

Visual Augmentation Glasses for People with Impaired Vision

Ali Al-Ataby, Ola Younis, Waleed Al-Nuaimy, Majid Al-Tae, Zain Sharaf, Baidaa Al-Bander
 Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3GJ, UK
 e-mail: {aliataby, ola.younis, wax, altaeema, hsbalban}@liverpool.ac.uk

Abstract— This paper presents the preliminary design and development of a visual augmentation glasses set to assist people with varying degrees of vision loss. The wearable spectacles are intended to be non-obstructive, thus employs a transparent OLED display providing 360° viewing angles and creating an assistive overlay rather than the simulated view of a virtual reality device. Several aspects relevant to software development have been achieved including (i) a functional operating system running on an embedded device, called Jetson TK1, (ii) face detection and eye tracking, and (iii) hand-gesture recognition and control. Preliminary hardware design for the glasses has also been developed. The obtained results from preliminary have been promising with considerable challenges remaining in the development of the visual perception aspects of the proposed visual aid.

Keywords- low vision; peripheral vision loss; tunnel vision; glaucoma; augmented reality glasses; virtual reality; image processing; OpenCV; OLED

I. INTRODUCTION

According to the World Health Organisation [1], more than 240 million people suffer from vision loss, with around 2 million in the UK. Low vision includes different degrees of sight loss from having blind spots, poor night vision, and problems with glare to almost a complete loss of sight, and cannot normally be treated; in most cases, the degree of vision loss increases with age [2].

The lens in our eye focuses light rays onto our retina. The retina converts these light rays into signals that are sent through the optic nerve to our brain, where they are interpreted as the images we see. A problem with any of these processes affects our vision in various ways. The most common types of low vision include the following:

1) *Night blindness (nyctalopia)*: the inability to see clearly in poorly lit areas.

2) *Blurred vision*: both close and distant objects appear out of focus.

3) *Hazy vision*: the entire field of vision appears foggy, as if covered with a film or glare

4) *Contrast sensitivity*: the ability to distinguish between objects of similar tones like milk in a white cup or to distinguish facial features. All eye problems can decrease contrast sensitivity.

5) *Depth perception*: the ability to judge the position of objects. New vision loss in one eye can affect depth perception, such as the height of a step.

6) *Loss of central vision*: a blind spot appears in the centre of one's vision. Central vision is the detailed vision we use when looking directly at something – the face of the waitress in the example in Fig. 1.

7) *Loss of peripheral vision (tunnel vision)*: manifests in an inability to see clearly to either side, above or below eye level, while central vision generally remains intact, as illustrated in Fig. 2. Peripheral vision is the less detailed vision used to see everything around the edges.

There can be one or more causes of low vision, usually because of disorders or injuries affecting the eye or conditions that affect the entire body such as diabetes. Some of the most common causes of low vision include age-related macular degeneration, glaucoma, diabetes and cataracts. Low vision may also result from cancer of the eye, albinism or a brain injury. Anyone who has had or is at risk of these disorders has an increased risk of low vision. These conditions can result in damage to the optic nerve, resulting in a reduced visual field [3].

Different types of wearable assistive tools have been developed to help people with vision problems. These technologies were designed for a variety body parts such as the head, chest, fingers, feet and ears to name a few. Head-mounted devices (HMDs) are common in the field of wearable assistive devices and used (usually) to present a virtual reality (VR) to the user utilizing other technologies such as cameras and sound devices [4].

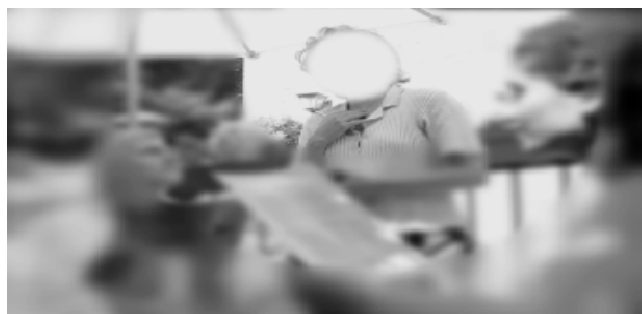


Figure 1. Blind spot in center of vision



Figure 2. Example of view with peripheral vision loss

People with low vision do not lose their visual field completely, so augmented reality (AR) devices can help in allowing the wearer to exploit the functioning visual field to compensate for the areas of lost vision. We propose an AR system that utilises these healthy areas by augmenting the visual scene with scenes captured by a camera.

