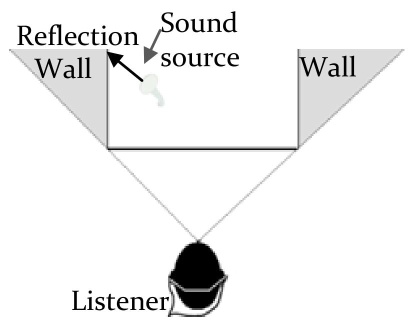

Figure 2.52 Reflection properties among the objects of a virtual environment

- **Speed and efficiency:** The sound generation in real time and the physical properties of the spatial sound should be well-organized. When an action is taking place the generated sound must be heard at the same time.

2.3.5 Surround Sound

Surround sound allows for incorporation of three dimensional sound in virtual environments. Surround sound mixes the sound into several channels and to be reproduced in some speakers placed in the corners. Currently most theaters are capable of reproducing sound in multiple channels. These systems are called multichannel sound and increase the illusion of width and depth in an environment (Kindem, et al., 2009)

2.3.5.1 Dolby Surround Sound or 3.0 Channel Surround Sound.

The 3.0 Channel Surround Sound or the Dolby Surround Sound uses three audio channels placed equidistant around a central position: two channels for speakers at the front: Left and right and one channel for surround sound at the rear (Briere, et al., 2006). Basic Dolby Surround Sound does not offer adequate separation between the left/right channels and the surround channel. With Dolby Surround, the single-channel surround information is produced into two discrete channels. See Figure 2.53.

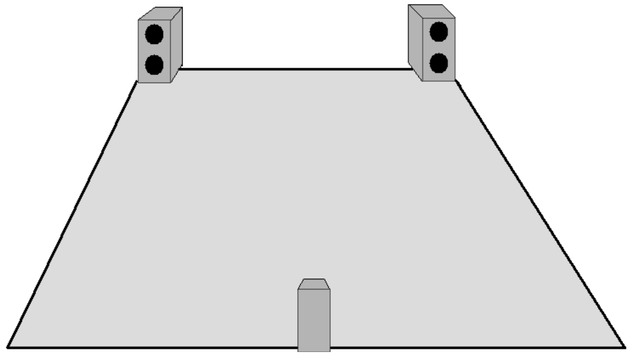

Figure 2.53 Example of 3.0 channels surround sound

2.3.5.2 *Quadraphonic Sound or 4.0 Channel Surround Sound*

Quadraphonic Sound or 4.0 Channel Surround Sound is designed for music and uses four audio channels. Two speakers are placed at the front: left and right and the other two at the rear: left and right, (Horn, 1994), see Figure 2.54.

Two different approaches to quadraphonic sound were developed- the matrix system and the discrete system. In the matrix system the record production was similar to the production stereo records, but had problems in the complete separation of the four channels. The discrete system allowed for a better separation of the four channels, but implied higher productions cost (Cabral, 2000).

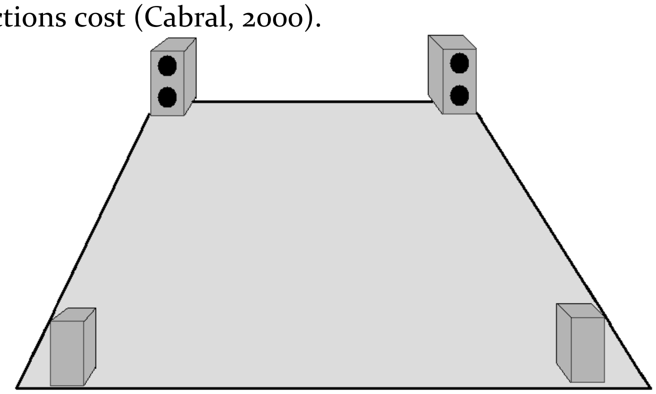

Figure 2.54 Quadraphonic sound

2.3.5.3 *Variations of 5.1 Channel Surround Sound*

The 5.1 Channel Surround Sound was used by the film industry in movies of 70mm, 6-track in the 1980s (Kindem, et al., 2009), (Hull, 2005). This system has been the starting point for surrounding sound at home, it allows the distribution of multichannel digital audio (Ballou, 2005). The 5.1 system enables the provision of stereo effects. This system does not directly support the concept of 360° image localization (Rumsey, et al., 2009).

