SiGHT

Final Report

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Background

The Cleveland Clinic defines blindness or low-vision as vision loss that cannot be corrected by glasses, surgery, or other corrective means. These impairments are most often caused by age-related macular degeneration, glaucoma, or diabetes. Low-Vision is a wide spectrum in which any given person can land on a different spot. It can range from blind spots, poor night vision, and problems with glare, to an almost complete loss of sight. Almost anyone is a target for vision issues, particularly those of greater age and with greater genetic predispositions for familial vision problems. While blindness has no true cure yet, low vision can be assisted with tools like lenses and prisms, but in our eyes, these are not enough.

According to the CDC, 93 million adults in the US alone are at a growing risk of severe vision loss, with these numbers only expected to rise in the coming years. Also, according to the CDC, since 2007 fall death rates in the US have increased by about 30%, and if the rates keep increasing, we might anticipate 7 fall deaths per hour by 2030.

In terms of existing methods of traversal for people with low vision or blindness, an article published by why.org (PBS) says that white canes, although very useful for the visually impaired, have certain caveats. One of which is the inability to detect certain obstacles that are hanging or hovering. White canes also require a lot of hand movement which takes time to get used to. Another big issue we take with the white canes is that it is quite inconvenient having to carry this additional tool anywhere you go, this can be simplified; there should be a better way for navigation and traversal. However; it is important to note that white canes will never be replaced. Through a sequence of interviews, we understood how rooted the cane is in the ethos of learning how to traverse with a visual impairment. We seek to not replace the cane but help it be better with the expertise of new technology.

Currently, the technologies that exist for assistive traversal technology for visually impaired people are either limited or expensive; they fail to either give a full grasp of the environment or do so with a price tag that is out of touch. For example, technologies like the WeWalk cane and Nearabl exist to aid this group, but they don't solve the main issues that we are trying to address: navigation through unknown surroundings with obstacles that are hard to detect with current methods for people with blindness or low vision and accessibility to a greater network of people with blindness and low vision.

Statement of the Problem

Currently, the technologies that exist for assistive traversal technology for visually impaired people are either limited or expensive; they fail to either give a full grasp of the environment or do so with a price tag that is out of touch. For example, technologies like the WeWalk cane (Yin, 2019) and Nearabl (https://nearabl.com/) exist to aid this group, but they don't solve the main issues that we are trying to address: navigation through unknown surroundings with obstacles that are hard to detect with current methods for people with blindness or low vision and accessibility. Since the innate sense of sight has been hampered, digital sight through a camera and haptic feedback will allow people with blindness or low vision to find their way through our complex world in the best and safest possible way.

Rationale of Solutions

After having seen a few similar ideas, but none to this extent, we decided that we want to have a device that someone holds to give haptic feedback to the user and guide them through their surroundings in the safest way. We wish to create an iOS application that will be available for iPhones and iPads, which will be helpful as we will have access to Apple's AR Kit development environment that enables accurate 3D localization. This app will allow us to get the data we need to direct people with blindness or low vision toward safe areas. The application will be delivered through the Apple App Store and will be advertised through specialty stores, online marketplaces, and events targeted at people with blindness or low vision. With the app active, the phone will be placed in a necklace-style case that the user can wear. From here, the phone talks to a sleeve-like attachment that we will design for the white cane which will vibrate and give signals to the user about their surroundings; simplicity for our users was our key idea for this aspect of the product.

In terms of the users, we look forward to working with societies focusing on career development and education created and maintained for people with blindness or low-vision, including Goodwill NY/NJ and Lighthouse Guild. So, by delivering to and focusing on them, we are getting to our target audience much easier. It is important that we target people in the workforce and look to get into it as SiGHT would be able to keep an unsighted worker much more safe and adaptable to their surroundings. People have been long discriminated against because of different abilities, so this product would help democratize hiring in workspaces where movement is essential. We also would like to approach families, workplaces, and schools with blind or low vision members to see how we can best adjust our product for those environments.

Design and Development of Systems

As seen in Figure 1, our initial design was a necklace style holder for the iPhone which interfaced with a vibrating attachment on the white cane which would talk in a proprietary language to alert the user of impending obstacles. The overall idea has remained the same, but we have changed a few pieces of the puzzle from the inception of the idea. Firstly, we have replaced the necklace-style holder with a full chest strap which will offer much more stability and allow us to lock onto a constant, flat plane on any given user. Another change we've made is making our attachment more of a grip than simply a vibrating box at the end of the cane, this would ensure that we could convey direction to the user and give them a more balanced hold on the cane.