In this paper, we propose a wearable visual assistant to aid those who suffer from the various forms of vision loss. While the design and testing of the visual perception aspects are still in the planning and development stages. This paper reports on the design and development of the hardware platform for this visual aid, in the form of a set visual augmentation glasses.

The remainder of this paper is organised as follows. Section II summarise the current state of the relevant wearable market and the differences between virtual and augmented reality, followed by Section III which provides an overview for the software and hardware aspects of the proposed system. Section IV describes the relevant technologies. Section V presents examples of some applications including face detection and tracking, and object tracking by segmentation. Some preliminary results are presented in Section VI and the work is finally concluded in Section VII.

II. WEARABLE TECHNOLOGY AND AUGMENTED REALITY

Over the last few years, mobile processors have seen a rapid increase in performance, reduction in size, and increased efficiency in terms of power consumption. However, the Smartphone market has been shifting towards large screen real estate. The increase in screen size greatly impacts the performance of the device both in terms of memory usage and battery life. The increase in size also makes Smartphones cumbersome and difficult to use, deviating from the original aim of a mobile cellular device. By opting for a wearable design, we eliminate the need for a large screen size by creating an immersive mobile experience and unlike a VR headset ensure that the user can comfortably see his/her surroundings [4].

Currently, there are several companies working on wearable smart-glasses. However, those devices are either aimed at the market as accessories to smartphones and tablet or as devices that are restricted to a singular environment (generally due to size). By introducing a device that is in the price range of current high-end smart phones, which provides a new mobile experience and prompts the user to actively engage with his/her surrounding, potentially a new market of smart wearable can be created that rivals the smartphone market.

To understand the concept of augmented reality, it is important to know the difference between virtual reality and

augmented reality. Virtual Reality or VR for short is the technology of creating virtual worlds that the user can interact with [5]. VR systems generally require a helmet or goggles; popular examples are the “Oculus Rift” by Oculus VR [6] and “HTC RE Vive” by HTC and Steam [7]. A VR world is designed in a way that the user would find it difficult to distinguish what is real and what is not [5]. Augmented Reality is the technology of superimposing computer-generated information, images or animations over a real-world image or video [8], [9]. Current AR implementations are mostly based on mobile applications and the upcoming hardware examples are Sony’s SmartEyeglass [10] and the Microsoft Hololens [11]. Both VR and AR technologies are similar in the goal of immersing the user, but follow a completely different approach. AR systems tend to keep the user in the real world while letting them interact with virtual objects whereas a VR user is completely immersed in a completely virtual world. The major difference between augmented reality systems and other systems that provide superimposition is the user’s ability to interact with the computer-generated information; the interaction can be audio based, gestured interaction, by simply changing the field of view of the camera...etc.

The concept is to design an AR system that can be used in every environment, is non-intrusive and provides real time data. To do so a pair of glasses was designed. The glasses use a Transparent OLED display as the lens. The system also uses a development board, which is the main processing unit. This aims at eliminating the use of devices such tablets and Smartphones which are obstructive in nature, while at the same time provide equivalent performance, if not greater, on a non-obstructive device by creating an overlay of information on areas of the user’s visual field that are not impaired, while retaining enough transparency that the information does not hinder the user’s functioning field of view.

III. SYSTEM OVERVIEW

Fig. 3 shows a general block diagram for the proposed system. It comprises a microcontroller unit (MCU), a transparent display and a camera module. The display is based on the organic light emitting diode (OLED) technology to eliminate the need for a backlight or enclosure, making it possible to create truly see-through installations. It offers virtually frameless glass with 45% light transmissivity, creating clear, unobstructed views of objects, scenes, or other digital screens behind the transparent display. Integration of the transparent OLED (TOLED) with the MCU the program structure in Linux4Tegra on board the Jetson TK1 and the communication cycle between the Jetson TK1 and the MCU represents the watch and glasses integration.