The 5.1 Channel Surround Sound has five channels for speakers: left, center, right. Two channels for surround: left and right, and a sixth channel for subwoofers, which produces low-frequency effects (LFE) and is known as the ".1". (Kindem, et al., 2009), (Hull, 2005) see Figure 2.55.

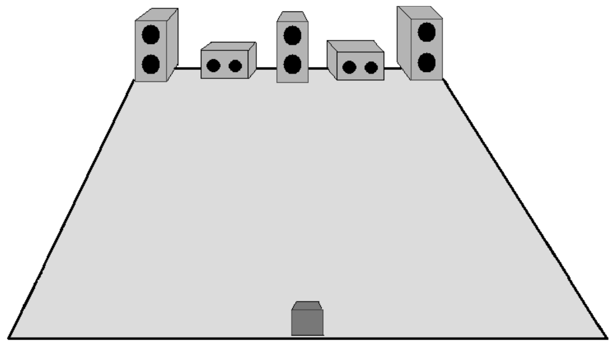

Figure 2.55 Sound for film industry of 70mm 6-track

There are others systems with 5.1 channels: Dolby Pro Logic II, Dolby digital discrete, Dolby Stereo "Baby Boom" and Dolby Digital, DTS, SDDS (Kindem, et al., 2009), (Briere, et al., 2006), (Hull, 2005), (Wyatt, 2005), see Figure 2.56.

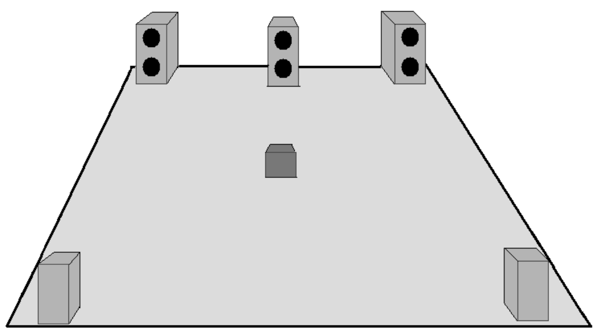

Figure 2.56 Channel Surround: 3-2 Stereo

2.3.5.4 Variations of 6.1 Channel Surround Sound

6.1 Channel surround sound is a system designed to complement the advanced television system and requires six channels of audio or six separate speakers (Kindem, et al., 2009), (Dobler, et al., 2004). This system provides greater continuity in the rearward sound field, resulting in a more seamless and enveloping surround presence. There are different ways of building 6.1 Channel Surround Systems:

- Dolby Pro Logic II is built with six audio channels and one LFE channel.
- Dolby Digital EX is built with: five audio channels, one extracted audio channel and one LFE channel.
- Digital discrete: DTS-ES is built with six discrete audio channels and one LFE channel from a seven channel source.
- Analog magnetic Cinerama 7-track uses seven audio channels from a 7 channel source

In Figure 2.57 there is an example of 6.1 Channel Surround Sound.

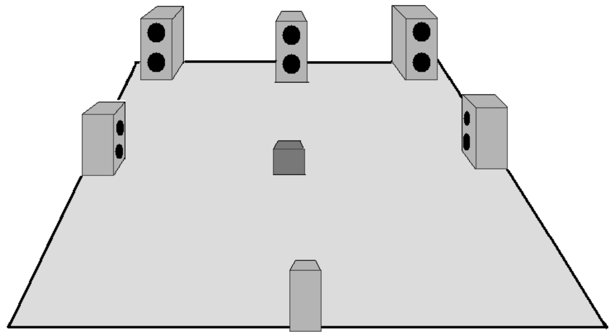

Figure 2.57 Example of a 6.1 Channel Surround Sound

2.3.5.5 Variations of 7.1 Channel Surround Sound

The 7.1 channel surround system incorporates all the elements of a 5.1 channel system, but it splits the surround and rear channel information into four channels. The 7.1 channel listening environment can add more depth to the surround sound experience; it provides a more specific, directed, and immersive sound field, especially for larger rooms. There are some variations of 7.1 Channel Surround Sound (Kindem, et al., 2009), (Briere, et al., 2006), (Wyatt, 2005):

