Proceedings of

SIACG2011

V Ibero-American Symposium in Computer Graphics

F. Silva, D. Gutierrez, J. Rodríguez, M. Figueiredo (Eds.)

Organized by
Algarve University

In cooperation with
Grupo Português de Computação Gráfica
Eurographics Spanish Chapter
and Eurographics Association

Published by Grupo Português de Computação Gráfica.

Proceedings of the V Ibero-American Symposium in Computer Graphics

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ISBN: 978-972-98464-6-5

Printed in Portugal

Cover design by Ideias Frescas

V Ibero-American Symposium in Computers Graphics – SIACG 2011
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Inexpensive 3D Stereo for Two Users Using a Single Display

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ABSTRACT

Multiuser computer systems allow several users to collaborate on the same task. Medium sized displays, like workbenches or tabletops provide a shared view of the task and a set of input devices to interface with the system. Some of the existing installations also provide 3D stereoscopic viewing, often also shared by all the participants and therefore incorrect for all of them but one. In these cases a different stereoscopic view for each user is desirable.
We implemented two hardware configurations that support independent stereo viewing for two users sharing a common display using a 120Hz monitor and a 120Hz projector. Our prototypes use off-the-shelf parts to create a functional, responsive and inexpensive two-user 3D stereo display system.
We also apply our systems to a competitive game, where each user has a private stereoscopic view of the game table, and a two-user multimedia player, where each user can watch and hear a different video on the same display.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Computer Graphics—Virtual Reality, I.3.1 [Computer Graphics]: Three Dimensional Displays—

1. Introduction

Stereoscopy or 3D imaging is a technique that creates an illusion of depth in images by displaying a different image for each eye. The brain fuses both images thus producing an illusion of depth in the image displayed. There are many different technologies to achieve stereoscopy, varying from simple anaglyph glasses to autostereoscopic displays.

Hardware prices are still high and it is difficult to gain access to all technologies. Furthermore, 3D stereo hardware has not been standardized, and many times, it requires custom devices that are difficult to integrate with each other. Finally, there are applications that require showing stereoscopic images to two different users on the same 3D display. In that case, current commercial hardware does not support that option.

For example, multi-player games require that multiple users view the same virtual world each from a different vantage point. This may be achieved by splitting the display into two or more independent areas of lower resolution. Collaborative work may also require that two users view the same object at the same time from different viewpoints (*e.g.* two engineers designing a car engine.)

We present a solution that solves some of the above problems. We propose a system that displays two stereoscopic images, one for each of two different users. We have implemented two prototypes. The first prototype implements a videogame that displays two different views for two players using only one display device. The second prototype allows two users to watch two different 3D movies.

Traditionally, workbench systems with stereo displays only provide a correct image for one user. This is the user wearing the tracker providing the rendering system with the position and orientation needed to compute the stereo pair the user sees. The other users of the system see the same stereo pair, which is only correct for the user wearing the tracker. Our system provides two stereo pairs, one for each user. In our current implementation we do not use head tracking, and assume a known position for both users.

The rest of this article is structured as follows. First we review previous work in stereoscopic displays and stereo for multiple users. Then, we introduce our system's video and audio implementation. In Section 4 we demonstrate our system with two sample applications. Finally, we present our conclusions and directions for future work.

2. Previous Work

There is a wide variety of techniques to create stereoscopy. H. Urey, *et. al.* classify them into three categories: 3D displays that require special glasses, head mounted displays, and autostereoscopic displays [UCES11]. We focus on the first category.

Color-Multiplexed Approach presents Anaglyph imaging that combines images for the left and right eyes using complementary color coding. The most common color coding is red for the left and cyan for the right eye. It suffers from loss of color information and a high level of stereoscopic crosstalk. There are studies that propose methods to reduce that crosstalk [KP08]. A variation is ColorCode 3-D, which uses amber and blue color multiplexed images. It produces full color 3D images, but presents ghosting and color issues that have not been completely solved.

Other approach is Infitec `http://www.infitec.de`. It can be implemented with two projectors, one for each eye, or a single projector with a color wheel that provides time sequential color multiplexing. In both cases, the images are projected onto a diffusing screen. Then, the filter in each lens of the user's glasses separates the proper image for each eye.

