AN INEXPENSIVE 3D STEREO HEAD-TRACKED DUAL VIEWING SINGLE DISPLAY

Armando de la Re[1], Eduardo Martorell[1], Gustavo Rovelo[1], Emilio Camahort[2] and Francisco Abad[2]
[1]*Departamento de Sistemas Informáticos y Computación, Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, Spain*
[2]*Instituto Universitario de Automática e Informática Industrial, Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, Spain*

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Abstract: Dual view displays allow two users to collaborate on the same task. Specialized computer systems have been designed to provide each user with a private view of the scene. This paper presents two hardware configurations that support independent stereo viewing for two users sharing a common display. Both prototypes are built using off-the-shelf parts: a 120Hz computer monitor and a 120Hz projector. The result is a functional, responsive and inexpensive dual-view 3D stereo display system where both viewers see stereo on the same display. We demonstrate our systems' features with three demos: a competitive game, where each user has a private stereoscopic view of the game table; a two-user multimedia player, where each user can watch and hear a different stereoscopic video on the same display and a head-tracked dual stereo 3D model viewer that provides each user with a correct perspective of the model. The latter demostrator also provides basic gesture-based interaction.

1 INTRODUCTION

The popularization of 3D in movies and videogames has driven down the cost of the devices used to implement stereo applications. Modern GPUs provide enough computing power to render scenes at the required frame rate, and paired with an emitter and a pair of shutter glasses that allow the user to play games in stereo at an affordable price. There are also some displays that do not require glasses, but they usually assume that the user is located at some predefined location. Those systems are primarily used in handheld video consoles, 3D cameras and some cell phones. On the other hand, 3D stereo hardware has not been standardized and there are different incompatible implementations.

Some applications require providing different users with private views on the same display. We will review several commercial implementations of those applications, though it is hard to find commercial systems capable of providing two users with two different stereoscopic views.

In this paper we present a solution that solves the problem of reduced spatial resolution and incorrect perspective for a two-user 3D display. We propose a system that displays two stereoscopic images in the same display. Our system can be implemented with a 3D monitor or a 3D projector. We also present three demos to support our claims.

2 PREVIOUS WORK

Several commercial companies have been interested in dual view displays. In 2005, Sharp announced a dual view LCD display that used a parallax barrier superimposed in the LCD to provide two views, depending on the view direction (Physorg, 2005). Land Rover launched the Range Rover Sport model in 2010, a car with a dual view touch screen display http://www.landrover.com. This display also uses a parallax barrier to separate each view. Sony has announced the launch of the Playstation television by the end of 2011 (Sony, 2011). It is expected to be a 3D dual view television with active glasses with their own earphones (Ko et al., 2009). The TV can deliver 3D stereo to a single player or a private, fullscreen 2D view for each user.

The Responsive Workbench uses a head tracking to render the scene from each user's point of

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view (Agrawala et al., 1997). The workbench had a 144Hz projector and custom modified shutter glasses for implementing two separate stereoscopic views. Since four different images are required for two stereoscopic animations, each eye sees a 36Hz animation. When one user is seing the current image with one eye, the other eye's shutter is closed, as well as the other user's shutters.

De la Riviere, Kervengant, Dittlo, Courtois and Orvain presented a multitouch stereographic tabletop that uses head tracking to provide two users with their own viewpoint (De la Rivière et al., 2010). The system is able to detect when a hand gets close to the screen.

3 INEXPENSIVE TWO-USER 3D STEREO MULTIMEDIA DISPLAY

Our system is designed to be very affordable: we use only off-the-shelf parts. Our design is based on the work by (Agrawala et al., 1997).

3.1 Our Prototype

In this section we describe several hardware configurations that support independent stereo views for two users. Every configuration provides each user with a 60Hz refresh rate video stream for each eye.

The configurations are: 1) a 120Hz monitor, two active glasses and anaglyphic filters, 2) a 120Hz projector, two active glasses and anaglyphic filters, 3) two 60Hz projectors, two polarization filters, two polarized glasses and anaglyphic filters, 4) two 120Hz projectors, two circular polarization filters, and two active glasses with circular polarization filters and 5) two 120Hz projectors, two active glasses and interference filters.

Configurations 1, 2 and 3 provide relatively low image quality, due to the use of anaglyphic filters. They provide stereo monochromatic views to the users. On the other hand, configurations 4 and 5 provide high-quality, full color images for each user.