- Dolby Digital Plus, DTS-HD, and Dolby True HD are built with seven audio channels and one LFE channel. Two channels for speakers at the front: left and right, one channel for speaker at the center, two channels for surround speakers at the sides: left and right, two channels for surround speakers at the rear: left and right and one LFE channel.

- There is a variation for 7.1 widescreen cinema format, this uses: Four channels for speakers at the front: left, Center-left, right and Center-Right, one channel for speaker at the center, two channels for surround speakers at the rear: left and right, one LFE channel. This variation is becoming popular in home entertainment systems, as well as for large cinemas (Rumsey, 2001).

In Figure 2.58 there is an example of 7.1 Channel Surround Sound.

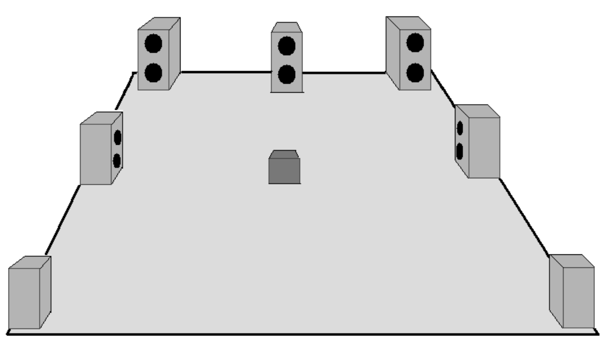

Figure 2.58 Example of 7.1 Channel Surround Sound

2.3.5.6 Channel Surround Sound

This system is the surround sound format developed in TMH Labs and at the University of Southern California. The purpose of this system, called 10.2 was to go one step further in filling the perceptual gaps left by the 5.1 channel system. The .2 refers to the addition of a second subwoofer. This system has 14 discrete channels: Five front speakers: Left Wide, Left, Center, Right and Right Wide. Five surround channels: Left Surround Diffuse, Left Surround Direct, Back Surround, Right Surround Diffuse, and Right Surround Direct. Two LFE channels: Left, Right. Two Height channels: Left Height, Right Height, see Figure 2.59

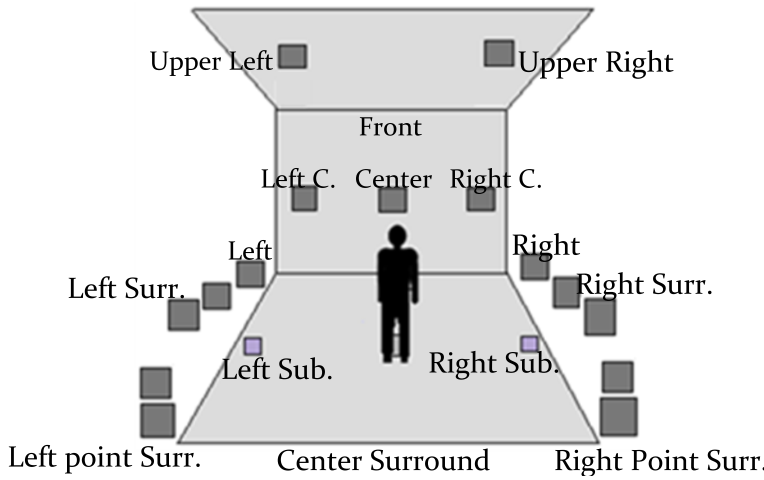

Figure 2.59 Example 10.2 channel surround sound

2.4 Summary

In this chapter the following characteristics of virtual environments have been described: the physic and virtual parts, immersion, the levels and type of immersion, the projection types and the user interaction. Besides, for general knowledge purposes, in this chapter a virtual world classification has been reviewed: According to (Zachmann, 1994) a virtual world is classified as follows: real or unreal, whether they already exist, will exist some time, or existed, or will never exist.

