Research Update for Flexible Heads-Up Displays

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Abstract

Through the development of organic light emitting diodes(OLEDs), flexible displays have been used in smartphones and similar devices, allowing for curved screens and, more recently, folding screens as seen in the new Motorola Razr folding smartphone. However, the low resolution and relative fragility of flexible displays have limited their uses, especially as heads-up display devices. This project is designed to test the potential and effectiveness of using flexible displays as heads-up displays.

1. Introduction

With new developments in computer science, such as big data, machine learning (especially deep learning), and the internet of things (IoT), information has never been easier to access than today. However, the user still faces difficulty when it comes to obtaining information, especially when they are on the move. Augmented Reality technology, and related Virtual Reality technology, provides a feasible and economically-sound way of providing on-route information.

Augmented Reality devices are, essentially, small, wearable displays with a computer and/or transmitter/receiver to communicate with other devices. They have been labeled as one of ten emerging technologies by the Massachusetts Institute of Technology. These devices lie between a real environment and a virtual environment as “mixed reality”, and are defined by three criteria: they combine real and virtual objects in a real environment, they align real and virtual objects together, and they run interactively, in three dimensions, and in real time. 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).

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

Figure 1. A US Army soldier uses a prototype heads-up display during the Land Warrior trials (Foote & Meltzer 2015).

Augmented Reality and Virtual Reality headsets themselves will benefit from connections to the Internet of Things (IoT) and information from big data services, allowing for superior information accessibility through the cloud and allowing for faster updates of information.

Modern headsets remain bulky when compared to their older counterparts (such as the Nintendo Virtual Boy), but with recent advances, flexible displays can be used in head-mounted display devices as a way to decrease weight and free up the user's peripheral vision.

However, flexible displays are unsuited to large scale use in devices due to their higher price fragile nature, with the flexible display we bought to test with was around $50 for a 1.81-inch long screen, whereas a normal flat panel display costs around $100 for a much larger screen and higher resolution). In addition, during the development of the device, we broke two displays due to bend tests. However, as this technology progresses 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.

Such a size decrease would allow for superior ergonomics and increased capabilities if used for a head-mounted display. A flexible display would allow for the user to better interpret the information given to them.

2. Concepts & Problems

Due to how information is unavailable directly to the wearer, information-based devices provide a disconnect from information, since these devices are usually stored separate 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, and 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.

2.1. Flexible Displays

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). Make it readable

However, to get a good resolution for a flexible display, the display size has to be increased. The problem now isn't about how to lighten an augmented reality display, but how big the screen can become before it is uncomfortable to use (Robbins & Bohn 2016).

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).

Organic light emitting diodes (OLEDs), when compared to inorganic light emitting diodes (ILEDs), are, however, shorter in lifetime, lower in efficiency, and lower in brightness. In 2005, after the development of flexible (what is this?) 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).

2.2. Military Heads-Up Displays

In fact, multiple forms of helmet-mounted displays (HMDs) have been developed throughout the latter half of the 20th century and early 21st century. These include HMDs for military 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).

Figure 2: A mechanic uses a heads-up display during repairs (Feiner & Henderson 2009).

2.3. Other Issues

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.

One of the largest problems with current head-mounted displays, however, is that the head-mounted display produces 2D images, which impacts user depth perception. 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. A 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). (Kim, et al.).

2.4. Future Direction

Both VR and AR technology reached peak interest from researchers in 2017, with the former receiving around 57,400 publications and the latter receiving around 35,400. These are reflected in VR game publishing on online game distributor Steam by Valve Software, which also peaks in 2017. Outside of video games, augmented reality systems were researched as a possible solution to issues, mainly research and development and healthcare (Muñoz-Saavedra Miró-Amarante & Domínguez-Morales 2020).

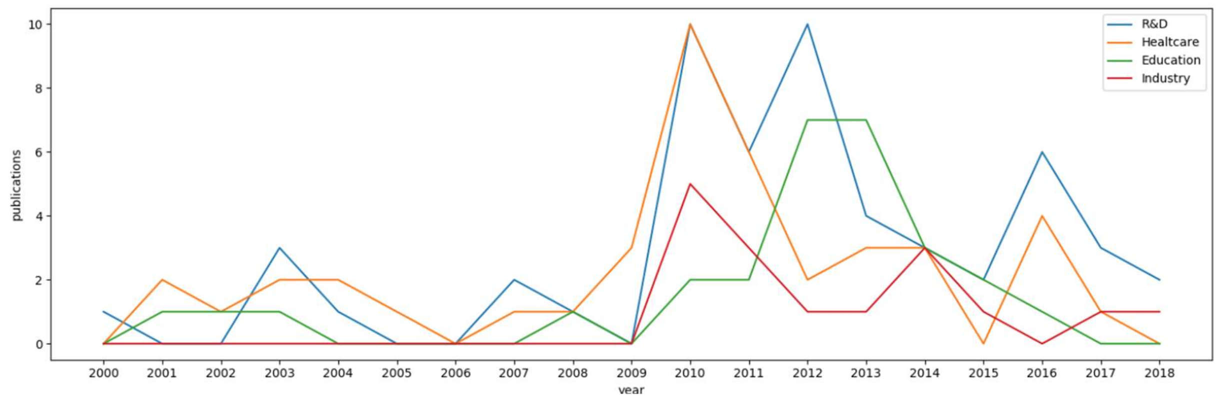

Figure 3. A graph detailing the number of publications per year for certain industries (Muñoz-Saavedra Miró-Amarante & Domínguez-Morales 2020).

