The Third Eye: A navigation glasses for visually impaired people

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ABSTRACT
In this paper, we present the Third Eye: a navigation glasses for visually impaired people. Utilizing ultrasonic sensors and live vibration actuation, this device allows users to understand the surrounding environment and avoid obstacles. Through this device, we intend to provide a better walking experience and enhance the matter of being mobile, safe and independent for the visually impaired.

Taking the shape of a pair of glasses, the Third Eye enables users to scan the environment simply by turning their head. The glasses detect obstacles not only on the ground but also hovering above waist height. Using 8 vibration motors, we introduce a series of animated vibration patterns to inform users about their environment.

AUTHOR KEYWORDS
Vibration patterns, Haptic interface patterns, white cane.

INTRODUCTION
Recent statistics from the World Health Organization, 39million people are blind and 246 million are suffering from low vision problem. As a whole, 285 million people are visually impaired worldwide [1]. Enhancing the matter of being mobile, safe and independent for visually impaired is the prioritized research topic among of its all. Various travel aids for blinds have been constantly introduced; although the white cane is the most universal tool used for its lightweight, low price and physical durability. Nonetheless, white cane has its disadvantages, coming from its cost of time in terms of training to use it effectively and that the user can only sense the objects that directly touched by white canes. More also, canes are meant to be swept along the ground, and obstacles on the ground level can be detected by cane, meaning that objects above the waist level of user becomes a problem and have caused constant issues. The range of cane (3-5 feet in a sector) also becomes the limit of visual range for blinds as well. A constant effort has been put into this field of technology-based gadget to assist visually impaired over past 40years, but Electronic Travel Aids (ETAs) have yet been successful on widespread use of users. Among the 25.2 million people in U.S. who is suffering from sight loss [2], only 19,500 were users of ETAs [3]. The reason for its failure gains from its relatively high price, heavy weight and lifestyle incompatibilities [4]. Moreover, despite the functionality that the white canes provide, the blind people are just avoiding obstacles in the space most of the time. They did not really know what is around them until they actually touched the objects with the canes. That is why we design the Third Eye that enables users to interpret spatial environment three dimensionally, helping them to understand the surroundings without touching the obstacles. It detects not only the objects on the ground but also hovering obstacles as well, together with the use of cane. In this paper, we present our first prototype, the 'Third Eye'. Third Eye is a sensor-based mobile aid that gives tangible feedbacks through different patterns of vibration that eventually leads the user to understand it's immediate physical environment.

Figure 1. Diagram Showing Drawbacks of White Cane (a: limited to ground level, b: only detects object it touches, c: cannot avoid obstacles over waist level)

RELATED WORK
Various existing ETAs use ultrasonic sensors as its primary sensor system. Mobility aid tool market for blind using ultrasonic sensor is widely divided into two, which is cane based and HMD (Head Mounted Device) based.

CANE BASED ULTRASONIC SYSTEM
The UltraCane uses two ultrasonic transducers embedded in the handle of cane to d3etect objects above and below the user, and provides vibrating buttons as a feedback mechanism [5][8]. It is currently available for purchase in the U.K. for $1000 USD. The K-Sonar system can be used as a cane attachment or as a stand-alone handheld device [6][8]. It works by translating ultrasonic feedback into 'tone-complex' sounds, which the user can use to navigate. K-Sonar has distributers globally and costs $1085 USD. Lastly a Korean company Primpo, is marketing a sensor-augmented cane called iSonic [7][8]. The iSonic uses two ultrasonic sensors for ranging (high and low angle), and includes a color sensor to tell users what color certain objects are. Additionally a light sensor is used to inform users of the light conditions around them (bright, medium, or dark). The iSonic costs around $800 USD [8]. Making comparison in terms of product's cost, we estimate the Third Eye can be purchase in less than $100 USD which is

several times cheaper than existing cane based ultrasonic system, affording better adoption for visually impaired.

Figure 2. Cane-based Ultrasonic System. (a: UltraCane, b: K-Sonar, c: iSonic)

HEAD MOUNTED DEVICE ULTRASONIC SYSTEM

The iGlasses by RNIB(Royal National Institute of Blind People) and AmbuTech Ultrasonic Mobility Aid is a head-mounted device which uses ultrasonic sensors to detect objects and communicate via gentle vibrations. As obstacles get nearer the frequency of the vibration will increase. The device is intended as a secondary mobility device. can be purchased in U.S. at price of $160 USD [9]. In sense that it is wearable glasses, used as secondary device along with white cane and it's use of vibration with ultrasonic sensor makes it comparable with our device Third Eye. However, whereas iGlasses simply stays with using vibration as a warning method, Third Eye uses vibration with more 3-dimensional pattern that allows user to tangibly interpret their immediate environment and helps orient them to safer direction as well. On followed up section in this paper where we introduce Third Eye user interface with vibration will clearly state the difference further on.

