A Low Cost Commodity Based System for Group Viewing of 3D Images

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Abstract

We have developed a commodity based projection system suitable for group viewing of 3D (stereoscopic) images. Using Linux, multiple projectors, a dual headed X server and multiple video cards, we have achieved a relatively high level of success with local data sets. Using passive polarized glasses and a special silver screen, multiple users view a stereoscopic presentation. Currently our example applications are produced with MESA, but this system can be used with any package capable of generating multiple views of an image. We will discuss our experiences and request comments.

1. Introduction

In many areas of science, data is most easily interpreted and inferences drawn by the use of a three dimensional visualization. In many cases it is difficult to interpret such a three-dimensional visualization without appropriate cues as to the relative distances of objects being represented. One way of achieving such cues is by providing stereoscopic or pseudo-stereoscopic representations. In this paper, we will discuss some experiments with implementing a low cost solution to provide such stereoscopic rendering of data, which is suitable for use in both research and teaching environments.

2. Methods of producing stereoscopic images

There are a number of techniques possible for producing pseudo-stereoscopic images. These include projecting two simultaneous images through differently polarized filters and using polarizing glasses, projecting two simultaneous images through colored filters and using colored (green/red) glasses, and projecting the images for the left and right eye alternatively and using liquid crystal shuttered glasses which are synchronized with these.

The idea of using polarized light to produce stereo images was proposed as early as 1891[Roques]. It involves projecting two images, slightly offset from each other, onto a screen; each projection is polarized so that it is not visible when viewed through a polarized lens aligned at 90°. The viewer wears a pair of glasses with polarized lenses so that the correct image is visible to each eye. On the other hand, systems such as the CAVE and Immersadesk alternative projection of left and right images and synchronized liquid crystal shuttered glasses to produce realistic virtual reality environments. These systems, however, are still relatively expensive and most researchers do not have access to them and hence are not able to experiment with displaying their data in this type of environment.

Recent advances in projectors, as well as in the speed of personal computers have made it possible to attempt to construct a simple system at very low cost that employ polarized light to produce stereoscopic images.

After demonstrating this system to researchers and educators at Kent State University, we felt that there was sufficient interest to pursue further development of this project.

2.1 Goals

Our goals for this project are:

- Creating a low cost system,
- Employing commodity parts to minimize system complexity,
- Providing capability for group presentation of 3D data,
- Allow portability of the physical system to remote presentation sites.
- Providing flexible software capable of meeting multiple visualization needs.
- Employ open source products whenever possible.

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3. Hardware

The hardware for this system is, for the most part, readily available. It consists of two projectors, a computer with multiple video cards, two polarized lenses, polarized glasses and a silver screen. For this experiment, we needed only to purchase the polarizing equipment and the silver screen as we were in possession of all other components needed.

3.1 Polarized Glasses

The glasses used by viewers are standard in the stereoscopic industry. The lenses are polarized plastic, set at 45° and 135°. They are available from a number of vendors (see Appendix A) for very little cost. The quality of the frames varies with the price, from low cost cardboard, to more stylish plastic, but the quality of the lenses seem to remain fairly constant.

3.2 Silver Lenticular Screen

A silver lenticular screen is the most expensive part of the system that we had to purchase especially for this project. The goal of most projection screens is to reduce the amount of glare produced by the projection, and to make the image equally bright from all viewing angles in the room, thus they tend to be designed to scatter the light as much as possible. This has the unfortunate effect of depolarizing the light projected at such a screen. Lenticular screens reflect light more strongly in the forward direction but there is essentially no depolarization effect.

3.3 Polarized Lenses

The next item in the system is a lens for each projector to polarize the light so that it is only visible to the correct eye. We ordered a sheet of linear polarizing plastic, cut it into two pieces, and crafted a crude set of mounting rings for our experimentation. We plan to produce a more professional mounting system in the future that will allow the ability to adjust the angle of polarization more precisely.

3.4 Projectors

The heart of the system is a pair of high intensity projectors. The image from each projector is passed through one of the polarizing lenses mentioned above. By it's very nature, 50% of the light is lost in this process. Since the lenses are not 100% efficient, even more light is lost, thus one of the primary requirements is for the projectors is to produce the brightest image possible. The latest LCD projectors available are rated at 650 to 2200 ANSI lumens. Systems rated much over 650 ANSI lumens are quite expensive, so we have used projectors rated at 650 – 700 lumens in our experiments. They are affordable and are sufficiently bright to produce a clear image in a room with low intensity lighting.