Polarization-Multiplexed Approach use matching filters in the projectors and in the glasses. The filters are based on light polarization, either linear or circular (the latter allowing more freedom in head movement). Two orthogonally filters separate the image for each eye. The images can be emmited by two aligned projectors [KNNY06], or with one projector with a filter wheel synchronized with the frames. Because of this, blanking is necessary between eye images to reduce crosstalk. However, it reduces the intensity of the output light. Polarization techniques require special screens that preserve the polarization of the projected images.

Time-Multiplexed Approach uses battery powered active shutter glasses. Left and right images are displayed on screen at higher frame rates, usually at 120Hz. The glasses are synchronized with the content using an infrared emitter or DLP link (that uses encoded white light flashes only detectable by the shutter glasses). The disadvantages of this technique are the cost of the glasses and the high video bandwidth requirements.

Certain application areas require displaying different images for different users simultaneously. Kitamura *et al* present a display device that uses a mask with a circular hole in its center. The display mask is positioned at a suitable distance from the display and the viewers. This way, each user sees a different region of the screen from her viewing position [KKYK01,KNNY06]. Additionally, the system displays a separate stereo image for each viewer using head tracking.

Agrawala *et al* present a workbench with a 144Hz projector and custom modified shutter glasses for two separate stereoscopic views. Since four different images are required, two for each user, each eye sees a 36Hz animation [ABM*97]. The authors modified the shutter glasses, adding a custom state where both shutters are closed. This state is enabled when the other user's images are displayed. They combine this technology with head tracking to render the scene from the user's point of view. This method requires modifying the shutter glasses, reduces the display rate in half, and the shutter glasses custom state makes the user see a black image during a fraction of the time resulting in flickering and a reduced perceived brightness.

Fröhlich *et al* implement a display for multiple viewers using one projector for each user eye [FBS*05]. The projector has a spinning disc with three opaque quarters and one transparent quarter. They also use liquid crystal shutter and polarizing filters.

Riege *et al* uses one projector to produce a stereoscopic image for each user [RHWF06]. To separate the users' views it uses circular polarization filters and stereo shutter glasses. It also provides interaction devices to support simultaneous object manipulation by multiple users.

3. Inexpensive Two-User 3D Stereo Multimedia Display

Our display system is based on the work by Agrawala *et al* [ABM*97]. We propose a system that can provide two users with separate stereo images and sound at a fraction of the cost of other solutions. We also describe the display prototype we implement using both computer monitors and regular projectors. Finally, we explain how we built the audio subsystem and present two demo applications.

3.1. Display Prototype

We have built two configurations that use sets of active shutter glasses and anaglyphic filters. Our system supports two options for anaglyphic filtering as shown in Figure 1, left. The first option uses opposite anaglyph filters for the users (red-blue lenses for one user and blue-red lenses for the other). The second option uses one color for each user (red-red lenses for one user and blue-blue lenses for the other).

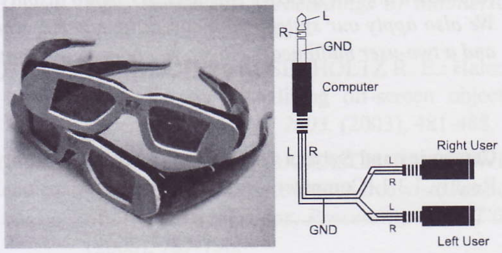

Figure 1: *Left, our prototypes use two NVIDIA 3D Vision^{TM}active glasses with two attached anaglyphic filters. The glasses on the top use the opposite anaglyph option, and the glasses on the bottom each user wear a different colored filter. Right, audio splitter connection diagram.*

To produce the images needed for the glasses we use OpenGL. The left eye/right eye separation is carried out using standard Quad-buffering. To compose one eye's view for both users, the images are rendered to that eye's back buffer. Rendering is done in two steps. First, a color matrix is used to convert the full color input image into a grayscale image. The appropiate color channel to draw that image is selected using a color mask: red for one user and cyan for the other.

3.2. Sound Subsystem

To provide an effective multimedia experience for each user, the system should be able to provide both separate video and audio channels for each user.

We present an implementation that provides a private audio channel for two users using only a stereo sound card. Other implementations are possible with multiple audio cards [MMW04]. However, for budget reasons, we prefer to use only one card. Our implementation uses a simple audio splitter, that separates each channel of the stereo sound card (left and right). Each user uses a pair of standard headphones, each connected to a different channel of the splitter (see Figure 1, right).

