A Low-cost, Low-latency Approach to Dynamic Immersion in Occlusive Head-Mounted Displays

Robert W. Lindeman*

HIT Lab NZ, University of Canterbury
HIVE Lab, Worcester Polytechnic Institute

ABSTRACT

In this poster, we introduce the notion of using LCD panels for controlling the level of immersion provided by head-mounted displays (HMDs). We propose replacing the cowling around typical "ski-goggle" type HMDs with LCD panels of the type used in commodity active-stereo glasses used in movie theaters. The panels can be controlled using very simple stand-alone circuitry and/or a micro-controller to vary the amount of the real world that is visible in the periphery of the user. This can drastically increase the usability of consumer HMDs, because it allows users to see objects in their immediate surroundings (e.g., the keyboard and mouse), can be used to counter cybersickness by providing natural cues when needed, and introduces no added latency into the system. We show several prototypes of our approach using Google Cardboard, and provide some initial thoughts on the systems.

Keywords: Immersion, head-mounted display.

Index Terms: Hardware: Emerging Technologies: Emerging Interfaces. Human-centered computing: Human computer interaction (HCI): Interaction paradigms: Virtual reality

1 INTRODUCTION

The current generation of Head-Mounted Displays (HMDs) has significantly improved the state of the art over previous generations in several key ways. The quality of the products versus their cost is probably the most important difference. Due to the main components (display, sensing, connectivity, battery) being based on mass-produced mobile-phone technology, combined with low-cost, wide-field-of-view optics, and software support from major game-engine companies (Unity3D, Unreal, Valve), HMDs are now poised to finally make major in-roads into the home market. Most of the devices provide deep immersion by physically blocking out as much of the real visual world as possible, and providing a very wide (>120 degrees horizontal) field of view to replace it.

Effectively blocking out the real world introduces some usability problems, however. For example, because the user cannot see their near-field environment, accessing physical items such as the keyboard and mouse (or a cup of coffee) becomes a challenge, requiring the user to grope about for them. In addition, such deep immersion can lead to an increase in the occurrences and severity of cybersickness (LaViola, 2000), since the feed of visual cues that the brain receives will be devoid of many of the rich, subtle cues present in the real world, and, more importantly, the latency of visual reaction to head motion is higher than it is in the real world. Thirdly, because the user is visually cut off from other people who may be in the near-field physical environment, the user is oblivious to any inappropriate behavior that may take place. This is especially worrisome for potentially vulnerable populations, such as children or women.

To rectify this situation, apart from the obvious solution of just temporarily removing the headset to interact with the real world, several technical solutions have been proposed. The simplest is to use a non-occlusive HMD, such as the Virtual-IO i-glasses or the eMagin z800 (Figure 1a & 1b). These headsets use dual LED panels mounted in front of the eyes, and suspended from a headband. By comparison, current HMDs, such as the Samsung GearVR or HTC Vive (Figure 1c & 1d) use more of a ski-goggle design, where the top, bottom, and sides of the unit block out the real world, leaving only the display for delivering visual stimulus. The no-latency real-world cues afforded by non-occlusive HMDs solve all of the problems produced by occlusive HMDs, but at the cost of the deeper immersion provided by occlusive HMDs.

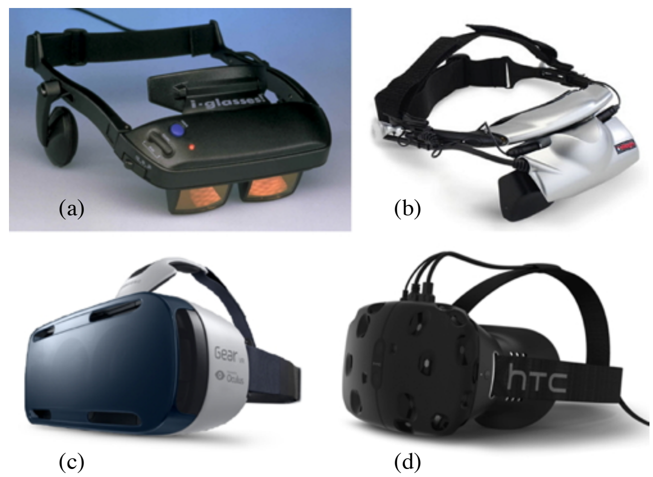

Figure 1: Commercial HMDs. (a) Virtual-io i-glasses, (b) eMagin z800, (c) Samsung GearVR, (d) HTC Vive.

