SixthSense: A Wearable Ultrasonic System with Haptic Feedback for Visually Impaired Individuals

Kaitlyn R. Lum; Olivia J. Wojnilo; Kunal Mankodiya; Dhaval Solanki;
Dept. of Electrical, Computer, and Biomedical Engineering, University of Rhode Island, Kingston, United States
corresponding author: kaitlyn_lum@uri.edu

***Abstract*—The advancement of wearable medical technology is evolving daily to support people globally. It is often difficult for most people affected by blindness to find tools to improve their quality of life. To assist in this issue, our device was designed to be worn around the user's limb to detect the distance between the user and their surroundings. The product was created to be convenient for everyday use and easy accessibility.**

Keywords—Wearable Sensors, Blindness, Distance Sensing, Arduino

I. INTRODUCTION

Navigating through crowds of people or cities may be effortless for the average person, but many struggle with this task. Visual impairment is a burden that affects 12 million people aged 40 and above as of 2020. Additionally, 1 million are affected with blindness in the United States. [1] Visual impairment worsens with age and affects over 2.2 billion people worldwide. As of 2022, 1.4 million children are affected by blindness. [2] Children with vision impairment can experience delayed motor, language, emotional, social, and cognitive development. Adults with vision loss experience lower rates of participation and productivity in the workforce. There are higher rates of depression and anxiety among the visually impaired. There is a greater risk of falling and injury which contributes to an earlier entry into nursing homes. [3] Beyond the personal impact, accommodations for the visually impaired can become extremely costly. Expenses to adopt a guide dog, which requires training and daily care outside of adoption, may cause a financial burden. There have been devices created to help those affected by blindness but are frequently overpriced. Walking sticks have been utilized for centuries, but disadvantages like getting stuck in sidewalk cracks or breaking arise.

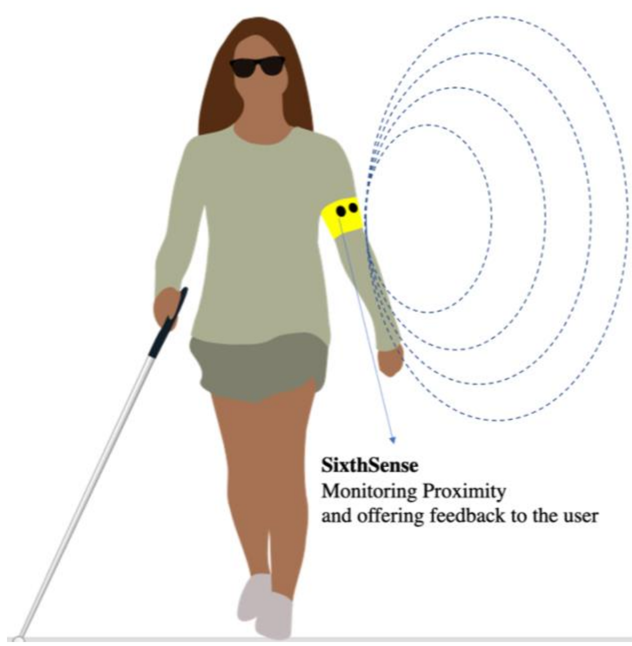

Fig. 1: A concept diagram was created to find pros and cons of different inventions.

The *SixthSense* introduces a solution to assisting those affected by blindness. Unless another sense is stimulated, the visually impaired cannot perceive an obstacle in front of them, endangering them. The wearable sensor uses an adjustable Velcro strap, which allows versatile functionality. The *SixthSense* can be worn anywhere on any limb to help navigate through daily life. This includes but is not limited to walking through crowded cities, searching for an item on a desk at work, grocery shopping, etc. A vibration motor alerts the patient when an object is within the range of the sensor. The vibration can aid deaf individuals as well, unlike if sounds were used to alert the patient. The frequency of the vibration increases as the distance between the object and the sensor decreases. With this wearable device, expenses may have become a limitation in the past. The financial burden of visual aid devices and guide dogs, along with the care and training the dogs require, may prevent the visually impaired from receiving the help they need. The affordable gadget has two rechargeable batteries that can easily be charged by plugging the *SixthSense* in similarly to a smartphone or laptop. There is a switch that allows one plug to charge both batteries. One battery is charged at a time and by switching the switch to the opposite side, the other battery is charged. A smaller switch turns the device on and off to allow for optimal usage.

II. System Design/Development

Two 3.7-volt 150 mAH lipo batteries were used in a series to power the wearable sensor. One battery did not have a high enough voltage to power the microprocessor. To increase the voltage, a series was created between the two batteries. The voltage of the two batteries is 8V, which successfully powered our microcontroller, but is too high for the ultrasonic sensor. Instead of directly connecting the power to the 5V pin on the Arduino Nano, the batteries are connected to the VIN pin. This pin converts 7-12V to 5V, to allow proper function of the circuit. The ultrasonic sensor measures the distance between the device and a person or object. The sensor is coded to detect objects up to one foot away. Although the sensor has a larger range, it is minimized for accuracy. The Arduino Nano is the microprocessor that receives information from the ultrasonic sensor. Lastly, the vibration motor will fluctuate in frequency depending on the data retrieved from the ultrasonic sensor to act as the alert system. As the patient approaches an object, the vibration will intensify. The vibration can prevent the user from being in danger by alerting the user about how near or far the object is from them.

