

A Design for a Smartphone-Based Head Mounted Display

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ABSTRACT

Thin computing clients, such as smartphones and tablets, have experienced recent growth in display resolutions and graphics processing power. In this poster, we show how to leverage these trends to create an experimental wide field of view, 3D stereoscopic head mounted display (HMD), based on two high resolution smartphones. This HMD prototype is unique in that the graphics system is entirely onboard, allowing it to be lightweight, wireless, and convenient to use.

Index Terms: H.5.1 [Information Interfaces and Presentation (I.7)]: Multimedia Information Systems—Artificial, augmented, and virtual realities B.4.2 [Input/Output and Data Communications]: Input/Output Devices—Image display

1 INTRODUCTION

In the 1960s, Ivan Sutherland presented a virtual 3D world to users using an early vector cathode ray tube (CRT) head mounted display. Tracking was performed by a set of either mechanical or ultrasonic sensors. A general purpose computer processed the tracking data, while a special purpose graphics processor made the appropriate perspective transforms on scene data. Sutherland wrote, “No available general-purpose computer would be fast enough to become intimately involved in the perspective computations required for dynamic perspective display.” [9]

Since that time, the graphics hardware industry has grown and matured. With the rise of the video game industry, there is now a commoditized marketplace for high performance graphics chipsets. Such chipsets enable almost any general-purpose computer to run 3D game engines and allow these machines to “intimately” participate in real-time perspective display. These chipsets are now in smartphones and other thin clients, like tablets, bringing 3D game engines to these smaller devices.

Head mounted displays (HMDs), and variants such as the Binocular Omni-Oriented Monitor (BOOM) [7] and head mounted projective displays [3], have provided gateways into various augmented and virtual realities. However, these devices have not experienced the same commoditization as graphics cards. These displays were typically manufactured in low volumes, were built for a customer base of researchers and niche application developers, and cost thousands, if not tens of thousands of dollars. There have been some steps towards commodity virtual reality displays for gaming, such as the Nintendo Virtual Boy, but these have been commercially unsuccessful. A variety of relatively low cost HMDs have been available in the \$1000 and lower price point, beginning with models like the Sony Glasstron, Virtual I/O iGlasses, and continuing with some models today.

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Even though HMDs have not been able to enjoy the same economies of scale as graphics cards, we have identified a different set of trends to leverage: the rise of smartphone graphics power, coupled with growing display resolution. These devices can provide a large portion of the components required for HMDs. To demonstrate this, we have integrated a lens assembly, game engine, and head tracking with two smartphones, creating an experimental commodity head mounted display. This HMD is unique in that it renders imagery onboard and is battery powered, allowing a truly untethered virtual reality experience.



Figure 1: Experimental head mounted display with lenses in place.



Figure 2: Experimental head mounted display with lenses removed, revealing the two smartphones that render and display imagery.

2 RELATED WORK

A variety of smartphone add-ons have been created to enable 3D image display. The 3deeShell and 3deeSlide [8] are parallax barriers for the Apple iPhone that create 3D images from interleaved stereo pairs. However, these cannot provide an immersive wide field of view experience. The My3D clip-on for the iPhone is a two eyepiece assembly that allows stereo display of image pairs [2], much like the classic View-Master 3D viewer. Again, a limited field of view reduces immersion.

The lens assembly used in this project is based on the Large Expanse Extra Perspective (LEEP) optics developed by Eric Howlett

for wide field of view 3D stereoscopic images [5, 6], later adapted by Scott Fisher for use in head mounted displays at NASA [4]. In fact, the same LEEP optics design was the basis for many early head mounted and BOOM-type displays from NASA, VPL, LEEP Systems, Fakespace, and other groups. Key to this adoption was the ability of LEEP optics to provide at least a 90 degree field of view, and even greater fields of view if the user can move her head laterally in relation to the optics (approximately 110 degrees), rotate her eyeballs (approximately 112 degrees), or both move and rotate (approximately 130 degrees) [6]. While head motion relative to the optics is not possible with traditional head mounted displays, these numbers demonstrate the field of view benefits of this optic design. Furthermore, this design provides a useful fisheye distortion that creates higher pixel density in the central region of the display and reduced density in the periphery, matching the resolution variance of the eye and retina. A drawback of these optics is that high resolution displays are necessary to create good imagery. Early head mounted displays suffered from blocky low resolution images due to low resolution displays exacerbated by the magnification of the optics. CRT based displays provided increased resolution, but at the cost of weight and bulk.

3 APPARATUS

Our experimental HMD design uses two iPhone 4's as displays and graphics engines. The iPhone 4 has a 3.5-inch (diagonal) display with 960x640 pixels (326 ppi) and a 3:2 aspect ratio [1]. The two iPhones are mounted on a fiberboard panel. Bolts allow for easy attachment of a LEEP-type lens assembly (see Figures 1 and 2).

In our demo, a simple virtual scene is rendered using the Unity game engine that is running on each of the phones. We are currently using a PhaseSpace Impulse active LED motion tracking system to compute head position and orientation. The tracking data is made available over UDP to the game engines using a Python script, running on another PC. The LEEP-type lens assembly was obtained from a Fakespace BOOM display.

When replicating this HMD design, we suggest using the standard spacing of attachment points on the BOOM lens and other LEEP-type assemblies (see Figures 1 and 2). These points are 7 inches apart, center to center horizontally, and 2 3/8 inches apart vertically. These points are vertically centered 1/4 inch below the horizontal center of the lenses.

Since acquiring a LEEP-type lens assembly may not always be possible, we can also suggest an alternative. A pair of 2 inch diameter plastic aspheric 5x magnifier lenses with a 2 inch focal length can be easily acquired. These can be mounted 2.5 inches apart to accommodate the average distance between a pair of eyes. These do not provide as wide a field of view as LEEP-type lenses. In our iPhone based HMD, these provide approximately 55 degrees horizontally and 85 degrees vertically.

4 DISCUSSION

Our system does exhibit some lag, due to the Python script used to distribute tracking data. This could be reduced by our planned port of a VRPN [10] client library to the Unity engine for the iPhone. We have also seen an issue with refresh synchronization between the two iPhones. Since each phone is drawing and refreshing the scene independently, one eye view is often drawn before the other. This time difference between display refreshes causes the perception of a vibration or a stuttering motion between the two eye images during a head panning motion. This could be addressed by a hardware modification that would link together the refresh signals of each phone display.

We hope that the convenience of this design will enable casual "pick up and use" immersive experiences for multiple users. These experiences could include engineering design reviews of complex 3D models or immersive classroom visits of historical sites.

5 FUTURE WORK

Future work for this design will be the systematic investigation of modifications to improve performance of our prototype. To address the refresh synchronization issue, we can use larger screen devices, such as the Apple iPad or Samsung Galaxy, which allow a single screen to address both eyes. Another modification would be the use of plastic LEEP-type optics, reducing the manufacturing cost and weight of the assembled unit. Glyph based tracking, using the built in smartphone camera, would allow low cost tracking. We plan to publish more mechanical and software details online.

6 CONCLUSION

We have demonstrated how to integrate stereoscopic lens assemblies, game engine software, and smartphones to create a head mounted display. This smartphone-based head mounted display is a unique platform since it combines a virtual reality display and powerful graphic computers into a single unit. With an appropriate tracking technology, this head mounted display can be wireless. By sharing the specifications and techniques that we have used, we hope to enable and encourage others to build and improve on such displays.

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