Chapter 1.22
An Introduction to Head Mounted Displays for Augmented Reality

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ABSTRACT

This chapter introduces design and principles of head mounted displays (HMDs), as well as their state-of-the-art examples, for augmented reality (AR). Section 2 introduces a brief history of head mounted displays, human vision system, and application examples of see-through HMDs. Section 3 describes designs and principles of HMDs, such as typical configurations of optics, typical display elements, and major categories of HMDs. Section 4 gives typical characteristics of HMDs, such as resolution, field of view, and distortion. Section 5 describes human perceptual and health issues such as depth perception and safety. Finally, Section 6 gives conclusions with future challenges and prospects. For researchers, learners, and HMD developers, this chapter is a good starting point to learn basics, state of the art technologies, and future research directions of HMDs. For system developers and end-users, this chapter will give a good insight to HMDs to choose a suitable HMD for their purposes.

INTRODUCTION

Ever since Sutherland's first see-through HMD in the late 1960s, attempts have been made to develop a variety of HMDs by researchers and manufacturers in the communities of virtual reality (VR), AR, and wearable computers. Because of HMD's wide application domains and technological limitations, however, no single HMD is perfect. This is why it is extremely important to appropriately appreciate pros and cons of each HMD, its abilities, and limitations. As an introduction to the following discussion, this section introduces three issues related to HMDs; a brief history of HMDs, human vision system, and application examples of HMDs.

Brief History of Head Mounted Displays

The idea of a head mounted display was first patented by McCollum in 1945 (McCollum, 1945). Heilig also patented a stereoscopic television HMD in 1960 (Heilig, 1960), then he developed

and patented a stationary VR simulator, the Sensorama Simulator in 1962, which was equipped with a variety of sensory devices including a binocular display to give the user virtual experiences. Comeau and Bryan at Philco Corporation built Headsight in 1961, the first actual HMD (Comeau & Bryan, 1961). This was more like a today's telepresence system. Using a magnetic tracking system and a single CRT mounted on a helmet, Headsight shows a remote video image according to the measured head direction. Bell Helicopter Company studied a servo-controlled camera-based HMD in the 1960's. This display provides the pilot with an augmented view captured by an infrared camera under the helicopter for landing at night. In a sense that the real world image is enhanced in real-time, this is the first video see-through AR system, though computer-generated imagery was not yet used.

The first HMD coupled with head tracking facility and real-time computer-generated image overlay was demonstrated by Sutherland in the late 1960's (Sutherland, 1965, 1968). This tethered display, called "Sword of Damocles," has a set of CRT-based optical see-through relay optics for each eye, allowing each eye to observe a synthetic imagery and its surrounding real environment simultaneously from a different vantage point.

Since the early 1970s, the U.S. Air Force has studied HMD systems as a way of providing the aircrew with a variety of flight information. As the first system in this regard, the AN/PVS-5 series Night Vision Goggle (NVG) was first tested in 1973. The Honeywell Integrated Helmet and Display Sighting System (IHADSS) is one of the most successful see-through systems in Army aviation, which was first fielded in 1985 (Rash & Martin, 1988). In 1982, Furness demonstrated the Visually Coupled Airborne Systems Simulator (VCASS), the US Air Force's "super-cockpit" VR system (Furness, 1986).

The large expanse, extra perspective (LEEP) optical system, developed in 1979 by Eric Howledtt, has been widely used in VR. The LEEP system, originally developed for 3D still photography, provides a wide field of view (~110°(H) x 55°(V)) stereoscopic viewing. Having a wide exit pupil of about 40 mm, the LEEP requires no adjustment mechanism for interpupillary distance. Employing the LEEP optical system, McGreevy and Fisher have developed the virtual interactive environment workstation (VIEW) system at the NASA Ames Research Center in 1985. Using the LEEP optics, VPL Research introduced the first commercial HMD, EyePhone, in 1989. The EyePhone encouraged VR research at many institutes and laboratories. Since then, a variety of HMDs have been developed and commercialized.

Human Vision System

Vision is the most reliable and complicated sensory, providing more than 70% of the total sensory information. Figure 1(a) shows the structure of a

Figure 1. (a) Human eye structure; (b) density of cones and rods
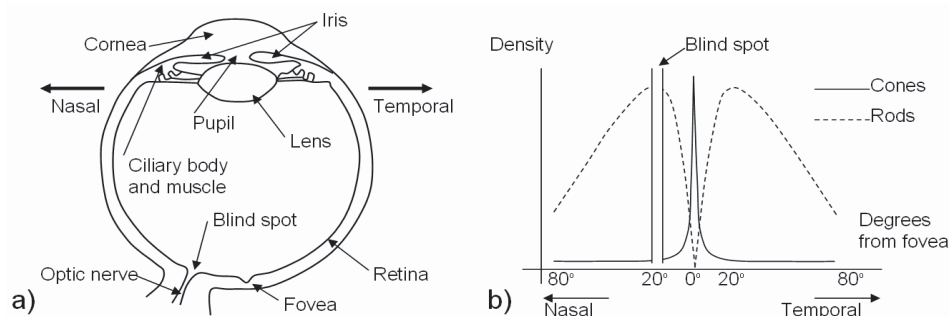
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