Two 3.7-volt batteries were used due to their compact size. This allows for a lightweight and non-bulky wearable device for everyday use. The system was developed specifically for all components to be close together. This allows for the rest of the Velcro strap to be thin and support the device. The electrical components are in one area protected by silicone.

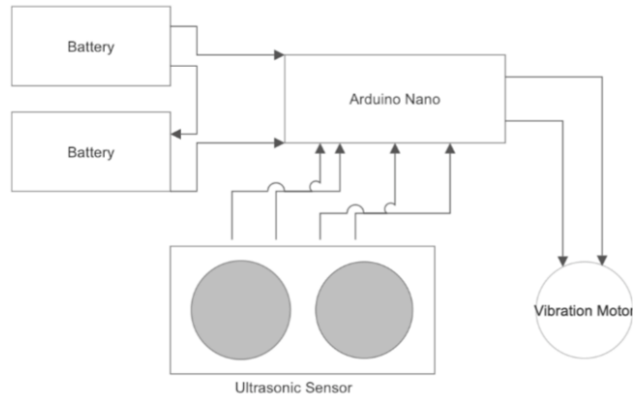

Fig. 2: The schematic for the wearable device. The arrows show how information is traveling.

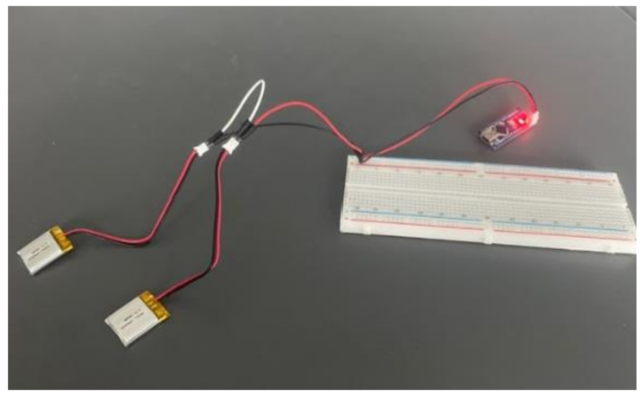

Fig. 3: The two batteries were used together in a series to power the Arduino Nano as well as the rest of the *SixthSense*.

Silicone is a waterproof material that allows for the device to be worn in inclement weather. Small wires are soldered and tucked away in the box. Electrical tape and shrink tubing were used between the components to allow electrical isolation.

Solidworks, a computer-aided design (CAD) software was used to design the *SixthSense*. A small rectangular box was constructed and 3-D printed to hold all the components together. The front has two holes for the ultrasonic sensors and is covered with a lid that was also 3-D printed. The lid has a slit that the Velcro strap runs through. The 50mm x 55mm x 30mm box was printed out of silicone so that it would be more fit for everyday use. Silicone is an inexpensive and common material that is easily accessible. All the components developed on Solidworks were designed to be inexpensive and easily accessible. In addition, the other components are low-cost.

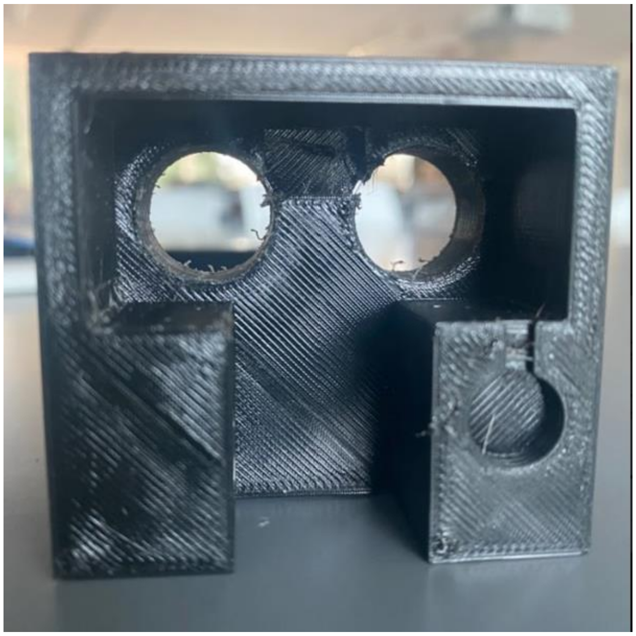

Fig. 4: The block was precisely measured to hold each component compactly to prevent excess bulkiness.

