Lightweight Wearable Device to Improve Safety for the Blind

OBJECTIVE

The objective of this research was to develop a wearable device that the visually impaired is able to use while walking to **improve their safety**, in addition to making navigation easier. A time of flight sensor was tested for effectiveness and safety benefits. Blind individuals volunteered to take part in the testing of the product for feedback and improvements.

BACKGROUND

When vision impairment is not treated properly, individuals can suffer from physical or mental health issues. Most people who are vision impaired often have difficulties connecting with the community, resulting in isolation, which will have the possibility of leading into mental and physical issues. **Common eye problems, such as cataract and presbyopia, lead to blindness if not treated**. Presbyopia alone cannot be cured and affects over one billion people in the world and 11 million in the U.S. alone. Now in the era of industrial innovation, the streets contain industrial machines, including small and large vehicles, construction zones, and hazardous debris. These lead to the increased possibilities of safety risks and injuries.

Estimated Prevalence for Vision Impairment

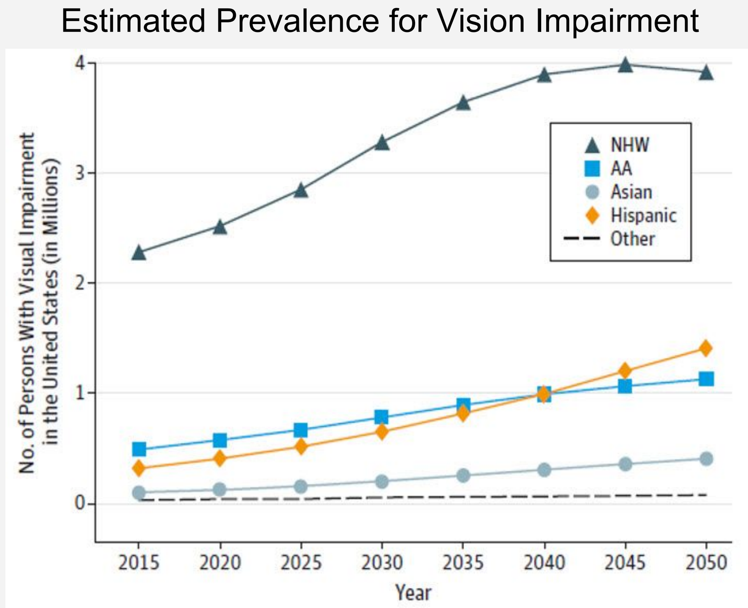


Figure 1 (Varma, 2016)

MATERIALS

Equipment and Tools:

1. Soldering Iron and Solder
2. Computer for programming and 3D Software
3. USB-A to USB-B cable
4. Philip Head Screws and Nuts (¼", 4-40)
5. Philip Head Screwdriver
6. Electrical Tape
7. Measuring Tape
8. 3D Printer

Other Project Parts:

1. Velcro
2. Belt
3. Cable Ties
4. 3D Printer ABS Filament

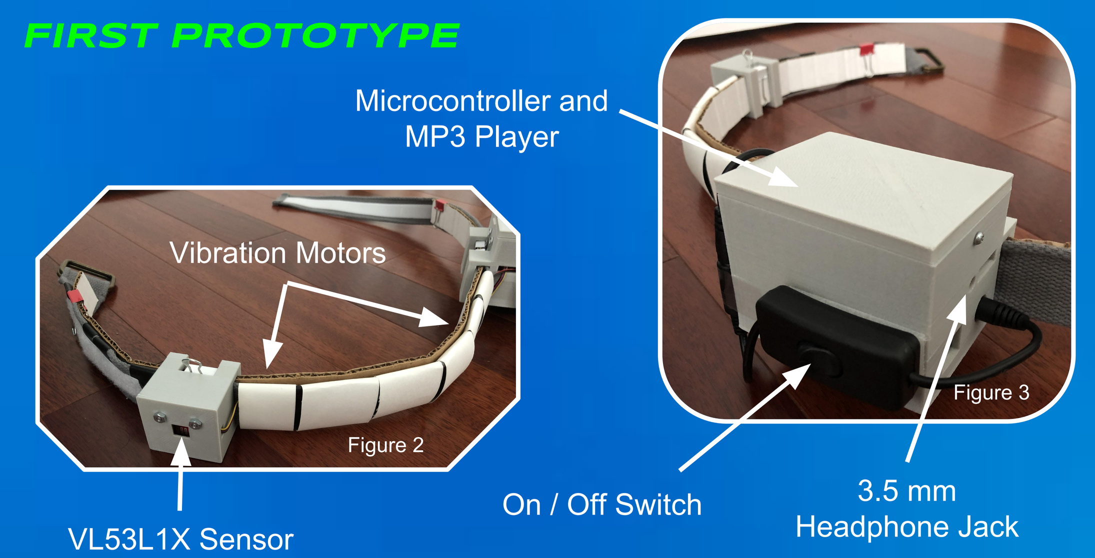
Project Parts (Electronics):

