Research Update for Flexible Heads-Up Displays

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Introduction

Augmented Reality (AR), labeled as one of ten emerging technologies by the Massachusetts Institute of Technology, lies between a real environment and a virtual environment as “mixed reality”, and is defined by three criteria: that it combines real and virtual objects in a real environment, that it aligns real and virtual objects together, and that it runs interactively, in three dimensions, and in real time. Such a system is not, however, restricted to a headset. There are three types of AR: (1) where the real world is turned into digitized images and the virtual items are overlaid onto those digitized images, (2) where the virtual items are projected onto the real world, and (3) projective displays (Van Krevelen & Poelman 2010).

Progress in bendable circuitry based on thin film transistors, which includes oxide transistors, nanotube/nanowire-based transistors, and organic thin film transistors have made such devices more capable, however, they lack color due to how liquid crystal displays (LCDs) cannot be bend without distorting color. OLEDs (Organic Light Emitting Diode) do not suffer from this problem. OLEDs, however, require a polarization film to increase color contrast and a glass cover to protect it from the elements (Kim, et al. 2011).

On the other hand, head-mounted displays (HMDs), also known as virtual image displays (made up of magnifying optics with a small image panel) have found application with computers as head-mounted displays. Most head-mounted displays are too heavy for constant use, obtrusive, and disorienting. Conventional virtual displays, such as flip-down screens and virtual displays in the form of glasses, have some deficiency: high weight, uncomfortable ergonomics, and/or lack of peripheral vision (Budd, Dove, Lovas, Olyha, & Powell 2012).

With the recent advances in flexible display technology, as well as how more modern headsets remain bulky when compared to their older counterparts (such as the Nintendo Virtual Boy), the use of flexible displays in a head-mounted display device is a much simpler way to decrease weight and freeing up the user's peripheral vision.

Literature Review

Due to how information is unavailable directly to the wearer, instead of having information tied to a mobile device or computer, the information devices provide a disconnect from information, since these devices are usually stored separately from the user. If given a device where information is directly available to the user (such as a smartwatch or a heads up display), then the user would be able to make better decisions at specific points in time by having more information at their discretion. Near-eye displays allow for higher mobility and privacy compared to mobile phones. Such displays can be incorporated into a head-mounted device by using items such as eyeglasses, goggles, helmets, and visors, among other things, as a mounting point for the display. However, to get a good resolution for the flexible display, the display size has to be increased. The problem becomes a question on how big the screen can become before becoming unwieldy to the user (Robbins & Bohn 2016).

In fact, multiple forms of helmet-mounted displays (HMDs) have developed throughout the latter half of the 20th century and early 21st century. These include HMDs for military (helicopter) pilots, as to give these pilots a better sight picture and the ability to use visual modifications such as thermal and infrared imaging, as well as for foot soldiers, as evidenced by the Land Warrior (begun in 2000 and was field tested in 2007) and Future Warrior (begun in 2003) projects to increase individual battle visibility with command, control, communications and information sharing (Foote & Meltzer 2015).

Another example of a military venture using helmet mounted displays is the use of HMDs for vehicle mechanics. By providing armored vehicle mechanics with a head-mounted display, the mechanics were able to complete their tasks more quickly while minimizing head movement. The prototype is a head-mounted display in the form of a pair of goggles with a single lens. The software is based on the Valve “Source” game engine and is designated as a “mod” by the software. The “mod” is designed to help mechanics in the turret of a LAV-25A1 wheeled armored personnel carrier through the use of overlaid markers, labels, graphics, and animated sequences to provide the mechanics with a visual to provide a much easier time designating areas that need to be checked. Mechanics reported that the augmented reality provided by the heads up display was intuitive and satisfying to use (Feiner & Henderson 2009).