The problem with this approach is that each user receives a mono aural signal, since both speakers in each headphone receive the same signal.

4. Demo Applications

We have developed two applications to demostrate the advantages of this system. The first application is based on a Battleship game. The second is a two-user stereo video player. This section describes both applications.

To run our demo applications, we use a PC equipped with a 3 GHz Intel Core2 Duo processor, 2 GB of RAM and an NVIDIA Quadro 600 graphics card. We use the integrated audio card of the motherboard. We also use a Samsung 3D monitor model 2233RZ, and a Dell projector model S300w installed in a workbench. The active shutter glasses we use are NVIDIA 3D Vision glasses (we use two pairs of glasses, synchronized using a single IR emitter).

4.1. The Battleship Game

In the Battleship game each user places a number of different battleships on a discrete grid. The positions of each player's battleships are unknown to the other player. After all ships are placed the first player selects a grid square to attack (Figure 2, center). Meanwhile the second player waits for the first player's attack (Figure 2, bottom). If the selected square is occupied by one of the other player's battleships, the first player scores a hit and can perform another attack until an empty square is selected. Then the roles are swapped between players. When a player hits every grid square occupied by a ship the game informs that the ship is sunk. The player who first sinks the other player's ships wins.

For the graphics rendering and user input of this game we use OpenSceneGraph (`http://www.openscenegraph.org`), a scene graph manager based on OpenGL. For the separation of both scenes (one for each player) we place two cameras, each one being the root node for a user's scene. The images rendered from the two cameras are processed as explained in Section 3.1. Finally stereo display is handled automatically by OpenSceneGraph allowing us to specify the fusion distance (distance from the camera where objects will show no depth) and the interpupillary distance.

For the audio part we use SDL library (`http://libsdl.org`), a multiplatform multimedia library which also offers support for window, network, 2D video framebuffer, 3D hardware and interaction with keyboards, mice and joysticks. Audio streams are converted to mono and then passed to the appropiate audio channel.

4.2. Two-User Stereo Video Player

Our system allows two users to watch and hear different video and audio sources simultaneously on the same display. The video sources can be both regular 2D content or stereo 3D content. Figure 3 shows a photograph of the application playing two 3D stereo videos at the same time. The double images shown in the filtered views are produced by the active stereo. When the application is paused, each user is able to watch a 3D still image, due to the active shutter glasses.

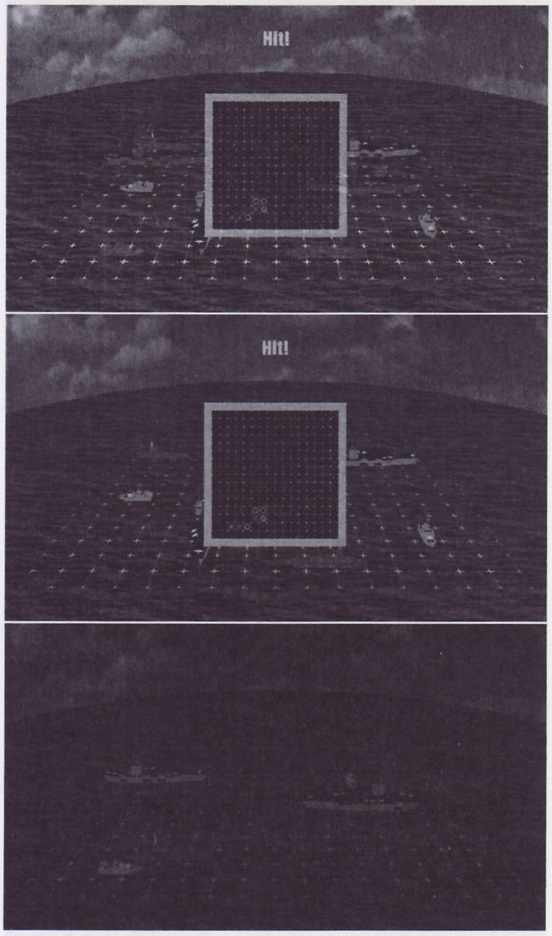

Figure 2: *The Battleship game. Top, unfiltered view of the game, showing both player's views. Center and bottom, cyan player's and red player's views of the game.*

Each user uses her own headphones, and is able to hear the soundtrack of her video.