The future of AR technology is far from over with the advent of better cloud and peer to peer technologies. For example, Valve Corporation's Steam Link software (and its discontinued hardware version), as well as Nvidia Corporation's GeForce Now software (formerly known as GeForce GRID), has allowed users to stream applications from their computer to their mobile devices. AR and VR systems could use this to allow for real-time information updates, giving the user more information than a normal device would be able to give.

3. Research : Design, Implementation, and Analysis

As detailed earlier, the majority of head-mounted displays, both military and commercial, remain bulky. These headsets, which include virtual reality devices, have a weight in front of the user’s face that is heavy enough to shift the user's 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).

3.1. Research Proposal

This research is to determine whether flexible OLED displays are better suited for information sharing compared to traditional flat panel LCD devices. Ultimately, flexible displays should be used in more applications where a flat panel display would not be practical, allowing the user to have easier access to information and better the user's experience.

However, there are some displays that are available in certain markets such as Sparkfun. They offer an adequate flexible display that can be used for the build. Besides the actual display, there would be a need for a compartment to hold the controller and power connections. The build will be an earpiece similar to that of the Google Glass. The compartment that holds the display driver board, temperature/humidity sensor, battery, and the microcontroller will be 3D printed. The flexible OLED display will be bought off the Sparkfun website and programmed by the engineering group.

3.2. Timeline

For the first quarter of the school year, the group will complete the electrical schematic diagram of the OLED display and the microcontroller compartment. In the second quarter, the group will take measurements of a pair of glasses. The group will begin the process of 3D modeling the HUD assembly and it will be 3D printed. The third quarter will be dedicated to programming the electronics and overall testing of the display. In the fourth quarter, the build can finally be assembled and tested. The build is expected to be connected to a microcontroller and the Arduino chipset within the first week as it only requires a simple soldering procedure. However, as the project further progresses, it will become more experimental as there is no definite method to accomplish something like this. A CAD model will be developed to determine the length and shape of the compartment that will hold the microcontroller and the processor. Then it is a simple matter of attaching the display to some glasses, and then just troubleshooting and working out bugs.

3.3. Proposed Results

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.

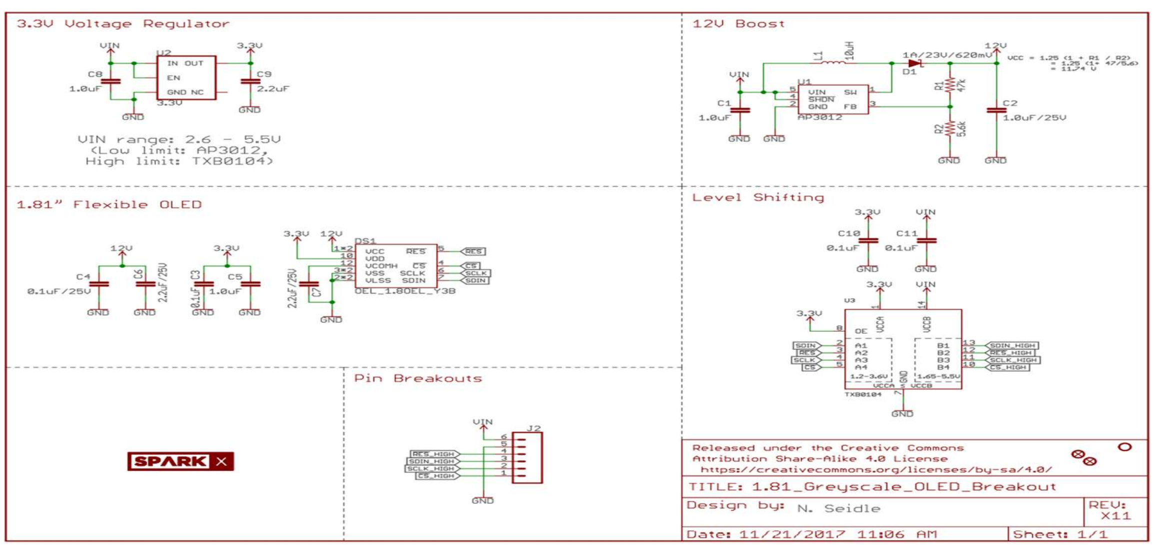

Figure 4. Flexible OLED Display Circuitry (Sparkfun).

