Portable 3D Stereographic Displays

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Abstract

Have you ever wanted to "spice up" a presentation with a futuristic feel, or give a lecture that really captures your student's attention? This tutorial describes how to construct 3D images that literally appear to "pop out of the screen", using a commonly known technique called linear light polarization. Stereographics are found in nearly all virtual reality projection systems, and simple stereographic displays can easily be constructed from equipment available on most college campuses. This paper discusses the basics of stereo viewing, the construction of a simple stereographic display system, generation of both static and dynamic stereo images, and some applications of 3D displays in a college environment.

Introduction

From industry to entertainment, stereographics are becoming increasing prevalent in today's society. At the heart of most virtual reality environments is a stereo viewing system that helps users to "see" applications in 3D. These heightened sensory environments increase the feeling of realism, and can be used to improve a number of tasks from training to virtual prototyping. Hollywood has even seemed to rediscover this appeal of stereo viewing, releasing a number of 3D movies in recent years [1]. Stereographics help to grab the attention of an audience, and make presentations more exciting and entertaining.

The purpose of this paper is to provide an overview of stereographics. First, the basics of stereo viewing will be presented, with a description of the human viewing system. Next, three methods for presenting stereo images to an audience will be explained: anaglyphs, light polarization, and active stereo. A few ideas for making these stereo image presentations portable using a laptop computer and an external PCMCIA video card are then discussed. Generation of stereo images (both static and dynamic) will be covered, followed by a brief discussion of applications for 3D images in an academic environment to conclude the paper.

The Human Viewing System

Our ability to perceive depth is due primarily to the fact that we have two eyes. There are other visual cues our eyes pick up on (like shadows and object occlusion), but the different perspectives our eyes perceive of the world provide the best information to the brain for determining relative distances of objects. As a simple experiment, try holding your index finger about one foot from your face, then look at your finger with one eye closed. Now, close that eye and open the other. You should notice that the perspective of your finger is slightly different for each eye. If you are not convinced, then observe that the background view behind your finger is dramatically different between the eyes when you try and keep your finger in focus. Our brain takes these two images from the eyes and merges them into one, with a dramatic sense of depth. Figure 1 shows the basics of the human viewing system.

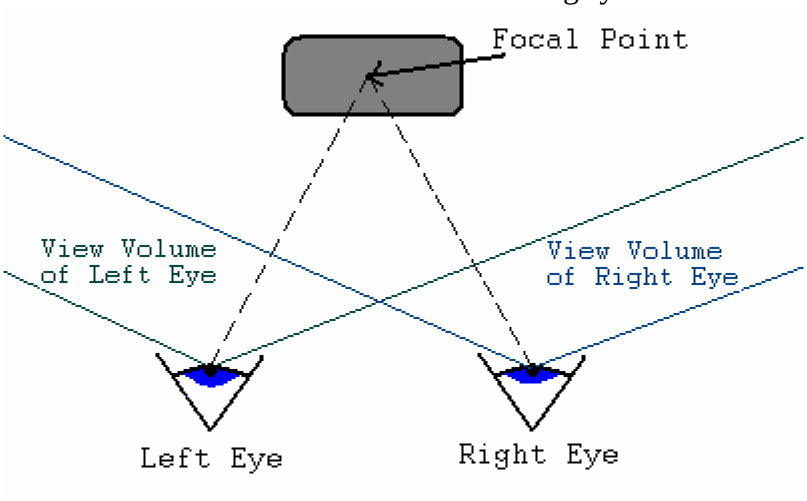

FIGURE 1

The view volume (the part of the world the eye is able to see) is different for each of our eyes. Most of the eye view volumes overlap, meaning that for the most part, our eyes are able to see the same objects in the world. The parts of the view volumes that do not overlap are the portions very close to the eyes. Try placing your index finger just to the right of your right eye so that it is barely visible. Now, close your right eye and you will notice that your finger is not visible by the left.

These view volumes can adjust depending on where your eyes are focused. Again, try holding your index finger about one foot from your face, but this time focus on an object several feet past your finger. While keeping this object in focus, you should notice that a double image of your finger is visible (since each eye perceives the finger to be in a different place). The focal point in a scene is the exact location where both eyes are focusing. This is the one place where your eyes try and generate a single image of an object. All other places in the world should appear slightly out of focus. Generally, you do not notice this phenomenon because your eyes can refocus very quickly. As your gaze travels from object to object, your eyes are constantly adjusting trying to bring the image into focus.

Creating graphical displays with the illusion of 3D requires the generation of two different views (which correspond to the different views of each eye) that focus on the object of interest. If these images are displayed in a manner such that each is visible to only the intended eye, then our brain will merge the images into one, and we will get the sense of viewing a 3D display. The next section focuses on techniques for making sure that each eye “sees” only its intended image.