Currently, however, most head-mounted displays are too heavy, obtrusive, and disorienting for constant use. HMDs are built with 1-2 cathode ray tube (CRT)/liquid crystal (LC)/organic light emitting diode (OLED) displays with other optical equipment in the form of a headset. This device is used in multiple applications, such as military, medicine, and entertainment. HMDs have the problem where they only display images in the central field of view. The lack of peripheral vision for extended periods of time may cause users to feel nauseous due to motion sickness (Tant & Farell 2012). Conventional virtual displays, such as flip-down screens and virtual displays in the form of glasses, have some deficiency:

high weight, uncomfortable ergonomics, and/or lack of peripheral vision (Budd et al. 2012). The paper “Three-dimensional holographic head mounted display using a holographic optical element” agrees with this statement, and goes on to state that there is also the issue where current HMDs may cause eye fatigue due to how the HMD may not have the same convergence distance digitally as the user’s real-life eye convergence distance. The proposed solution is to develop an HMD system based on a 3D hologram displayed on a holographic optical element (HOE), which reflects an image displayed by a spatial light modulator (SLM). The device developed in the article, which was supported by “The Cross-Ministry Giga KOREA Project” of The Ministry of Science, ICT, and Future Planning in South Korea, is a proof-of-concept, placing the parts on a surface and around an inch apart (Kim, et al.).

On the issue of replicating normal human horizontal peripheral vision, which is a little more than 180 degrees in the horizontal, head-mounted displays have 90 degrees of horizontal vision for fully enclosed headsets (e.g. Oculus Rift) and 40 degrees for glasses type (e.g. Microsoft HoloLens). A possible solution proposed by the article is to place light-emitting diodes and a light diffuser around the display to emulate peripheral vision by producing more blurred colors.

The development of flexible displays also allows for developers to design software that utilizes the flexing of the display as a gesture. One such device, the Paper Phone (developed by the Queen’s University in Canada and Arizona State University), was developed with the idea that people would prefer gesturing the screen over swiping across the screen. To approximate the feel of a paper document, the PaperPhone’s design requirements were: to be thin, lightweight, and rugged, as well as flexible to a certain degree and able to sense gestures such as bending. The survey was done with a (small) study group of 10 detailed that each user preferred a single plane of motion gestures and preferred gestures that were simpler (such as bending the screen inward).

Other flexible displays, when compared to inorganic light emitting diodes (ILEDs), organic light emitting diodes (OLEDs) are, however, shorter in lifetime, lower in efficiency, and lower in brightness. In 2005, after the development of flexible III-V material, there was a development in flexible ILED technology with the creation of Gallium arsenide (GaAs) LEDs on a plastic substrate. In 2011, another different flexible ILED was developed, this one being made with Gallium nitride (GaN) material (Yoo, et. al 2012).

Analysis

As detailed earlier, the majority of head-mounted displays, both military and commercial, remain bulky. These headsets, which include virtual reality headsets, have a weight in front of the user's face that is heavy enough to shift the center of mass. With regards to prior research, the flexible display as part of a head-mounted heads-up display system is a less expensive and lighter system when compared to previous head-mounted displays such as that of the Land Warrior project. However, with the cost of a rigid screen being 10 cents per square centimeter, it is unlikely that computer firms will invest in flexible display devices until flexible displays eventually become more cost efficient with regards to durability, weight, and functions (such as touch gestures) become better defined when compared to rigid displays (Smith et al. 2015).

However, flexible displays are unsuited to large scale use in devices due to their higher size to price ratio (the flexible display we bought costed around $50, a normal flat panel display costs around $100 for a much larger screen and higher resolution) and fragile nature. If fact, during development of the device, we broke two displays due to bend tests. However, as the technology progress and flexible displays become cheaper, they will most certainly overtake flat panel displays due to their lower weight and smaller overall size compared to a flat panel display of the same screen size, as a flexible display is much thinner when compared to a flat panel display.

Such a size decrease would allow for superior ergonomics and increased capabilities if used for a head-mounted display, as it would allow for the user to better implement the information given.

The original design of the project was based on being attached to the frame of the glasses and only having one compartment. By the middle of the second semester, we decided to instead split the device into two compartments, one housing the microprocessor, the flexible display's controller, the wiring, and the flexible display itself, and a second one to house the battery and be worn on the other side of the glasses as a counterweight.

We had multiple difficulties during the prototyping phase of this project, namely the issue of compatibility of the microprocessor with the flexible display. Our original goal was to have the device display temperature; once we obtained a microprocessor with wireless capability, we attempted to add more capabilities to the device. However, we faced multiple compatibility issues with regards to the microcontroller, mostly due to the flexible display controller requiring a higher voltage to what the microcontroller outputs. We attempted to modify the cache files and the SPI library in order to get the second microcontroller to cooperate, but ultimately we swapped to another microcontroller. And during the second half of the semester, the computer we were coding on also had to be reset due to how the microcontroller backfed 14 volts into a USB port, and we lost most of our code. We had already rewritten most of the code by the time we presented.

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