1. Three Vibration Motors
2. Open-source microcontroller
3. VL53L1X Time of Flight Sensor
4. Three HC-SR04 Ultrasonic Sensors
5. Qwiic Shield
6. Qwiic Cable - 500mm
7. Stackable Header Kit
8. MP3 Player Shield
9. 6 Inch Jumper Wires (M-F, M-M)
10. Barrel Jack Power Switch - M-F (3")
11. 9V Battery and Battery Holder
12. microSD card (2GB)
13. 3.5mm Headphone Jack Extender (M-F)

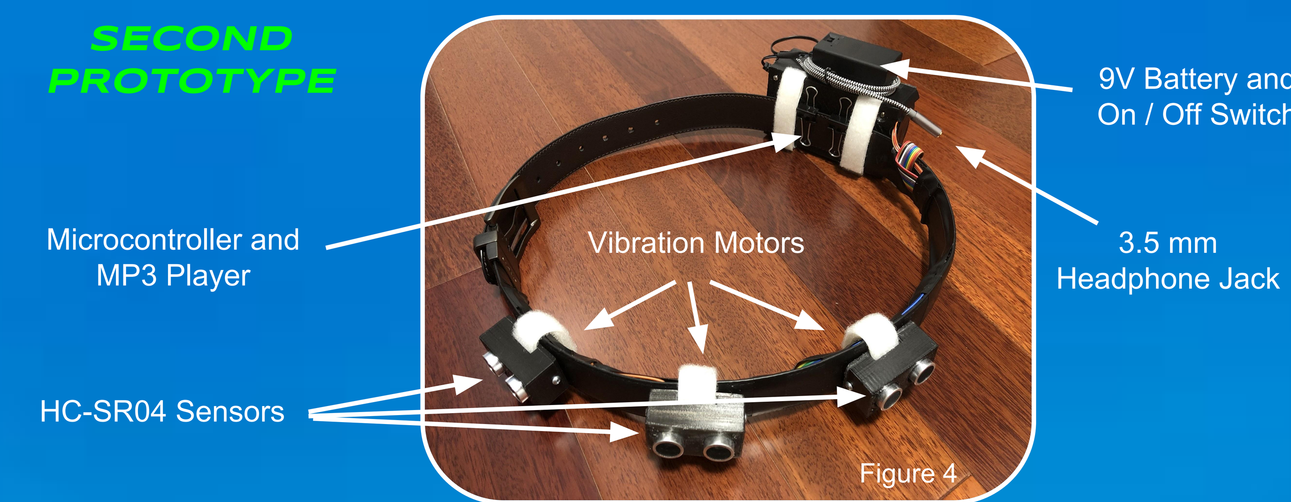
METHOD

A survey was conducted on three blind individuals to understand what their needs and wants are and discuss about the project. A circuit was built using a **VL53L1X time of flight sensor** and an MP3 player shield containing warning audio files. To gather the accuracy of the sensor, four sets of data were conducted: accuracy in the light at 90 degrees and 45 degrees, and accuracy in the dark at 90 degrees and 45 degrees. The sensor was tested on five different types of objects: a person, clear plastic, white object, black object, and a metallic (reflective) object. Six different distances were set up to gather the data: 10, 20, 50, 70, 90, and 110 inches away from the sensor. Based on the data and the survey conducted on the blind, 2 meters was chosen as the starting distance for warning signals. All algorithms were programmed to finalize the functionality and maximize the effectiveness of the product. To secure all the electronics and wiring onto the belt, 3D models were created for the encasing of the sensor and microcontroller. Once all parts are in place, the product was personally tested and was ready to be tested on the blind, gathering final data about the product's effectiveness. Additional improvements were made do the product, testing the accuracy of **HC-SR04 ultrasonic sensors**. The same data collection methods were used from the VL53L1X data collection. After concluding that the HC-SR04 was more accurate, new 3D models were created for these sensors and a more efficient mounting system was designed for the belt.

FIRST PROTOTYPE



SECOND PROTOTYPE



PRODUCT

The product is in the form of a belt that is **recommended above the waist, secured using velcro**. The sensors are capable of detecting obstacles up to four meters (roughly 12 feet) away, and begins warning the user at two meters (roughly 6 feet) through a slow "beeping" from a 3.5 mm headphone jack. At one meter, the "beeping" sound becomes quicker and the vibration motors activate in which the user can feel around their body. At 400 millimeters (roughly 16 inches) away, the "beeping" sound becomes steady and the vibration motors are vibrating at maximum power to warn the user that they are about to come into contact with an obstacle.