Presentation of Stereo Pair Images

There are a number of techniques for presenting stereo pair images to an audience. One of the simplest approaches is to use *anaglyphs*, which is based on the principle that if you view an image through a certain color filter, that filter's color will disappear in the image.
Separate left and right eye images can be generated using shades of colors that will not be visible to both eyes. These views can then be merged into a single image using image processing software, and displayed with a typical projector. However, when the audience dawns the special glasses with the funny red and blue lenses, each eye will actually see the image in a different way, producing the 3D effect. The children's movie, "Spy Kids 3" was made using this technique [2]. The drawback with anaglyphs is that the color in these types of displays is poor at best – each eye is unable to see one of the primary colors of light! The advantage with this approach, however, is that in order to project the 3D image, you only need a single projector.

Another approach for presenting stereo pairs is to use *light polarization*. With this technique, the left and right eye images are projected through separate projectors that have opposing polarizing light filters in front of their lenses. The audience watches the presentation while wearing special sunglasses with the corresponding filters. Each eye, then, is only able to "see" the image that was projected through the same filter as the one in front of it in the sunglasses. This makes it possible for both images to be projected on the same screen, but for each eye to view only its intended image. There are two types of polarizers, linear and circular. The linear polarizers are considerably cheaper than their circular counterparts, but are subject to more crosstalk (one eye is able to see some of the image that was supposed to be visible only by the other eye). However, the circular polarizers eliminate a great deal more light than linear ones, resulting in a much darker image on the display screen. For this reason, most 3D movies choose linear polarizers and try to model the scene with color intensities that result in less crosstalk. Generally speaking, the brighter a color, the more crosstalk it will produce. Light polarization also requires the use of a silver projection screen. The standard white matte projection screens common today have diffuse surfaces that scatter the light evenly in all directions, destroying the polarization of the light. The older silver screens are very directional and preserve the polarization. The major advantage of this technique over anaglyphs is that the color is much better in the final 3D image. The obvious drawback is that two projectors are required in order to produce the display, meaning that movie theatres require a special projector to show 3D movies created using this technique. The IMAX version of the "The Polar Express" was the most recently released 3D movie that used light polarization [3]. Figure 2 shows two projectors with linear polarizing filters and the corresponding glasses.

FIGURE 2

The final technique for generating stereo pairs is to use an active stereo approach, where the display for each eye alternates in coordination with special LCD shutter glasses worn by the users. When the left lens is open, the display for the left eye is on the screen. Then the left lens closes and right one opens while the right eye image is on the screen. Our brain once again fuses these images producing a 3D display. This alternation of the images must take place approximately 120 times per second, or users will see a "flicker" in the display. This approach can be very pricey! The LCD glasses themselves can cost as much as $600 per pair, and the CRT projectors needed to achieve such high refresh rates can cost well over $15,000. This approach was popular with early virtual reality systems like the CAVE [4], since it does not make the images darker (as does light polarization) or reduce the color spectrum (as do anaglyphs). However, this is by far the highest price option, particularly for large audiences. If single user displays are desired, then much cheaper glasses that connect to a standard desktop computer can be purchased for only around $150.

Making 3D Presentations Portable

The trickiest part of setting up a stereo projection system is actually getting the images to the projector(s). In the case of linear polarization (the preferred method of the author) two projectors are needed, one for each eye. In the case of 3D movies, two separate films are created with the left and right eye images. With a computer generated display (digital images or even dynamic computer graphics), these two separate images must be sent from a computer (or computers) to the different projectors. Generally speaking, it is easier to run a presentation of this sort from a single computer, and thus it would be very nice to have the computer capable of generating multiple displays that could be sent to more than one projector. Two options exist here, a dual-headed video card, or multiple video cards in a single machine. Windows supports multiple video cards in a PC and allows the user to spread the desktop out over all the display devices [5].

For a stereo viewing presentation, the computer can be attached to LCD projectors that are used to display the left and right eye images [6]. Then, all that needs to be done is to get the appropriate images on each display device.

