Poster: Towards a Handheld Stereo Projector System for Viewing and Interacting in Virtual Worlds

Andrew Miller * Joseph J. LaViola Jr. †

Interactive Systems and User Experience Lab
University of Central Florida

Abstract

We present a proof-of-concept implementation of a handheld stereo projection display system for virtual worlds. We utilize a single pico projector coupled with a six DOF tracker to generate real-time stereo imagery that can be projected on walls or a projection screen.We discuss the iterative design of our display system, including three attempts at modifying our portable projector to produce stereo imagery, and the hardware and software tradeoff decisions made in our prototype.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality
I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 Introduction

Small affordable handheld projectors are a rapidly advancing technology. In the long term, we can hope that markerless six DOF tracking and a bright auto-focusing projector will be integrated into powerful smartphones or be a part of a console gaming system that many consumers can afford. Users may feel more familiar and comfortable with a handheld projector than with other virtual and augmented reality interfaces such as head mounted displays, since the projector behaves a lot like a flashlight or a laser pointer. Thus, a handheld projector coupled with a six DOF tracker could be considered a virtual reality display with the wand built right in.

We have developed a proof-of-concept stereo display system that uses a handheld projector (see Figure 1). In this paper, we present the details of our display system and discuss the design decisions and tradeoffs that were required to create our prototype.

2 Related Work

The bulk of the UI literature related to projectors has come from the Office of the Future project [4] and its spin-offs. Among these contributions are techniques for quickly calibrating clusters of projectors to produce a seamless image [2], and projecting on arbitrarily complex surfaces [5]. For our system, we assume only a single projector and simple surface geometry. This work will likely be applicable as we try to improve and extend our prototype. To the best of our knowledge, ours is the first project to incorporate stereo with a handheld projector.

3 Prototype Display System

Our prototype hardware consists of an off-the-shelf handheld projector, tracking device, a custom stereo controller, shutter glasses, a computer or smart phone, and a portable power supply. There are many available projectors to choose from, with tradeoffs between cost, size, brightness, resolution, and frame rate. We use a Dell M109S projector, which is small enough to hold comfortable in one hand, and just fast enough for stereo with a frame rate of 60Hz. This projector uses LED lamps and a DMD chip to create the image. The image is bright enough when the lights are turned off (see the photo in Figure 1).

*e-mail: amiller@cs.ucf.edu
†e-mail:jjl@eecs.ucf.edu

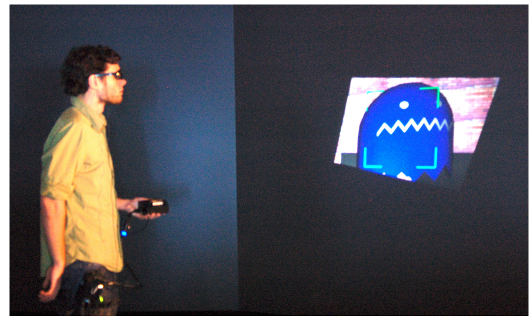

Figure 1: A user of our prototype system for interacting with objects in a 3D virtual world. The virtual world is revealed wherever the user points the projector. The 3D ghost is revealed when the users points the handheld projector in a given location on the screen. Although the projector is clearly oblique to the projection surface, the crosshairs appear orthogonal because of compensation using the tracker.

We achieved a stereo display by using a single projector and shutter glasses synchronized to the projector's frame rate. This required custom electronics, shown in Figure 2, to sample the VGA vsync wire and alternate left/right for each frame. We spliced a VGA cable to expose the vsync pin, and programmed a Texas Instruments MSP430 microcontroller to detect rising edges of the pin, which correspond to the beginning of each frame. The Dell M109S projector only supports 60Hz, which means that our best solution requires the shutter glasses to present only 30Hz frames to each eye, causing flickering. Although the flickering is noticeable, pilot testing with members of our lab has shown it not to be distracting.

One of the appeals of mobile projection is that nearly any surface can be used as a screen to display 3D content. White diffuse surfaces, such as typical indoor walls and ceilings, provide better contrast and brightness than colored walls or shiny objects. In the general geometric case, a perspective-correct image can be projected on to any surface as long as there's a 3D model available [3]. Simple flat surfaces orthogonal to the projector are the least susceptible to skewing artifacts. With our prototype, we use a large three-panel screen intended for rear projection, shown in Figure 1. It provides adequate contrast for our front projection scenario.

For our prototype, we chose to avoid the problem of mobile tracking by using the Intersense IS-900 tracker. It requires a number of acoustic beacons to be mounted in the ceiling and their positions carefully measured. This system works very well, since it combines data from inertial sensors with the acoustic measurements as an external frame of reference. However, the effort required to install the beacons and the cost of the entire system do not fit the requirements of a consumer market.

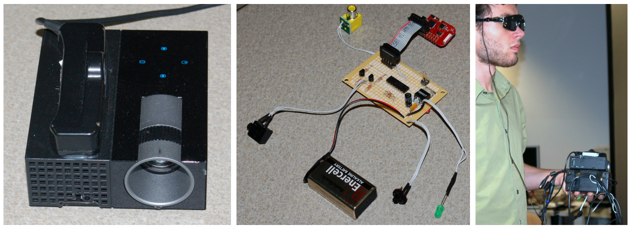

Figure 2: Hardware components: *(left)* handheld projector with attached tracking device; *(center)* custom microcontroller board for synchronizing shutter glasses; *(right)* user holding the microcontroller board and projector, wearing shutter glasses

4 Prototype Software

To generate 3D stereo images, we need to consider a single projector, a single user (with two eyes), a virtual world, and an actual world. For the actual world, we only concern ourselves with available projection surfaces where we want to see the virtual image. We measured the three projection screens in our lab to define our *actual world* coordinate system. The virtual world overlays the actual world and shares its coordinate system.