The application has been implemented using OpenGL, ffmpeg (`http://ffmpeg.org`) and SDL. ffmpeg is a cross-platform open source video library that is able to decode a wide range of video file formats. For each frame, OpenGL draws two quadrilaterals, one for each video stream. Each quadrilateral is defined to have the same aspect ratio as the original video, and is scaled to use the maximum display area. Each polygon is textured with the frame provided by the ffmpeg library, and uses the process described in Section 3.1 to convert from a color image to a grayscale image to an anaglyph image. The sound from each video source is converted to mono and played in one of the two stereo channels of the audio card.

A video of our system working can be downloaded from `https://loto.ai2.upv.es`. It shows the multimedia player playing two 3D stereoscopic videos at the same time. It also shows the different views through each filter and how the different audio streams are played.

Figure 3: *Stereo video player for two users. Top, actual view of the monitor, showing both videos. Center, viewing the monitor through a red filter. Bottom, viewing the monitor through a blue filter.*

5. Conclusions and Future Work

In this paper we introduce two different systems that provide independent 3D stereoscopic views for two users sharing the same display. We have implemented two alternative configurations using two pairs of active shutter glasses, anaglyphic filters and a 120Hz monitor or 120Hz projector. Both alternatives can be built with off-the-shelf parts and for around 1000€. Since our goal was affordability, some compromises had to be made. First, we do not use head tracking, thus imposing the restriction that the users do not move during display. The second compromise is image quality. We use anaglyphic passive filters which produce some loss of color in the original images and a loss of perceived brightness due to the use of two stage filtering.

Still, our system provides an interactive two-user 3D stereo system including independent audio channels for each user. This allows us to implement complex interfaces for collaborative applications without specialized hardware. We have demostrated the use of our setup with an interactive game application and a 3D stereo multimedia player.

In future implementations we plan to provide tracking for the users' heads to properly generate the viewpoints and allow the users to freely explore the 3D scenes.

6. Acknowledgements

This work was partially supported by grant ALFI-3D, TIN2009-14103-C03-03 of the Spanish Ministry of Science and Innovation.

The video sequences accompanying this paper contain footage from the following two videos: `http://www.youtube.com/watch?v=YuxqPuhLBZg` (The Coke Zero & Mentos Rocket Car) and `http://www.youtube.com/watch?v=YiEcUlNN79Q` (Comic Con 3D Project).

References

[ABM*97] AGRAWALA M., BEERS A. C., MCDOWALL I., FRÖHLICH B., BOLAS M., HANRAHAN P.: The two-user responsive workbench: support for collaboration through individual views of a shared space. SIGGRAPH '97, pp. 327–332. 2

[FBS*05] FRÖHLICH B., BLACH R., STEFANI O., HOCHSTRATE J., HOFFMANN J., KLÜGER K., BUES M.: Implementing multi-viewer stereo displays. In *WSCG '05* (2005), pp. 139–146. 2

[KKYK01] KITAMURA Y., KONISHI T., YAMAMOTO S., KISHINO F.: Interactive stereoscopic display for three or more users. SIGGRAPH '01, pp. 231–240. 2

[KNNY06] KITAMURA Y., NAKAYAMA T., NAKASHIMA T., YAMAMOTO S.: The illusionhole with polarization filters. VRST '06, pp. 244–251. 2

[KP08] KRUPEV A., POPOVA A.: Ghosting reduction and estimation in anaglyph stereoscopic images. In *ISSPIT '08. IEEE International Symposium* (2008), pp. 375 –379. 2

[MMW04] MORRIS M. R., MORRIS D., WINOGRAD T.: Individual audio channels with single display groupware: effects on communication and task strategy. CSCW '04, pp. 242–251. 2

[RHWF06] RIEGE K., HOLTKAMPER T., WESCHE G., FROHLICH B.: The bent pick ray: An extended pointing technique for multi-user interaction. VR '06, IEEE Computer Society, pp. 124–. 2

[UCES11] UREY H., CHELLAPPAN K. V., ERDEN E., SURMAN P.: State of the art in stereoscopic and autostereoscopic displays. *Proceedings of the IEEE PP*, 99 (2011), 1 –16. 1