Another approach is to use a head-mounted camera to capture video of the real world and merge it with the virtual world. This well-established, video-see-through augmented reality lets in the real world, but still incurs the cost of latency to process the video feed and merge the two world representations. In addition, the offset between the camera location and the eyes creates distortion, making it difficult to properly align the virtual and real visuals.

Other approaches capture/scan the real world from one or more fixed cameras, and then create virtual versions of the near-field environment (Nahon et al. 2015). By calibrating the offset from the capture and head poses, virtual representations (e.g., point clouds) of the real environment can be brought into view of the user, providing strong cues for grounding the user in the real world. By segmenting the data, objects can be selectively shown or hidden. One drawback of these systems is the need for external infrastructure (e.g., calibrated cameras fixed in the scene), as well as the processing latency.

To address the problems described above, we propose a novel method for dynamically controlling how much of the near-field

*e-mail: gogo@wpi.edu

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physical world the user can see while using an occlusive HMD. Our approach uses low-cost common off the shelf (COTS) materials, adds no latency to the system, and supports both user and computer control of the immersiveness. We call our approach "Dynamic Immersion" (Lindeman, 2015).

Figure 2: Modified Google Cardboard, with the LCD Panel Windows (circled in white)

2 Details of Dynamic Immersion

We have built a prototype of our approach using Google Cardboard (Figure 2). We replace the sides and bottom of the Cardboard with LCD panels taken from low-cost, commercially available active-stereo glasses. In our prototype, we control the opacity of each panel using a battery and switch that selectively applies and removes current to the panels. When current is supplied, the panels become opaque, and when the current is removed, they become transparent. In addition, the current can be selectively increased or decreased, changing the level of transparency of the LCD panels over a continuous scale. This could be done using a microcontroller (e.g., Arduino) and either a linear soft potentiometer (Figure 3), or through computer control from a host/phone connection. Since there is no need to continually and rapidly switch the panels on and off like is done for 3D glasses, we drive the LCD panels directly by varying the current, so there is no "flicker." A change in current only results in a change in opacity.

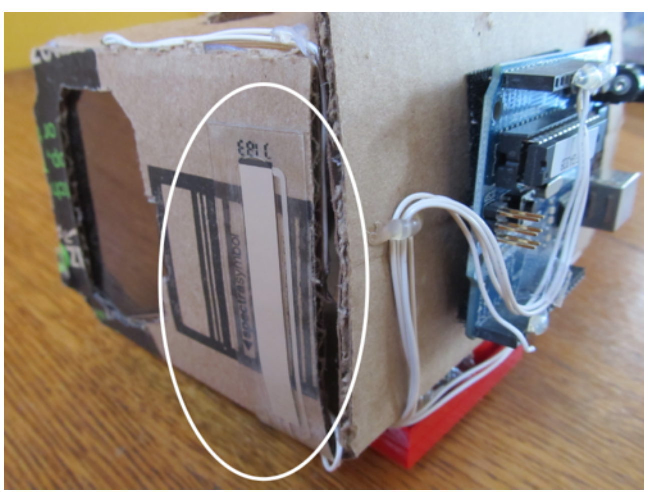

Figure 3: Variable Opacity using an Arduino and a Linear Potentiometer (circled in white)

The LCD windows are placed such that light being let into the unit does not enter the viewing chamber made up of the wall holding the optics, the cardboard sides, top, and bottom, and the display (Figure 4). The LCD windows are only visible to the user in the periphery of the sides and bottom of the unit in our current prototypes (Figure 5).

Figure 4: View Inside the Cardboard, with Baffles (circled in white) to Keep Light Out of the Viewing Chamber.

(a) (b)

Figure 5: Transparent (a) and Opaque (b) Bottom LCD Windows

3 Future Work

LCD panel technology is very well developed today, and we envision creating an entire HMD shell out of controllable LCD material. In this way, full control of the light let into the HMD can be controlled, while keeping the cost and complexity down. We are currently designing studies to compare our approach with other methods of improving the VR user experience afforded by current HMDs. In addition, we are continuing to improve our design, focusing on increasing the opacity of the panels, as well as the overall design of new shells.

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