We want the user to see the virtual world as if it were fixed to the actual world. To project an image, we take a 3D point in the virtual world, cast a ray from the user's point of view, and intersect the ray with the model of the actual surfaces. Finally a camera matrix corresponding to the projector's resolution and field of view maps points from world surfaces to pixels.

While the above description is straightforward for individual points, a useful OpenGL implementation needs to consider entire polygons, texture mapping, and depth buffering. There are several valid approaches to use involving multiple-pass rendering, the efficiency of each depending on the number of virtual world polygons and the number of display surfaces [3]. We simplify this approach with the approximation that the projector is coincident with the user's viewpoint, so the projection can be performed in a single pass of conventional rendering. This results in shearing at discontinuities in the projection surface, and is less noticeable when the user holds the projector near the eyes, like a rifle.

Stereoscopic graphics can be achieved by treating the user's eyes as individual viewpoints and rendering separate frames to the projector for each eye. In order to be compatible with the approximation described above, we use the toe-in method of creating stereo disparity [6] and determine the screen distance by intersecting a ray with the modeled projection surfaces. This correctly produces zero disparity for virtual world objects that lie on the projection surfaces.

5 Interaction with the Virtual World

Our virtual world consists of a static terrain with miniature skateboard ramps, a distant brick-textured wall, and an animated ghost that advances towards the user and appears to pop out of the screen.The simplest interaction is passively viewing the landscape, controlling the point of view by walking around and pointing at the terrain from various angles. As a natural consequence of the projector's resolution, the user can stand back to reveal a wider area, or walk closer to view a smaller portion in finer detail. We speculate that users will have better spatial awareness using this natural interaction than with other virtual world locomotion techniques. The user can also actively participate in the virtual world by using the projector as a pointing device. The crosshairs appear to slide along the actual projection surface, shown in Figure 1. After the ghost pops out of the screen, the user can grab the ghost and then drag it around as though attached to the end of a pole.

6 Discussion and Future Work

Stereoscopic graphics seem to be more important for handheld projectors than for other displays. The active shutter glasses provide very good eye separation, with no visible 'ghosting' between frames. While tracking latency and jitter disrupt the perception of motion parallax, the stereo depth cue is unaffected by motion. The stereo works well even when the projector is out of focus and when the color accuracy and brightness aren't ideal.

Azuma describes the problem of a virtual wand 'swimming' around the user's actual wand when using an HMD [1]. With a handheld projector, the crosshairs and the attached ghost are always drawn in the center of the projector display, even though their orientation and size depend on the tracking data; their motion appears immediate and precise. However, the rest of the virtual world appears to 'swim' as it compensates for the projector's movement. We suspect that handheld projector games will be more immersive if they emphasize pointing and dragging and only display the background when necessary.

Handheld projectors have a number of advantages over alternative displays. Although glasses are needed for the stereo display, and the amount of weight the user has to carry will depend on the hardware choices, handheld projectors are more portable than display walls and allow for a natural field of view like the best see-through HMDs. Compared to the LCD displays on mobile phones or laptops, the projector allows the user to focus his eyes at a greater and more comfortable distance.

7 Conclusion

We've presented a prototype system that uses a handheld projector to display a 3D virtual world. The projector serves both to reveal the virtual world by projecting tracking-compensated images and as a pointing, selection device. We've described our approach to developing a hardware prototype and its limitations, as well as a software implementation of stereoscopic projection and suggested some approximations. We feel optimistic that handheld projectors will lead to a rise in popularity of augmented reality applications and stereoscopic 3D interfaces.

Acknowledgements

This work is supported in part by NSF CAREER award IIS-0845921 and NSF Award IIS-0856045. We wish to thank the anonymous reviewers for their valuable suggestions.

References

[1] R. Azuma. Predictive tracking for augmented reality. *PhD. Thesis, University of North Carolina at Chapel Hill*, Jan 1996.

[2] T. Johnson, G. Welch, H. Fuchs, E. la Force, and H. Towles. A distributed cooperative framework for continuous multi-projector pose estimation. In *VR '09: Proceedings of the 2009 IEEE Virtual Reality Conference*, pages 35–42. IEEE Computer Society, 2009.

[3] R. Raskar, M. Cutts, G. Welch, and W. Stürzlinger. Efficient image generation for multiprojector and multisurface displays. In *Rendering Techniques*, pages 139–144, 1998.

[4] R. Raskar, G. Welch, M. Cutts, A. Lake, L. Stesin, and H. Fuchs. The office of the future: a unified approach to image-based modeling and spatially immersive displays. In *SIGGRAPH '98: Proceedings of the 25th annual conference on Computer graphics and interactive techniques*, pages 179–188. ACM, 1998.

[5] R. Yang and G. Welch. Automatic projector display surface estimation using every-day imagery. In *In 9th Int'l Conference in Central Europe on Computer Graphics, Visualization and Computer Vision*, 2001.

[6] J. M. Zelle and C. Figura. Simple, low-cost stereographics: Vr for everyone. In *SIGCSE '04: Proceedings of the 35th SIGCSE technical symposium on Computer science education*, pages 348–352. ACM, 2004.