Figure 3. Photo of iGlasses

DESIGN DECISION

At the beginning of the design process, we were constantly thinking of removing the interface of walking canes in order to provide a better walking experience for blind people. We implemented different forms of wearable gadgets such as Navigation Gloves as well as Ultrasonic shoelaces (Figure 4a, b). Despite the functionality that the devices provide to the users, there is one significant aspect that was not taken into account - psychological aspect. The cane does not only work as an aiding tool for visually impaired people, it also allows them to feel safer and more confident while using [10]. Therefore, we decided to design a device that could work with the cane, solving the problems that the cane has and help the visually impaired users to have a better understanding of the environment where they are.

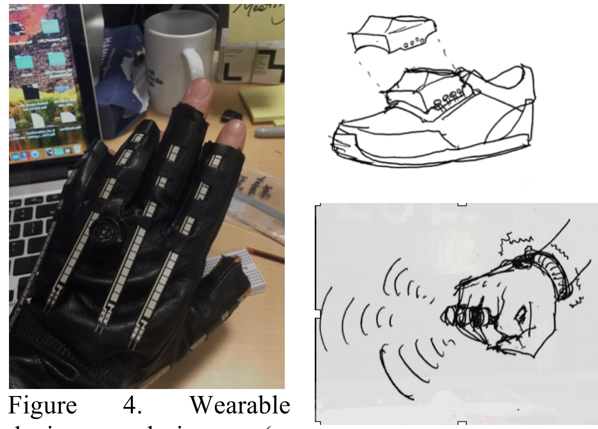

Figure 4. Wearable devices design (a: navigation gloves, b: ultrasonic shoelaces, c: navigation ring).

IMPLEMENTATION

To implement the system, hardware components of the system were chosen based on portable form factor while maintaining the ease of prototyping (Figure 5). Each frame of the glasses contains three eccentric rotation motors (ERM) and one linear resonant actuator (LRA) for haptic interface, and these actuators are driven by digital pulse-width-modulation (PWM) and I2C-communication signal through their own motor drivers. These motors vibrate with specific given pattern based on the distance measured by ultrasonic distance sensor. Main microcontroller, teensy 3.2 with 1.4 x 0.7 inch^2 form factor, interface these sensors and actuators and control the overall system. The glasses are powered by 1-cell 3.7V Li-Po battery due to their portable form factor. Figure 6 shows the hardware rendering.

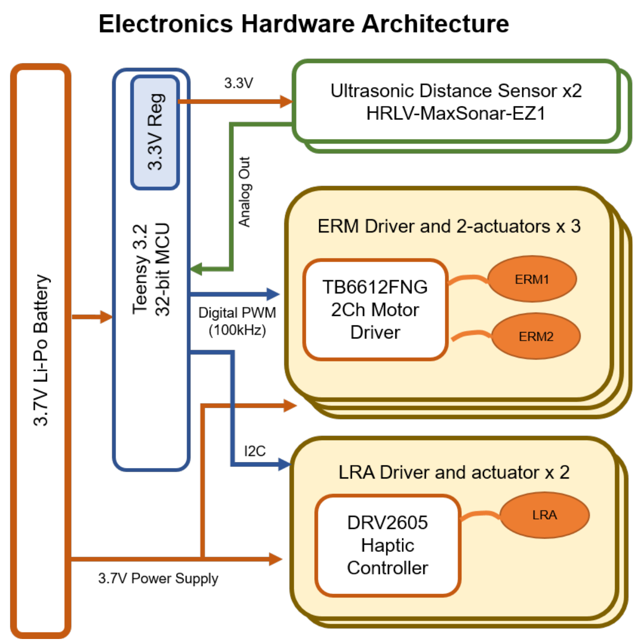

Figure5. Components and overall hardware layout

SOFTWARE

To provide seamless haptic feedback for users, haptic interface pattern is required to be precisely controlled. In order to interface the sensors and actuators seamlessly while providing varied pattern with high-resolution information, multi-threaded software architecture of the system is designed (Figure 7).

Four threads are processed with different bandwidth. First thread handles sensor updates and calculates hardware control variables, and this thread runs in 10Hz bandwidth due to the ultrasonic sensor update rates. Second thread handles actuators control to update their operation status with 100 Hz bandwidth. Third and fourth threads handles haptic interface pattern generator with finite state machine.