DATA

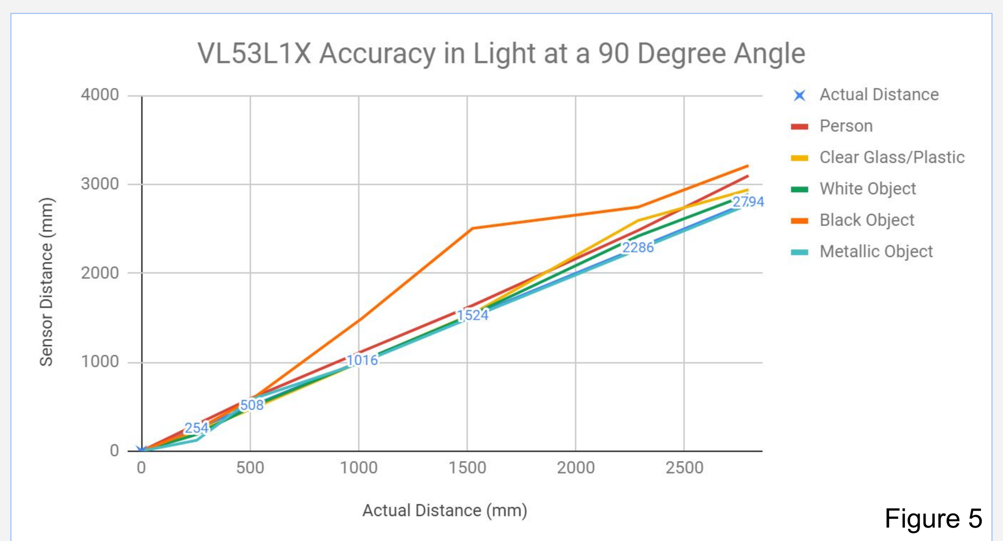


Figure 5

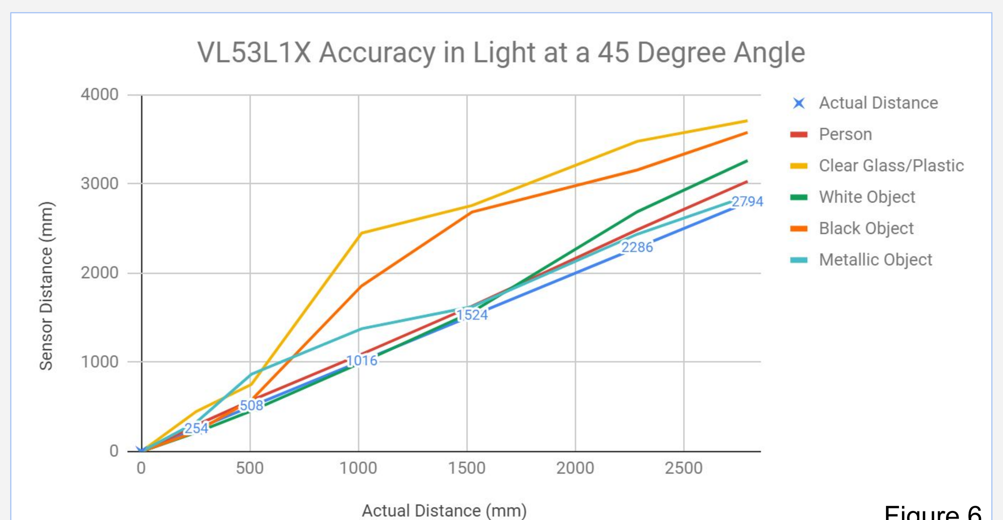


Figure 6

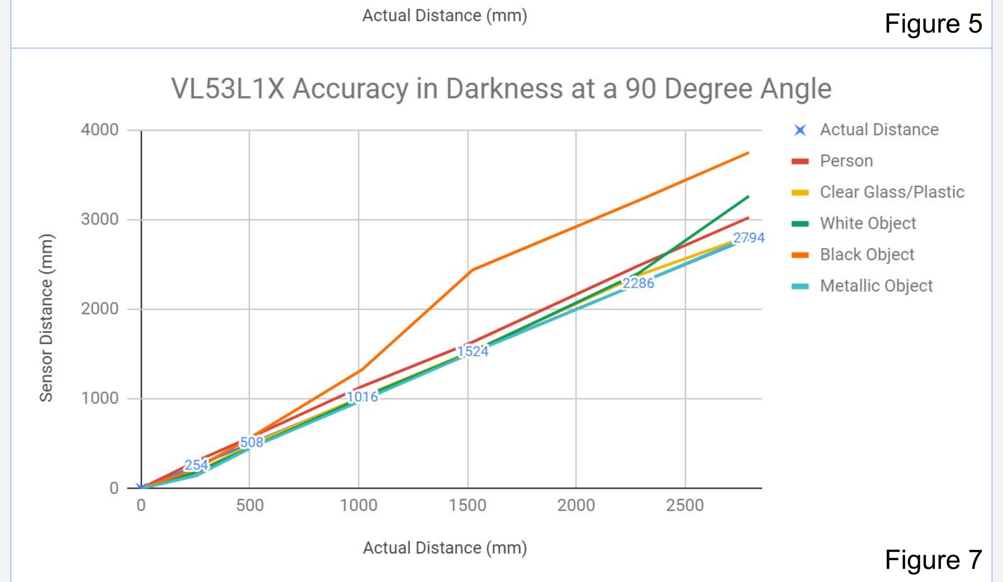


Figure 7

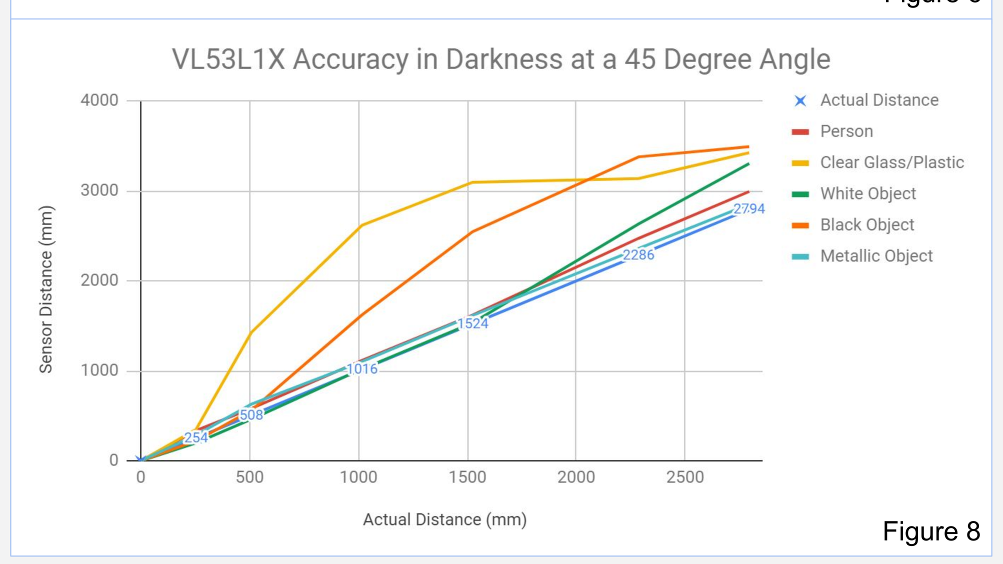


Figure 8

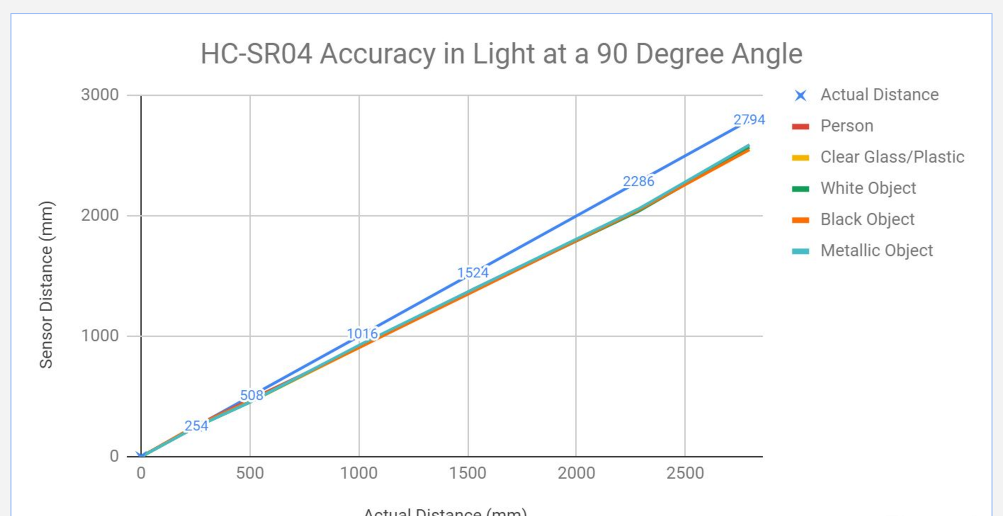


Figure 9

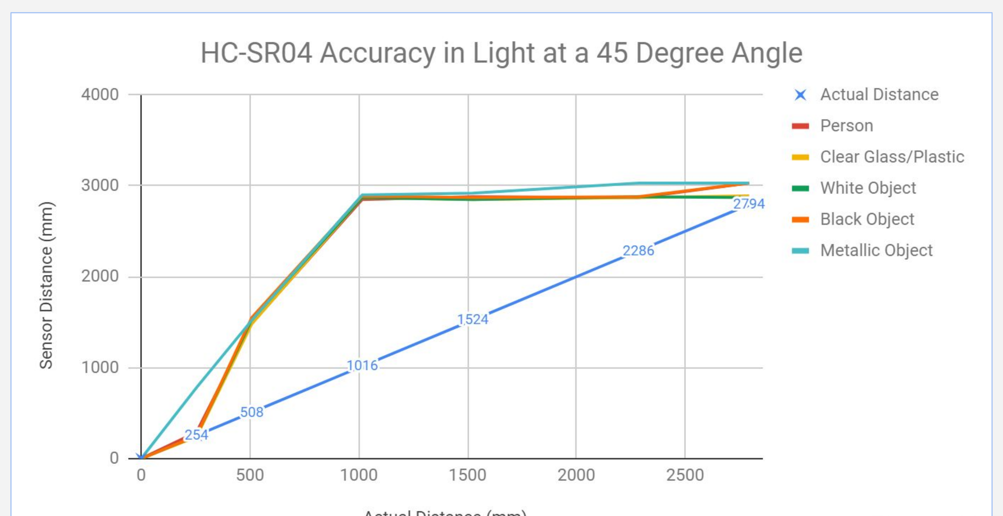


Figure 10

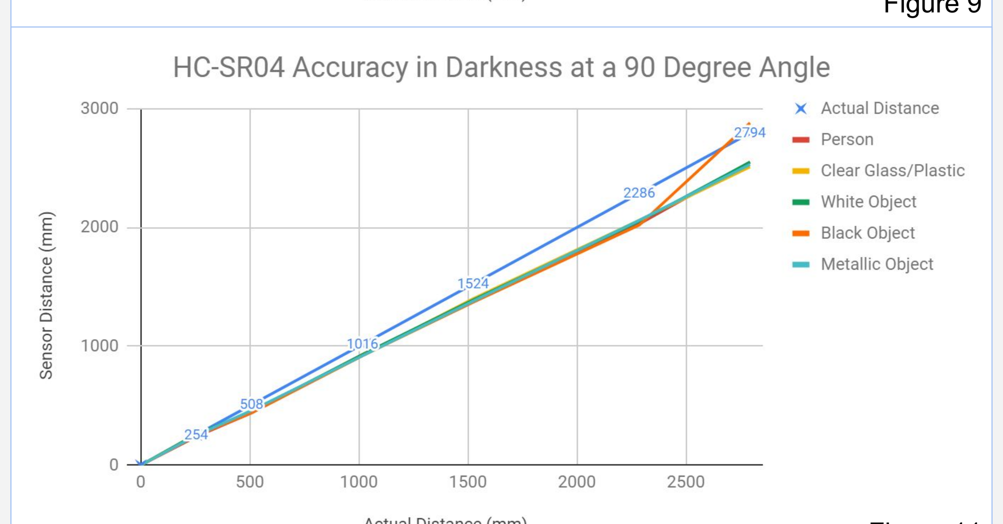


Figure 11

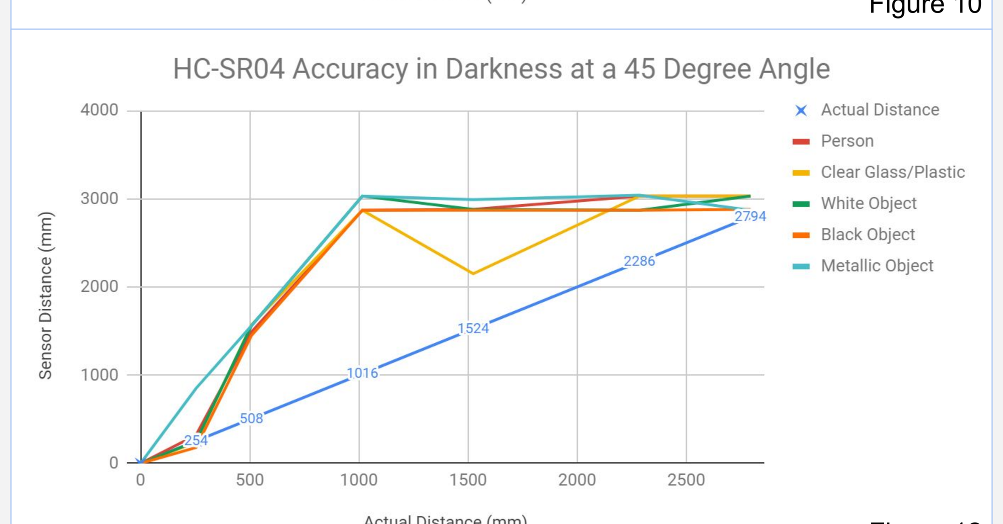


Figure 12

**Numbers on the graphs shown in blue are the actual distances between the sensor and the objects.*

DATA ANALYSIS AND CONCLUSION

The **VL53L1X time of flight sensor is more accurate at shorter distances, and begins to have a larger range of error as an object moves further from the sensor**. The VL53L1X sensor sends out class one lasers, which are light waves that can be obstructed by outside sources of light, and can also be affected by absorbance. Based on the data, **black objects absorb the laser**, causing a longer and inaccurate reading from the sensor because dark objects absorb light waves in the form of ultraviolet energy, reflecting back less light (Figures 5 to 8). **Clear objects negatively affects the accuracy