The listed configurations are sorted according to implementation cost. Configuration 1 is the most affordable at around 800€, while configuration 5 costs more than 6000€. None of these costs include the computer equipment.

We have built the configurations 1 and 2. Figure 1 left, shows the two options for anaglyphic filtering supported by our system. The first option uses opposite anaglyph filters for the users (red-blue for one user and blue-red 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).

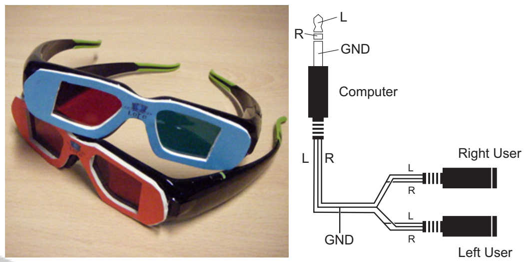

Figure 1: Left, our prototypes use two NVIDIA 3D Vision™active glasses with two attached anaglyphic filters. Only one pair of each configuration is showed. Right, audio splitter connection diagram.

We use standard quad-buffering for rendering the animation. We render both users' left eye in the left color buffer, and vice versa. To compose one eye's view for both users, we convert the full color input image into a grayscale image. Both users' left images are composed into the same color buffer using a red color mask for one user, and a cyan color mask for the other. Both images are rendered to that eye's back buffer.

We present an implementation that provides a private audio channel for two users using only a stereo sound card. With the simple audio splitter shown in Figure 1, right, our implementation separates each channel of the stereo sound card. A software mixer has been created to take the stereo audio stream from each video source, convert it to mono, and route it to one channel of the stereo output.

3.2 Head Tracking

We use a Microsoft Kinect along with OpenNI-NITE libraries (http://www.openni.org) to perform head tracking. The Kinect is able to capture depth images using an IR laser projector and an IR camera. The depth images are analyzed by the OpenNI-NITE libraries to detect users in the scene and get their position and pose. It requires calibrating the skeleton at least once in each room configuration.

We use OpenSceneGraph (OSG) to render our scenes. OSG is a scene graph manager based on OpenGL (http://www.openscenegraph.org). The default coordinate system used by OSG is shown in Figure 2. We define the origin of the World Coordinate System (WCS) to be located at the center of the screen. The XZ plane is parallel to the screen and Y points into the screen. The Kinect defines its origin at the center of the IR camera and uses a right handed coordinate system, with the positive X pointing to the left, the positive Y pointing up and the positive Z pointing out into the room. The Kinect measures the position of the skeleton joints in cm.

To transform the locations of the heads and hands provided by the Kinect into the WCS, we have to locate and orient the Kinect with respect to the WCS, as shown in Figure 2. $M_{k \rightarrow w} = T\left(\begin{array}{ccc} x & y & z \end{array}\right) R_x(\alpha)$ provides the transformation matrix required to transform from the Kinect coordinate system to the WCS. (x,y,z) represent the position of the origin of the Kinect with respect to the WCS and α is the angle between the WCS's Y axis and Kinect's Y axis. This transformation assumes that both X axes are parallel. If that is not the case, add another rotation about Y to account for the difference.

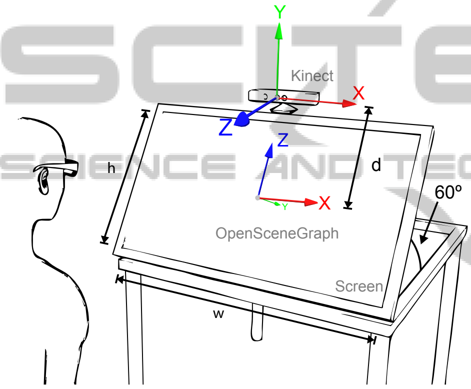

Figure 2: The distance between the origin of the WCS and the Kinect (d) is 36 cm (so, (x,y,z) in the equation is $(0,0,36)$. α is 120° (90° to account for the different orientations of the Z axes plus 30° due of the screen inclination).

Using the equation above, we can compute each user's head position in the WCS and therefore a virtual camera can be located at that position to render the scene from each user's point of view. The advantage of using the Kinect is that it also provides each user's hands positions and a gesture recognizer.