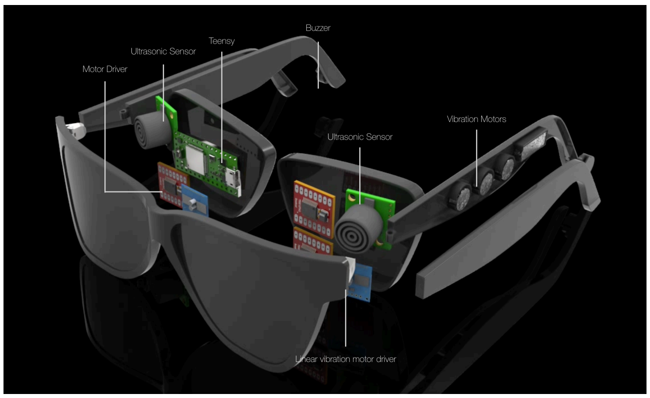

Figure6. Hardware layout

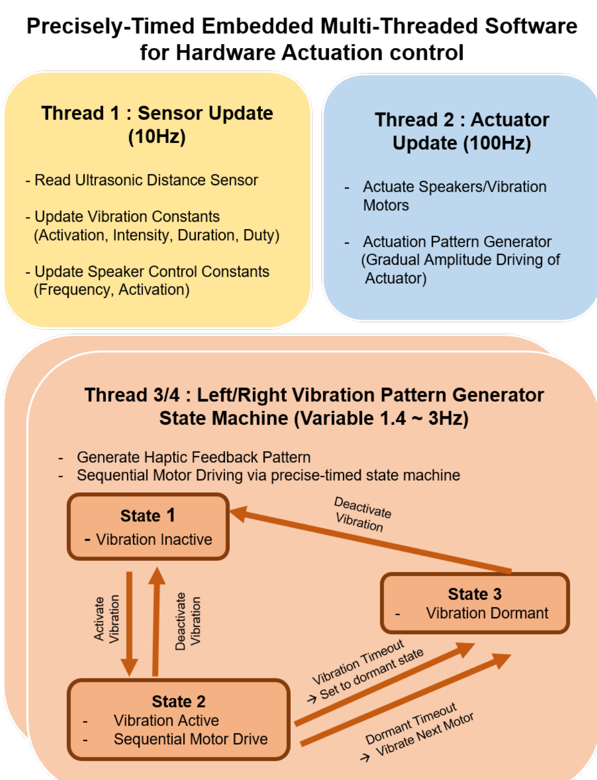

Figure 7: software architecture diagram.

DESIGNING VIBRATION PATTERNS

We designed multiple vibration patterns in order to enable blind people to understand the environment from tangible approach. By feeling and understanding the patterns, the visually impaired users are able to have a general understanding of the obstacles in the space as well as how the environment could be like.

As the affordances of the Third Eye, we use vibration patterns to simulate the interaction between two people. For instance, when a person wants to warn the other about the obstacles lying ahead. One tends to push the other towards the opposite side of the obstacles. The idea of the vibration patterns is to create the experience as if there is someone guiding the users by their side.

- **Default mode** - moving forward

  While the glasses is not detecting any obstacles within 5 meters (16 feet). The vibration pattern goes from back to front (L4 - L1), signaling that the user could move forward (Figure 8).

- **Obstacle detected** – moving backward

  When the glasses detect obstacles within the range, the vibration pattern goes from L1 – L4 (Figure 8), signaling the user should move backwards. This pattern simulates the action of a person is pulling the user from the back, reminding the user to avoid the obstacles.

- **Moving closer to the obstacles** – sound feedback

  As the user move closer to the obstacles, the frequency and intensity of vibration motors increase as well. The glasses would then start sounding to remind the users. The sound feedback is to replicate the scenario while someone is shouting from behind to warn us the obstacle lying ahead.

- **Multi Sensing**

  The two ultrasonic sensors on the glasses could work separately. That is to say, when the ultrasonic sensor on the left detects obstacles, it generates the vibration pattern from L1 – L4. Meanwhile, the ultrasonic sensor on the right does not detect any obstacle, the pattern goes from R4 – R1. In this case, user could easily have a general idea of how the environment could be like just by a glance.

- **Three dimensional scanning**

  The user could use the glasses to scan around the environment and have an understanding about the spatial arrangement base on the vibration pattern they received. They no longer need to actually touch the obstacles and find out where they are.

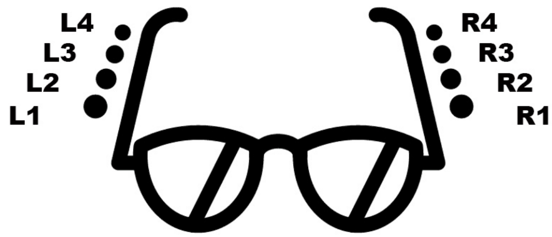

Figure 8. the Third Eye vibration motors allocation.

CONCLUSION

In summary, we proposed the Third Eye, a device that enhances the visually impaired people's ability to navigate the space through haptic feedback.

During project demo, we received positive feedbacks from various users. The animated vibration pattern provides clear directional information to users. This makes us think that there could be a new kind of interface that utilizes a grid of vibration motors to generate different haptic patterns.

As future directions we would look deeper into the relationship between the traditional cane and the Third Eye. Right now, the cane and the glasses work as two independent systems, which requires the user to combine them together. This could cause confusion at first, since two systems are giving feedback simultaneously. Moreover, the position of the vibration motors needs further adjustment, because there might be some interference to hearing due to the close proximity between the current motors and ears.

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