of the sensor only at a 45 degree angle** (Figures 6 and 8). Clear objects reflect light, including lasers, away if it is being hit at an angle. The lasers are being reflected at a 45 degree angle, causing a much longer and inaccurate reading from the sensor. According to the data, **metallic objects did not significantly decrease the accuracy of the sensor**, despite it being the most reflective object tested, because of how time of flight sensors operate: the laser emitted does not reflect in one direction, but rather scatters multiple lasers at different angles after it reaches an object. The strong reflectance of metallic objects help in scattering the lasers better than any other object, so even if the metallic object is at a 45 degree angle, the lasers are still being scattered towards the VL53L1X sensor. The ambient light level also affects the distance reading, where **harsh ambient light causes shorter readings**. This is found to be great factor while testing the product in sunlight. Since the sun produces a significant amount of ultraviolet and infrared rays, they interfere with the light sensors within the VL53L1X. Therefore, the sensors will always produce readings under one foot during harsh daylight during product testing. Another issue found was that the sensor occasionally fluctuated below one meter even when the actual distance was significantly higher than one meter due to minor dust particles or small objects interfering for a brief second.

The **HC-SR04 ultrasonic sensor was determined to be more accurate and reliable when detecting objects perpendicular to the sensor** as sound waves do not get obstructed by a difference in light nor a difference in the material or type of object it is hitting. This is because the HC-SR04 produces sound waves while the VL53L1X produces light waves. The sound waves produced by the HC-SR04 have a frequency of 20,000 hertz and does not get obstructed by light because sound waves are not based on light. However, the problem with the HC-SR04 is that, unlike the VL53L1X sensors, the sound waves do not scatter when it interacts with an object. As a result, having an object at a 45 degree angle significantly decreases the accuracy of ultrasonic sensors as the sound waves reflect away from the sensor and does not read the sound waves.