Unfortunately, PCs are not very portable, particularly PCs that have a number of video cards inside them. This became very obvious to the author a few years ago when he was giving a paper at a conference and had hoped to demonstrate a multi-monitor display system [7]. The conference was about 500 miles from campus and he drove the entire distance with the multi-monitor modified computer in the trunk of his car. When he tried to boot up the computer at the conference, the operating system would not load. This was a few minutes before the talk was to begin, and thus, the presentation had to be given without the demonstration. As it turned out, one of the video cards had "jiggled" slightly out of its slot during the long drive, preventing the computer from starting up correctly. The author had been wandering how to make these types of systems more portable, until he attended a presentation by Robin Snyder at ASCUE 2004 [8]. Snyder discussed the use of a device from Margi Systems called the Display-to-Go that attaches to the PCMCIA slot of a laptop computer [9]. The Display-to-Go card makes it possible to attach a second monitor (or video projector) to a laptop computer. Since laptops are considerably easier to transport from one location to another, the author thought this would be a much better approach for creating portable 3D presentations than carrying his multi-video card computer from venue to venue. A Village Tronic VTBook 32MB graphics card [10] was purchased specifically for this project, at a cost of around $250. The VTBook was chosen over the Display-to-go since it has considerably more memory (32MB as opposed to 4MB). With the second video head available through the VTBook, two LCD projectors can be attached to the same laptop providing both left and right eye views. Figure 3 shows the setup.

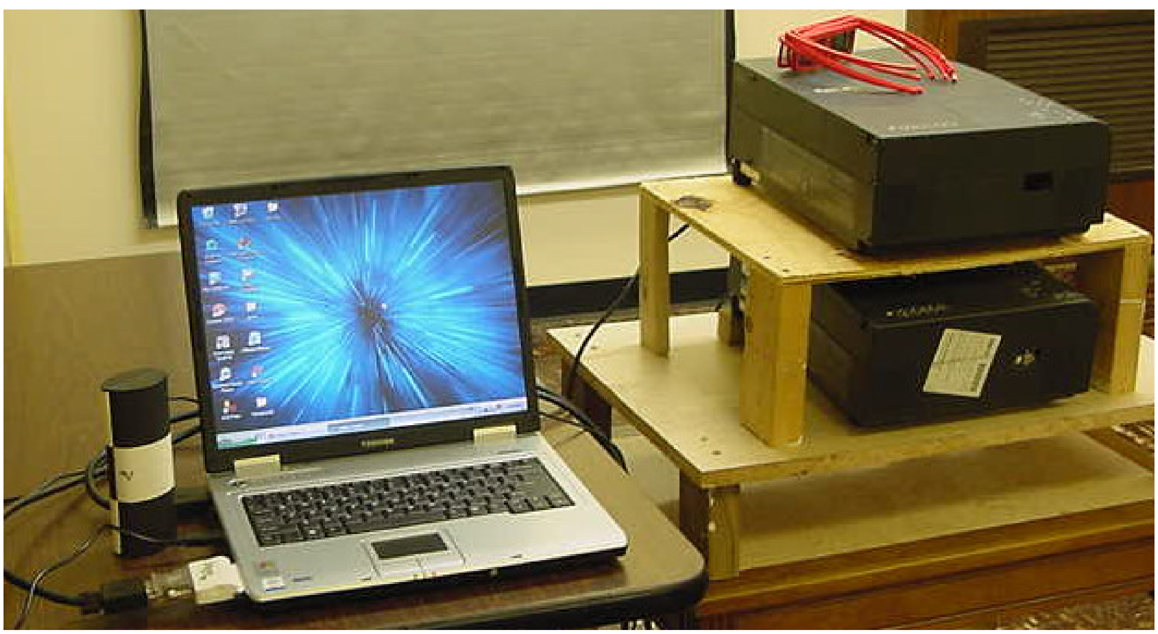

FIGURE 3

If your presentation does not need to be portable, it is probably easier and cheaper to build a dedicated stereo projection PC. NVIDIA [11] has excellent video cards and drivers for multi-monitor display systems. Interested readers should see [5,6,7] for more information on setting up a multi-monitor stereo projection environment with a single PC and multiple video cards.

Generating Stereo Pair Images

Once you have a computer and two projectors in place, all that remains are the stereo pair images to present. Essentially, you can display static (or still) images, or try and create something with dynamic content (like a 3D video game). In many ways, the still images are easier. Theoretically, if you take two cameras and hold them apart a distance equivalent to the space between your eyes (the interocular eye distance), focus them on the same object, and then take two pictures, this will create stereo pair images. Initially, the author thought that this would be quite easy. He purchased two cheap digital cameras and proceeded to photograph a number of items holding the cameras a short distance apart. However, he found it very difficult to get photos that were very close at all to the views of the eyes. The cameras must be held almost perfectly level with exactly the same focus to get images that produce the desired stereo effect. The author ended up editing the pictures in an image processing program to get stereo pairs that were "workable". Several models of professionally constructed stereo image cameras are available for purchase. A simple web search for the phrase "stereo cameras" will produce a number of options. If high quality images are desired, the author strongly recommends the purchase of a special stereo camera. The left side of figure 4 shows stereo images being projected on a silver screen. Notice that the image is blurry. This is because both the left and right views are concurrently being projected on the display screen, and the polarization glasses are not being used to view the image.