There are many different types of virtual environments. Section 2.1.3 is focused on three examples of virtual environments.

Furthermore, in this chapter the Vision foundation was described. The following topics were reviewed: monocular and binocular depth cues, vision binocular, and limits of depth perception. Additionally, a brief overview of the history of stereoscopy was described. Moreover four basic stereoscopes were specifically mentioned: Wheatstone-type stereoscope, stereoscope of lenses (Brewster and Holmes), boxed-type stereoscope, and Cazes-type stereoscope. These stereoscopes were described because three of them will be used in chapter 5. Other stereoscopic techniques were mentioned for general background, Table 2.1 describes the advantages and disadvantages of these techniques.

Table 2.1 Advantages and disadvantages of the stereoscopic techniques

Stereoscopic Technique	Advantages	Disadvantages
Parallel viewing	This technique allows viewing 3D photographs with true colors and does not require any optical viewer.	Parallel viewing is limited to images about 2.5 inches wide.
Crossed-eye viewing	This technique allows viewing 3D photograph with true colors and does not require any equipment.	Crossed-eye viewing can be somewhat stressful.
View-Master	This device allows viewing colorful images and is easy to use.	Currently, this device is not common any more.
Head-mounted display	Due to the proximity between the eyes and the HMD the images look bigger than those displayed on normal screens. The user can see a computer-generated image considering the viewer position. This technique provides bright, vibrant color and a good quality image.	This device is heavy.
LCD Shutter Glasses	The number of colors seen in the images depends on the monitor or projector.	This technology has problems such as: difficulty in synchronization, ghosting, and flickering.
Polarized glasses	Using this technique a group of people can see the stereoscopic images at the same time. Multiple viewers can view an image simultaneously.	This technology has some problems such as: reduction of brightness and ghosting The user has to keep his/her head in an upright position.
Two-color Anaglyphic	This technique uses minimal equipment. The images can be easily created. Multiple viewers can view an image simultaneously.	This technique has some disadvantages such as: ghosting, retinal rivalry, and loss of color.

Wiggle stereoscopy	This technique does not require any special device. This method can be used by people with limited or no vision in one eye.	Nevertheless, it is difficult to appreciate some details in images due to the movement. The movement in the images can become be annoyed.
Autostereogram	This technique does not require any special device.	Autostereograms can be tiring for the eyes.
Pulfrich effect	This technique does not require any special device.	This technique cannot be used to show a stationary object. The objects moving vertically will not be seen as moving in depth.
Displays with Filter Arrays		This technique is expensive.

There are many stereoscopy techniques, but only some of them are used to build a Virtual Environment. Currently, Parallel viewing, Crossed-eye viewing, View-Master, Wiggle stereoscopy, Autostereogram, and the Pulfrich effect are not used in a virtual environment because these techniques use static images or are considered not appropriated.

The Shutter glasses technique is the technique most commonly used in the construction of virtual environments, but this technique has problems of flickering and ghosting. The polarized glasses technique is used in some virtual environments, it can be used in large groups of people, but it duplicates some resources increasing the expenses. The two-color anaglyphic technique can also be used in virtual environments with large groups of people; the main problem is the loss of color.

Finally, the sound factor is important when a virtual environment is built, because it adds a feeling of presence, and immersion for users. The sense of hearing is often neglected in the implementation of a virtual world, on some occasions because the technical resource limitations; but is important to consider it, because sound can provide a level of high realism unachievable with visual aspects alone. Due to the importance of this topic, different themes were reviewed in the section of sound. First, the human hearing system was discussed. This system has many possibilities to be used in virtual environments due to its characteristics, which include the ability to indentify sound and its location as well as the possibility for improving interaction in diverse environments. Second, different sound techniques were offered. Currently, there are complex sound configurations that improve realism in virtual environments. Finally, different surround systems were reviewed; in which one of the differences is the number of channels involved, woofers, and subwoofers.