A second consideration in selecting projectors is the ability to adjust the shape of the image produced. The overall quality of the final image produced is very dependent on how closely aligned the two component images are on the screen. We have been most successful with projectors that have controls to vertically adjust the lens. In projectors of this type, it is possible to shift the image on the screen vertically so that the two images can be superimposed without distortion to either picture.

If this type of projector is unavailable, we have had reasonable success in aligning the center of the images. Details on the extremes of the images will suffer, but the stereo effect in the center of the image is acceptable. We are fortunate to have had projectors of the same make and model for our experiments, and thus have not investigated the effects of different intensity on the stereo effect.

One final issue involves controlling the projectors. Most of the projectors we have encountered have their controls built into a panel on the top of the projector. To align the images, it is necessary to stack one projector on top of the other, rendering it almost impossible to change the configuration of the bottom projector. It is fortunate that these projectors almost always come equipped with a remote control, which, while not necessary, is sufficiently useful to mention here.

3.5 Video Cards

The primary considerations for the video cards used in our experiments were availability and the ability to work with a multi-headed X server. In order to avoid synchronization problems, we decided to use a single machine to produce our images, thus a machine capable of supporting multiple video outputs was required. In keeping with our goal to produce a truly low cost system, we further decided to use commodity PCs assembled from components.

In the current market, there are two choices to achieve multiple video outputs in this class of machine. Most motherboards have multiple PCI slots, thus a number of PCI based video cards can be placed in a machine. Alternatively there are a number of AGP cards with dual video outputs, so called dual headed cards, that can be placed in the single AGP slot available on most motherboards. We have a number of PCI cards on hand that were used for our experiments.

3.6 Workstations

The last item of hardware to consider is the workstation. It must have sufficient slots to accommodate the video card solution chosen above. Since they were readily available to us, we used a 450 MHz Pentium III with 256 MB of memory. We note that, since most of the rendering is currently being done in software, the speed of the machine greatly effects the production of images.

4. Software

The greatest challenge of this project has been to find software that can be used to tie the entire system together. Even moderately priced graphics cards have the ability to perform at least part of the graphics rendering in hardware, and one would like to take advantage of this. Unfortunately, until recently, multi-headed X servers, servers capable of displaying on multiple video cards, available did not support this.

4.1 X Server

We are aware of three sources for X servers. We currently use the 2-D Accelerated X server from Xi Graphics. This commercial server supports a large number of video cards in multi-headed mode, but provides no direct hardware support for graphics rendering. The recently released 3-D server supports a number of high end cards with hardware acceleration, but does not currently support multi headed operation. Representatives from Xi inform us that support for a wider range of cards, as well as multi-headed support will soon be implemented.

XFree86 produces a free X server that supports hardware acceleration on a number of video cards. Recently they have released version 4 of their server which also supports multi-headed operation. We have not yet tested this configuration, but expect to have done so by the time this poster is presented.

MetroX produces a commercial server that supports a number of video cards in multi-headed mode as well. This server does not support hardware acceleration, and we have not tested it.

4.2 Mesa/OpenGL

For experimentation purposes, we have developed a number of example applications using the OpenGL graphics system. Both Xi Graphics and MetroX provide commercial implementations, which provide hardware acceleration of OpenGL. However these currently do not support hardware acceleration in a multi-headed mode. Thus, in keeping with our goal of using open source software as much as possible, we have used the open source Mesa implementation. A topic of interest for later experimentation, is the extent to which hardware acceleration and choice of graphics card improves the rendering performance.

5. Putting It All Together

Assembling the system is just a matter of patience. We have found it best to set the projectors on a sturdy table, one stacked on top of the other. A remote control proves very useful at this point to allow you to turn the projectors on and off, focus and position the image. Next each of the projectors is focused and the image is aligned as closely as possible. Unless your projectors are equipped with a lens shift mechanism, it will be necessary to use shims to align the images. In this case, it is often not possible to align the images perfectly over the entire screen, and it is best to align one area and attempt to restrict the presentation to that portion of the screen.

After the images have been aligned, the next step is to align the polarizing filters on the projectors. This is best accomplished by holding a pair of polarized glasses in the path of the projection. Light should be able to pass through the lens for one eye - that for the eye that will view the image produced by that projector - but not through the other lens.