Now, let's dive into some of the specifics of the system by looking at Figure 2. First, we obtain the depth map from the LiDAR sensor on the back of the iPhone which is on the user's chest via the strap and is facing the direction in which they are traversing. Both the depth map and confidence map are obtained through built-in features of our language of choice: Swift, which is the premier IOS app programming language and has a lot of packages that we leverage, such as ARKit for augmented reality functionality.

After interpreting the depth map and storing it, we reduce the resolution of the depth map from 192×256 to around 30×40. The first resolution may seem small, but that is 49,152 pixels that have to be taken into consideration compared to the 1200 of our reduced solution. By doing this we significantly save on computational costs. Next, we have a partitioning system that splits the frame into a grid where we can see if there is an object that is the closest based on the depth map distances, however we need to obtain the objects. To do this, we have two methods: an objection detection machine learning model and a hand-made image segmentation algorithm. Initially, we wished to have two models concurrently running, but this was proving to be too CPU intensive. Naturally, we moved to an algorithmic approach by taking an idea from the field of image processing: quantization. Quantization is a process of transforming a real valued sampled image to one taking only a finite number of distinct values. By converting our image to grayscale and quantizing, we have clusters of objects that land in the same range of predetermined grey values. This quantization method is used when the CoreML model, which is an Apple made and trained model, we discovered in our research doesn't work. This method of object detection classifies an object and also draws a bounding box around it, however it has certain gaps in its training such as certain planes(walls, counters, poles), so the quantization method takes over there. After getting the object information, we overlay the depth map information on it and determine which is the closest object and use that as the object of interest we wish to alert the user about.

In terms of alerts, we have two main types: Verbal and Haptic. Verbal warnings are resolved by a built-in package in swift called AVSpeechSynthesizer which allows for text-to-speech synthesis. All we do is provide it a string which contains the information of the kind of object, direction, and distance and it will speak it out of the iPhone. In terms of the haptic warnings, we have to discuss two facets: the sender of the signal and the receiver of the signal. The sender is the iPhone which will use some basic grid based logic to send a string of 3 strengths to the receiver which is the DFRobot Beetle in the handle. The Beetle is the smallest microcontroller we could find that filled our need of enough space for connections to the vibration motors. From here, the string gets interpreted by the microcontroller and the vibration strengths are sent to the motors. The motors then vibrate within our 3d printed handle which acts as a grip for the user. To keep from overloading the user on input, we’ve implemented timers with the Swift timer package that can be adjusted by the user based on their preferences. This loop will update in real time for as long as the app is active and will feed the user information for their entire use.

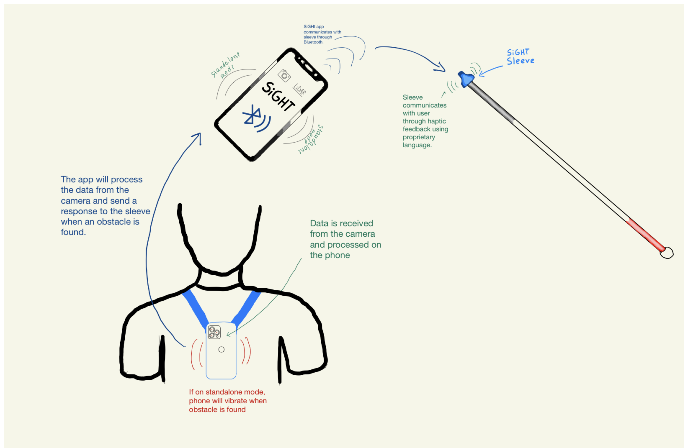

Figure 1. The SiGHT hardware and software designs.