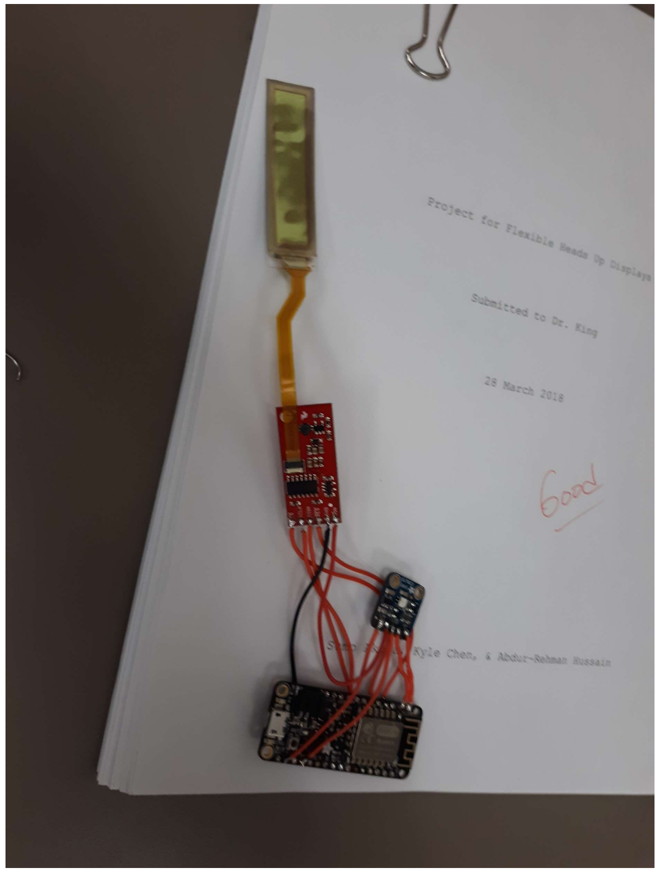

Figure 5. Physical device.

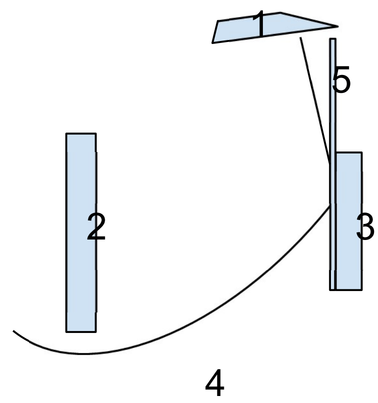

Figure 6. A diagram of the device; 1 - the flexible display, 2 - the battery pack, 3 - the flexible display control board, temperature sensor, and microcontroller, 4 & 5 - wires.

3.4. Development Results

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.

Ultimately, we were unable to find conclusive evidence to support the claim that flexible displays were capable of being used in heads-up displays as reliable display devices.

3.5. Future Developments

The issue with the current flexible display technology is that it is extremely fragile. Small nonflexible displays, however, are much stronger for more weight. Trials with nonflexible displays will be conducted in the future before moving back to flexible displays.

Other important things to consider during redesign is the compatibility of the parts, as the display controller was incompatible with the microcontroller, and the time needed to test compatibility and fix any bugs in the temperature sensor-microcontroller-display system.

Future developments will mainly involve expanding the amount of sensors on the device and expanding its capabilities beyond temperature readings.

Due to the fragility seen during testing, we will work to improve the durability of the product during regular use. This would expand its applications to other areas where more rigorous application of the device is more likely. For example, the addition of a frame around the flexible display may allow for superior strength with regards to tension and compression; however, it will decrease the overall flexibility and increase overall size.

On the subject of weight reduction, smaller parts and lighter material will be used; the amount of wiring and the battery size especially. Until the final design specifications can be completed, wiring will be difficult to decrease in size; on the other hand, battery size can be set from the beginning. Smaller batteries such as Turnigy nano-tech drone batteries can decrease overall weight, but will increase wiring required through conversion of the drone port output to a Micro-B USB input.

Figure 7. Turnigy nano-tech 200mAh 3.7V 35-70C Pico drone batteries, each with a mass of about 6.5 grams and are about the size of a pencil (HobbyKing).

4. Conclusion

Flexible displays, through the development of organic light emitting diodes, are much more prevalent. However, the low resolution and relative fragility of flexible displays have limited their uses, especially as heads-up display devices. Until the technology is developed to such an extent where a flexible display has comparable cost and resolution to a non-flexible display, flexible displays will have limited uses beyond the folding screens of smartphones and similar devices. Developmening the prototype itself saw multiple setbacks including order issues and compatibility issues between the microcontroller and the display. Future development will require using a non-flexible display as an analogue for other forms of displays we use, and this development will commence in the summer of 2020.

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