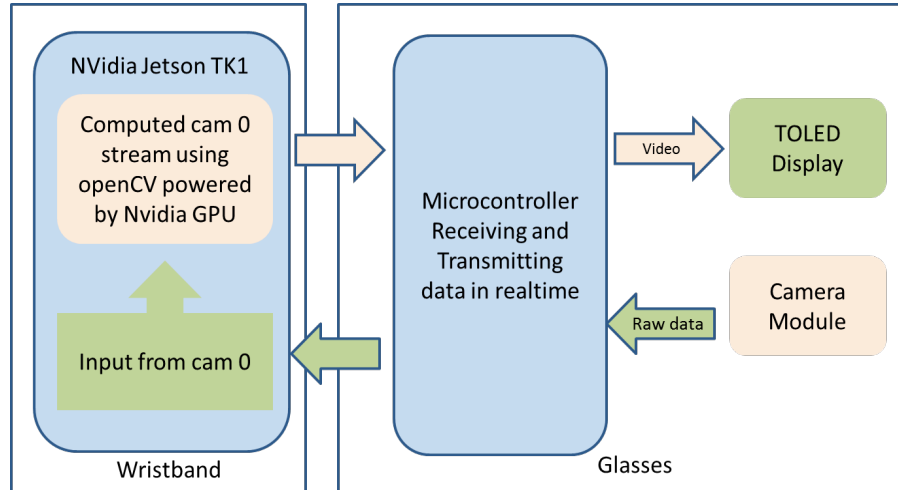


Figure 3. Jetson TK1 and MCU flowchart the arrows show directions of dataflow

Software design of the proposed application is based on Linux operating system with JavaFX [12], using the model-view-control (MVC) architectural pattern. MVC provides a practical solution to separate the user interface (view) from the data (model). The model manages the application and state and the view presents the model to the user using appropriated interface. The view also allows the user to manipulate data. In this pattern, the view interacts with the model through the controller that mediates the input and converts it to commands for the model or view. This logical division of the applications development improves interlayer operability, software reusability and maintainability across the system. It also enables the software developers to implement various applications without the need to know low-level details of the platform.

IV. HARDWARE TECHNOLOGY

A. Transparent Display Module

A transparent OLED Display has only transparent components (substrate, cathode and anode) and, when turned off, are up to 85% as transparent as their substrate. When a transparent OLED display is turned on, it allows light to pass in both directions. Transparent OLED modules can be either passive or Active-matrix. The two OLED Display types used for this experiment are passive matrix OLED displays. This choice was made retroactively due to availability and cost. The display consists of a 2.4" active working area, and a resolution of 320×240 pixels [13].

The Mbed Microcontrollers are series of ARM microcontroller development boards designed for rapid prototyping. The Mbed NXP LPC1768 Microcontroller is designed for prototyping devices. It is packaged as a small DIP form-factor for prototyping with through-hole PCBs, strip board and breadboard, and includes a built-in USB FLASH programmer.

B. NVidia Jetson TK1

The Nvidia Jetson TK1 is a development board by Nvidia housing the Nvidia Tegra K1 SoC, which is based on

Nvidia's Kepler GPU microarchitecture that is the first mobile processor to have desktop grade graphical performance while being energy efficient. The Jetson TK1 comes with a Linux-based board support package [14], [15].

C. Linux4Tegra

The Jetson TK1 comes with a Linux-based board support package, which is a version of Ubuntu 14.04 for embedded devices with pre-configured drivers for the Jetson TK1. The platform supports OpenGL 4.4, X Resize, X11 Support, U-Boot. In order to develop for the development board a host PC running Ubuntu Linux is required [16].

D. OpenCV

OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OpenCV makes it easy for businesses to utilize and modify the code. [17], [20]

E. EA LPC4088 Quick Start Board

The mbed-enabled LPC4088 QuickStart Board from Embedded Artists is a easy to use ARM Cortex-M4 rapid prototyping board in a standard through hole DIP package (44-pin), targeted at high-performance as well as low-power applications.

V. OPENCV APPLICATIONS

A. Face Detection and Tracking

The face detection and tracking software is developed in the programming language java using Eclipse IDE and JavaFX. JavaFX is a development platform for creating and deploying rich client applications that operate consistently across a multitude of platforms. The application UI was developed using JavaFX scenebuilder 8.0 by Gluon.

B. Object tracking by segmentation

The basic functionality of object tracking application is detecting the difference in the foreground from the background. The application works by taking an initial background image as a sample and then using the Background subtractor function available natively in OpenCV compares the succeeding image to create a foreground image. The Background Subtractor works by discriminating between foreground and background pixels by creating an average sample of the background [18]. Fig. 4 and Fig. 5 show the object tracking done in the Jetson TK1 using the CPU before and after the GPU optimization.

VI. RESULTS

In this section, some of the initial software and hardware tastings are presented, as follows.