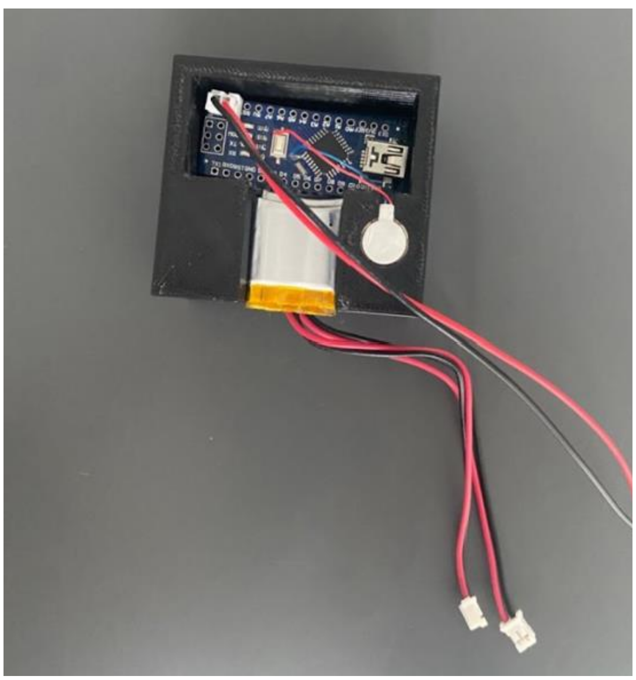

Fig. 5: The *SixthSense* contains all of the components in a compact block that is to be worn by the user.

The materials used include Arduino Nano, two switches, two 3.7 V 150 mAH lipo batteries, an ultrasonic sensor, a vibration motor, wires, and silicone. Each component was chosen for this project due to its low cost and accessibility. In total, the device costs about $35.00. This is a major difference between the cost of the device and the cost of an alternative visual aid such as a service dog which costs thousands of dollars. The parts can be bought in most hardware stores as well as online platforms such as Amazon.

Table 1: Components of the *SixthSense*

Component Name	**Description**	**Cost**
Arduino Nano	Microprocessor that allows code to control additional components	$12.00
Switches (x2)	Turns on and off the device, allows for one plug to charge the batteries separately	Less than $1.00 each
3.7 V 150 mAH lipo battery (x2)	Powers Arduino Nano for the device to run	$7.00 each
Ultrasonic Sensor	Senses distance to an object	$1.50
Vibration Motor	Oscillates without using sound	$0.75

III. Code Development

The code that allows for the wearable device to function is programmed on Arduino. Arduino is a programming software written in the C++ language. The Arduino Nano is a microprocessor that contains all of the coding information from the Arduino software. In the written code, the distance was programmed in centimeters for the ultrasonic sensor to measure. By measuring in centimeters, the distance between the sensor and an object is more exact than by using inches as the unit.

The Arduino Nano is programmed to power the vibration motor. Based on the output of the ultrasonic distance, the Arduino Nano would "tell" the vibration motor how fast it should oscillate. The smaller the distance of the ultrasonic sensor, the faster the Arduino Nano would tell the vibration motor to oscillate. The map function allows for a gradual increase in vibration as the distance decreases between the sensor and an object. The vibration alerts the wearer on how close or far an object is based on the vibration the *SixthSense* is programmed to vibrate.

IV. Results/Discussion:

Four subjects tested the *Sixth Sense*. The user strapped the device to their ankle and upper arm. The user then approached walls and tables with their eyes shut to simulate the device being used to assist the visually impaired. The subjects also tightened the sensor to the palm of their hand. The *Sixth* Sense was successful on each part of the body that the device was tested on. With no sense of vision, they were challenged to find objects scattered on the desk. All were successful and filled out a questionnaire about the comfort and effectiveness of the *SixthSense*. All the volunteers agreed that the wearable device was straightforward to use and comfortable on the body. There was an average rating of 4.75/5 for how useful the device would be for the visually impaired. The alert from the vibration allowed those who were utilizing the device to find an object easier due to the fast reaction time of the vibration motor. With the strength of the vibration, there was a common consensus that objects are easily able to be found with the increasing strength of the vibration. Improvements that they suggested included a broader range for the sensor and a stronger vibration motor to be felt over thicker clothing.

V. Conclusion:

We developed an easy-to-use product for the visually impaired to utilize that allows the user to know how far away they are from another object or person. The user is alerted based on distance. The closer the user is to an object, the more the vibration motor would oscillate. The higher oscillation frequency is used as a preventative measure. When in a crowded environment, it is more feasible to navigate by oneself. The *SixthSense* is cost-effective, with one device costing about $35.00. This affordable wearable sensor would alleviate the financial burden upon the visually impaired, while providing them with an artificial sense, leading to a better quality of life. In the future, we plan to improve our product by implementing a broader range for the sensor, a stronger vibration motor, and reducing the bulkiness. To increase the range, a stronger sensor would be used that is also more accurate than the ultrasonic sensor. To improve the strength of a vibration motor, multiple motors or a stronger motor can be used. This way there is also a larger range of vibration. Eventually, the patient would associate a vibration with distance, so the device would be more effective. Stronger batteries will be used so the device can be on all day, constantly alerting the individual of their surroundings. To reduce the bulkiness, a microchip can be applied instead of the Arduino Nano. Microchips are significantly smaller than the Arduino Nano. Although there are improvements that can be made, we successfully developed and tested The *SixthSense* to be an effective resource for assistance to those affected by blindness.

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