For the first prototype utilizing the VL53L1X time of flight sensors, in order to minimize the errors outputted from the VL53L1X sensor, an algorithm was programmed to select the maximum distance over 15 distance readings. If an obstruction was detected for less than a second, that reading will be disregarded and no warning will be outputted. This is to make sure a warning is not played to the user when no danger or risk is approaching. However, this does not solve the issue with harsh sunlight. For the second prototype utilizing the HC-SR04 ultrasonic sensors, in order to minimize the inaccurate distance readings for objects at an angle, three sensors were used for the product. One detects objects in front, while the other two detects objects at a 45 degree angle in both directions. This ensures that if there is an object in front that is at an angle, the front sensor will not be able to recognize it, but one of the angled sensors will.

Both of these products should be used alongside the white cane, as the survey suggests that the white cane can only detect objects on the ground. **They do not completely replace the white cane**. Any obstacles that are not in contact with the ground cannot be detected by the white cane. This product was able to detect objects in the user's blind spot, detecting raised objects while the white cane is detecting ground objects or holes on the ground. Additionally, these products should only be used for individuals who are experienced white cane users because one cannot solely rely on technology. At a young age, most blind individuals are learning to effectively use a white cane. If they are exposed to a device that is capable of detecting obstacles, they will prefer using that device over the white cane, which is a safety concern for that person and others around them.

FUTURE STUDIES

- Develop a device utilizing both the ultrasonic and time of flight sensors to ensure accurate and reliable readings at all times. If one sensor were to provide false information, the other sensor will be able to provide the correct information to the user.
- Develop an algorithm and electronic component to detect the type of object the time of flight sensor hits to reduce inaccurate distance readings.

All photos and graphs created by student researcher unless otherwise stated