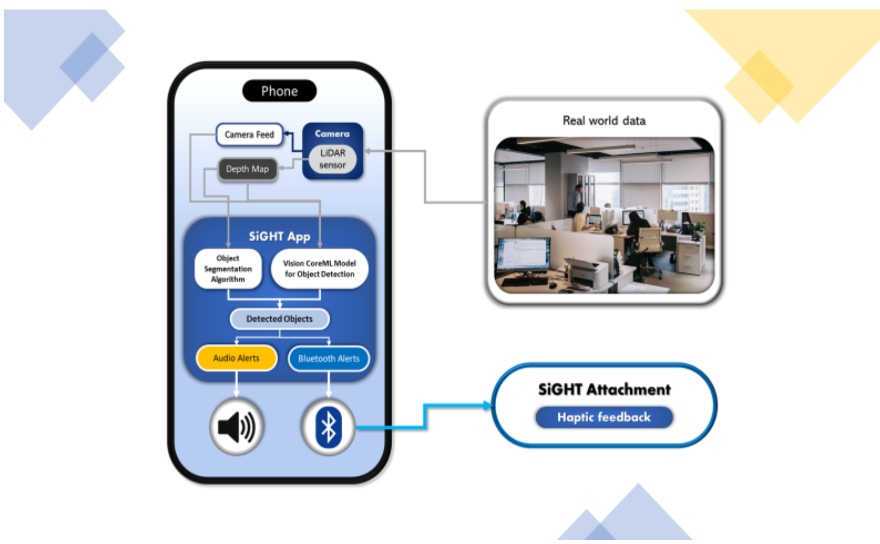

Figure 2. System Diagram

Team Contributions

All teammates contributed in different fields according to their function, here are some of the tasks each team member was able to complete:

- **Avigayil Berkowitz (External):**
    - **Technical:** Design and printing of the attachment case.
- **Justin Jacob:**
    - **Administrative:** Weekly logs, meeting scheduling, presentation management and organization, written reports.
    - **Technical:** Main idea for the system, UI design, design of the object segmentation algorithm, design of main logic of the app, implementation of voice alerts.
    - **Entrepreneurship:** Design of business model, value proposition canvas and customer profiles, user interviews.
- **Jed Rendo Magracia:**
    - **Administrative:** Budget management, presentation management and organization.
    - **Technical:** Handle attachment electrical design, coding for the microcontroller, implementation of bluetooth link with CoreBluetooth on the iPhone.
    - **Entrepreneurship:** User interviews.
- **Raynel Sanchez:**
    - **Administrative:** External relations and communications, presentation management and organization.
    - **Technical:** App user interface design, design and implementation of the object segmentation algorithm, implementation of machine learning model, implementation of main logic of the app, implementation of voice alerts.
    - **Entrepreneurship:** Brand logo and design language, user interviews.

As for the grading distribution, since all the team members accomplished each task successfully we all agree to receive the same grade. Thus all our teammates are **equal contributors**.

Evaluation with Users & Partners

In collaboration with Goodwill, one of our partners, we began the testing phase of our product. First we went to our main patient, who we will refer to as D for sake of privacy, and conducted an interview on things that would be useful to the community based on a small test of our app alone. After working on an upgraded version of our product, we went back to D so that they were able to test it. Though the experience was overall positive, we had a few critiques which we wanted to focus on. This includes: adjusting the delay on the app and cane in terms of feedback, elevation changes, walls/turning detection, cane malfunctions, chest strap malfunctions, more adjustable verbal feedback rate, weather resistance, and priority-based detection.

After receiving these critiques from D and our associates at Goodwill, we decided to begin iteration on our product. First, we began by purchasing more microcontrollers and reinforcing the connection ends of wires to prevent further cane malfunctions as this is an integral part of our product. Next, we added a slider to adjust the speed and frequency of verbal feedback to the user so that they can make quicker adjustments to their gait. Next, we addressed the concerns about weather resistance and cane ergonomics by designing a better cane shape and sealing it with a plastic adhesive for increased vibration sensitivity and weatherproofing. Our next steps will include implementing the priority system and the chest strap malfunctions.

We were able to present our project at the CREATE symposium in Albany. We received a lot of feedback from people with different expertise and experiences with assistive devices for employment. Many of the judges agreed that expanding to the Android market was a great target for future plans as Androids occupy most of the phone market currently. They also reinforced our previous goals for the product as they also pointed out certain flaws that D and our associates from Goodwill pointed out.

Discussion of Potential Markets & Future Work

Our main market is focused on the following kind of customer: Someone who is blind or low-vision, who lives in a metropolitan area(such as NYC), who is inquisitive and open to new solutions, who is looking for a reasonable alternative to expensive solutions, who feel a missing piece in the white cane, who own iPhones and use them often, and anyone who is beyond the teen stage in life. Besides the trait of blind and visually impaired, the traits we are looking for cast a very wide net which will also attract family and friends of the visually impaired. This will expand our reach beyond just targeting the blind and visually impaired.

In collaboration with our affiliated organizations, we would like to begin mass-scale testing, iteration, and advertising(using social media and word of mouth) on our product. Also, through them we would wish to apply for some sort of governmental funding so that we have the resources for the following technological updates: Android compatibility, a better handle construction, and durable and miniaturized hardware. The first of this list is of most importance to us as it has been the biggest point of feedback during the existence of this product. Work on that may even lead to a product which is no longer reliant on a phone, but to explore this future we'd need the help and support of our partners.

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