All that remains is to project a stereo image. This is done by opening the left image on the display connected to the projector polarized for the left eye, and similarly for the right images, and aligning the borders of the images. One should then experience a 3D stereo effect. It should be noted that viewers often experience discomfort while the images are being aligned.

6. Demonstration Applications

We have developed a number of example applications to experiment with this system and to display its capabilities to others. The simplest of these are stereo photographs. There are a large number of such available on the network, and these images make quite striking presentations. Equally striking are still images rendered with photo realistic techniques such as ray tracing. To produce such an image, one needs to generate two pictures of the same scene with a slight offset between the camera position. The best offset seems to be about 1/30 of the distance from the camera to the closest point in the scene. [Roques].

Simple applications can be created by taking existing OpenGL demo programs and altering them slightly. Code must be added to open graphics windows on multiple displays and to render the scene from different camera positions offset by the correct amount. Motion, even slow, adds to the effect, thus the ability to spin, rotate or fly by the image enhances the presentation.

6.1 Modeling the Desert

One of the most rewarding uses of this system thus far has been the rendering and display of microclimate analysis data provided by Dr. Rachael Craig of Kent State University. In these data sets the simultaneous representation of surface altitude information, precipitation and temperature data were to be compared to vegetation maps in the southwestern U.S. The added ability of seeing the digital elevation model (DEM) in 3D freed the visualization process from using color to indicate height. As a result, additional visualization information on precipitation and temperature could be included in the final rendering. This, plus the ability to dynamically "fly" through the DEM produces a dramatic visualization. In the future, we will be using the temporal information which Dr. Craig also has to view historical evolution of climate change in this 3D environment.

7. Problems

We have encountered a number of problems in our experimentation with this system. They range from hardware and software incompatibilities to basic understanding of the human imaging system.

7.1 Hardware/Software Compatibility

One of the most frustrating problems is an incompatibility between hardware and software. In our current system, we are experiencing an interoperability issue with the Xi Graphics X server and the current generation of Panasonic projectors. It is hoped that new releases of X servers will eliminate this problem.

A second hardware software compatibility issue is the inability of the X server to take advantage of hardware capabilities to render images. One would expect a significant speed up in rendering time by offloading this function to multiple cards. Again, it is hoped that the new X servers will solve this problem, as well as make a larger range of high end graphics cards available.

7.2 Projector Alignment

As mentioned above, the alignment of the images on the screen is an important, yet non-trivial task. It is believed that a simple cabinet with horizontal adjustments used in conjunction with projectors with vertical lens shift will eliminate this problem. Improperly aligned images reduce the stereo effect and can cause eyestrain or even headaches in the audience. It should be noted that similar problems have been experienced by those using more expensive equipment such as CAVEs for prolonged periods.

7.3 Intensity of Projection

Loss of intensity in the projection, due to polarization, the polarizing filters, and the polarized glasses, is a problem that will persist through this generation of projection equipment. Darkened rooms seem to be the only interim solution to this problem.

8. Future Plans

This system has proven sufficiently interesting to continue development. There are a number of areas in which to pursue such development. The most obvious area is to perform the modifications discussed in the problems section above. These simple modifications will yield a more stable and useful system. In addition we have identified a number of other areas for improvement.

It is apparent that a number of tools are necessary to make this system usable to its intended audience. It should be fairly easy to modify an existing VRML viewer to generate images from two viewpoints, thus creating a stereo image. A library of C routines, perhaps even an adaptation of the CAVE library, will prove quite useful to programmers. More ambitious plans include a dual stream MPEG player for the display of stereo movies.

Our current applications have been constructed for demonstration purposes. The researchers we have been interacting with, however, see sufficient potential to warrant further development. We are early enough in the development cycle that we are considering the visualization environment in which we will develop these applications. We are presenting this poster and participating in VDE2000 as part of our decision process concerning the most effective visualization environment for this purpose.

9. Current Configuration

Item	Source	Price	Comment
PC	Generic	$1,300.00	
Video Card	Matrox G200	$100.00	Two needed
Projector	Sharp Notevison 5	$5,000.00	Two needed
Polarized Plastic	Edmund Scientific	$14.95	8.5”x11” sheet
Polarized Glasses	Reel 3D Enterprise	$5.95	For 10
Silver Screen	Reel 3D Enterprise	$314,95	
X Server	Xi Graphics	$199.00	

References

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