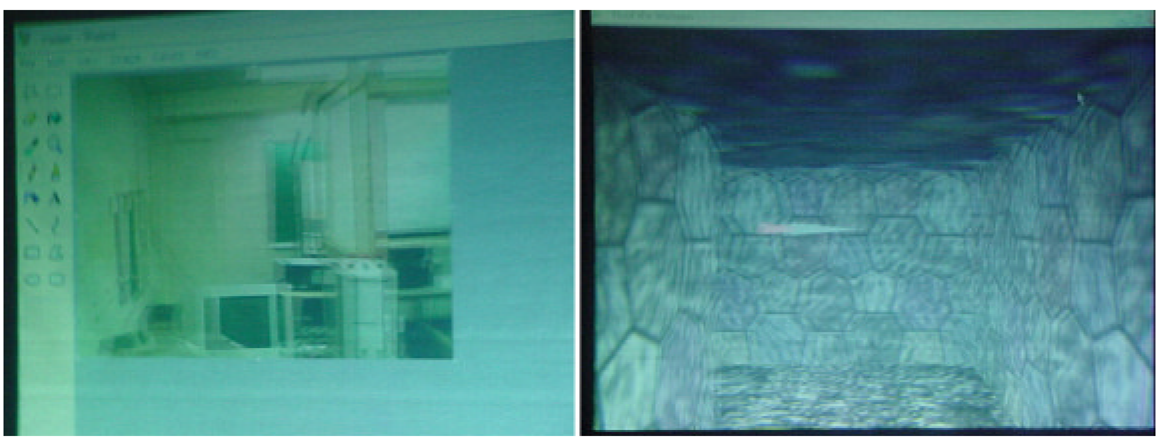

FIGURE 4

Generating dynamic stereo images takes considerably more work. Of course, one approach would be to use two video recorders held a distance apart equal to the interocular eye distance. Creating a stereo computer graphics application (which is essentially what is done with virtual reality) requires knowledge of a high level 3D graphics application programming interface (API). Modern day graphics APIs like OpenGL [12] use a camera analogy when determining the viewing position. The camera orientation is based on three parameters: the eye position, the aim point, and the up direction. Generating stereo pairs simply involves shifting the eye position to the location of the left eye, calculating an image, and then doing the same for the right eye. A complete description of the mathematics behind stereo viewing calculations is outside the scope of this paper. Interested readers are referred to Paul Bourke's excellent web tutorial on "Calculating Stereo Pairs" [13].

The author and his students have been developing virtual reality applications to run in this type of stereo viewing environment for a few years now. The right side of figure 4 shows a virtual reality video game running from the laptop computer using the VTBook. The display drivers for the VTBook are not quite as "friendly" as the NVIDIA drivers. With the laptop, all windows must be created on the primary display and then dragged to the appropriate projector. With the PC and NVIDIA cards, it is easy to create windows in full screen mode that pop up on any projector [7]. However, the ease of traveling with the laptop is probably worth the inconvenience of dragging the windows if a portable stereo viewing environment is needed.

Uses of Stereo Displays

Stereo images have a number of exciting uses in an educational environment. They can make a presentation more fun and entertaining, and its not that much work and extra cost to set up the equipment needed to project a 3D presentation. A number of vendors are available that sell the glasses and filters for very reasonable costs (the author has purchased most of his equipment from Berezin Stereo Photography Products [14]). End of the year organizational "get-togethers" (like for your local computer club) would be a great venue for this kind of presentation.

Stereoscopy makes a great instructional example for teaching about optics and the human viewing system. This material could be appropriate in a number of disciplines. The author and his students gave a presentation at ASCUE 2004, describing a number of computing camps put on for local elementary age students [15]. One of the courses at these camps was on virtual reality, and students were taught much of the material described in this paper as part of that course. The visual nature of the information helped to keep the young students' interest.

These stereoscopic viewing environments can also serve as the foundation for a virtual reality display system. A number of resources are available describing the use of low cost stereographic displays as the basis for a virtual reality environment in an educational setting [6,16,17]. These environments make it possible to teach about virtual reality and to develop interesting applications, even if very little funding is available.

Stereo images are a lot of fun, and can add some extra "spice" to a lecture, presentation, or even an entire course. The mechanics of stereo viewing are really pretty simple, and anyone with the desire and motivation can build an environment at their home institution. If you are looking for something to grab your audience or students' attention, stereo viewing might be just the thing.

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