4 DEMO APPLICATIONS

Our demos run on a 3GHz Intel Core2 Duo processor, with 2 GB of RAM and an NVIDIA Quadro 600 graphics card, a Samsung 3D monitor model 2233RZ and a Dell projector model S300w installed in a workbench. To implement stereoscopy we used two shutter glasses NVIDIA 3D Vision, synchronized to a single IR emitter.

4.1 The Battleship Game

In this video game, each user places a number of different battleships on a discrete grid. The battleship positions of each player are unknown to the other player.

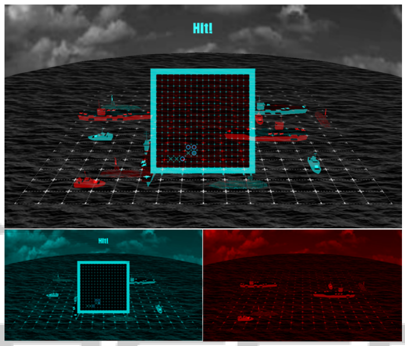

Figure 3: The Battleship game. Top, unfiltered view of the game, showing both players' views. Bottom, cyan player's and red player's views of the game.

We use OpenSceneGraph for user input and graphic rendering. To separate the scenes of each player we place two cameras, one at the root node of each user's scene graph. The images are rendered from the two cameras as explained in Section 3.1. Stereoscopy is handled automatically by OpenSceneGraph allowing selection of the fusion and interpupillary distances.

4.2 Two-user Stereo Video Player

Our second demo application allows two users to watch and hear different video and audio sources simultaneously on the same display. The video sources

Figure 4: Stereo video player for two users. Top, photograph of the monitor, showing both videos. Bottom, viewing the monitor through a red filter and blue filter.

can be both regular 2D content or 3D stereo content. The active stereo produces a double image made of the images shown in the filtered views. When the application is paused, each user is able to watch a stereo still image due to the active shutter glasses (Figure 4). Each user is able to hear the soundtrack of her video. We implemented this application using OpenGL, ffmpeg (http://ffmpeg.org) and SDL.

4.3 Stereo 3D Model Dual Viewer

Our third demo shows how to visualize a 3D model in stereo for two users. Each user sees the correct perspective from both eyes. It also provides a simple interaction model to tag points of interest in the scene or model.

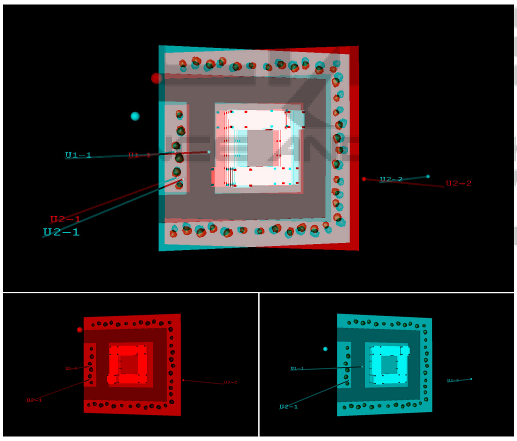

Figure 5: The Stereo 3D model dual viewer. Top, unfiltered view of the application, showing both users views. Center and bottom, cyan and red user perspectives of the 3D model.

Using the head position, we transform the Kinect-relative coordinates to the World Coordinate System and we define the virtual cameras' positions for each user (see Figure 5). We perform the same transformation to the left hand position to control a virtual cursor in the scene. This cursor allows the users to introduce tags in a 3D location of the scene. When our system detects a push gesture from the right hand of a user, it creates a new tag in the current position of the 3D cursor. We use different colors to identify the user that created the tag.

5 CONCLUSIONS AND FUTURE WORK

We have implemented two configurations that can provide two users with independent 3D stereoscopic views sharing the same display, using two pairs of active shutter glasses, anaglyphic filters and both a 120 Hz monitor and a 120Hz projector. For around 1000€, they can be built with off-the-shelf parts. We also implemented head tracking using a Microsoft Kinect. This enhances the 3D experience, since we can render the proper points of view of the scene for each user's eyes. We have built three demo applications that generate two independent stereo animations on the same screen.

Since our goal was affordability, some compromises had to be made. The anaglyph passive filters severely affect the color of the original images and there is a significant loss of perceived brightness due to the use of two-stage filtering. Still, our applications provide an interactive 3D stereo animation and independent audio channels for each user. These are the basic requirements to implement complex interfaces for collaborative applications without specialized hardware.

In future implementations, we plan to remove the anaglyphic filtering to improve the color quality and brightness using other types of filters.

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