A. Initial testing (μ TOLED-20-G2)

The initial testing was done using the μ TOLED-20-G2. The device was connected to the mbed LPC 1768 (the cortex M3 rapid prototyping board). The glasses required two OLED modules for stereoscopic output and since this module went out of production an alternate had to be used. The display also suffered from dead/corrupted pixels, the cause of which is unknown. Fig. 6 illustrates the TOLED running the clock application with dead pixels.

B. TOLED Breakout board (402024130-X Module)

To test the 402024130-X Module, a breakout board had to be developed. The module is in SMD form and comes with FPC/FFC type ribbon connector that cannot be integrated directly with a DIP configuration and therefore cannot be developed for without an intermediary board to bridge the two systems. To develop the breakout board Eagle 7.2 by CadSoft was used. The final board is show in Fig. 6. There were three designs in total. The initial designs were relatively complex and did not justify the level of complexity for a basic breakout board.

The first board layout had narrow and complicated tracks that make fabrication difficult. The second board featured wider tracks but had a complex structure due to many vias and complicated track paths. The final design used less vias, wide tracks for the connections and has a simpler track path

C. 3D Printed Frames

One of the primary goals of this work was to design pair glasses that looked (even at development stage) sleek and could still hold the mbed development board. 3D development allows for very cheap design prototypes and with relatively little knowledge designs can be fabricated and tested to see whether they would work in real world, whether it is aesthetics or durability. From a physical development stand point the glasses design has had many variations with each design printed to test durability, ergonomics and the ability to hold the hardware components. It was learned early on that the placement in the 3D printer software is vital as it factors into the strength of the shape produced. Fig. 7 shows the evolution of the frame design along with descriptions.



Figure 4. μ TOLED-20-G2 in frame Version Object detection software running on CPU with average FPS @ approx. 10.6

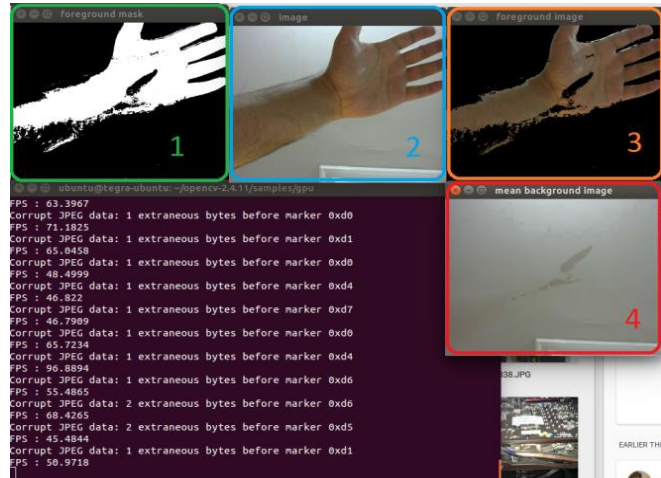


Figure 5. Hand detection with average FPS @ approx. 60 because of GPU optimisation



Figure 6. μ TOLED-20-G2 with corrupted and dead pixels



Figure 7. Final prototype frame with on-board webcam, improved nose bridge and frame curved by 15° for a more natural wearing experience

VII. DISCUSSION AND CONCLUSIONS

While the aim of this work is to design and develop a prototype set of visual augmentation spectacles to help people with low vision to experience their surrounding in an immersive way, this paper presented the hardware design for this prototype. The preliminary TOLED test proved that the concept is possible; however, with one lens it is not possible to view an image close to the eye. With two displays in stereoscopy, it is possible to reduce the distance between the eyes and the screen and to provide a depth of field and emulate 3D objects. Perhaps the biggest challenge this work has faced is choosing the most suitable hardware, as the premise for the project is relatively new. Transparent displays have been around since 2009 and coloured versions were announced in 2010. There has been a lack of products that support the technology and therefore finding off-the-shelf has proven difficult.

In terms of feasibility of a small form factor portable AR system, the Jetson TK1 has proven that real-time AR and tracking are possible with a mobile processor as suggested by the frame rates shown in previous results. Although the development board is not optimised, power consumption suggests that the SoC itself is capable of being used in a battery-powered system with AR capabilities.

In addition to the intended application of assisting people with low vision, the prototype hardware platform has interactions from many areas, such as 3D CAD, additive manufacturing, computer vision, Java/JavaFX, CUDA, Linux, multilayer PCB fabrication using an EDA application and augmented reality from a software and hardware standpoints. The market for AR devices is growing and technologies like HoloLens and Meta starting to populate the market with hardware based solutions. AR technology is expected to introduce a new computing ecosystem.

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