Design document for ECE 445
Spring 2019

Project Title : Safe-Walk Hat for people with visually impaired

Team # 72
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Assigned TA : Dongwei shi
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1. Introduction

1.1 Objective

There is a high chance that people with vision impairment or blindness would get involved with traffic accidents including collision accidents with bicycles. According to a research, Are Normally Sighted, Visually Impaired, and Blind Pedestrians Accurate and Reliable at Making Street Crossing Decisions written by Shirin E. Hassan, there are two decision variables to consider in order to cross a street safely; the time that it will take them to cross the street; the time available before the next vehicle reaches them[1]. Compared to people with normal vision, visually impaired people or people with blind disability recognized 12% fewer crossable gaps, and made 23% more errors by estimating a gap as crossable[2].

The chance that people with blind disability get involved with accidents has been increased since electric automotives, which does not make any noise even on the road, started to draw people's attention because global warming is one of biggest problems needed to be solved around the world. People with vision trouble will have more difficult time to safely cross a street as the number of electric automotive keeps increasing. For example, the number of electric automotive increased from 160,000 in 2016 to 280,000 in 2017 in the united states, and is estimated to keep increasing in the future[3]. Furthermore, the number of people using bicycles which poses a danger to people with blind disability in the U.S has been also increasing from 36 million to approximately 48 million since 2006[4].

1.2 Background

There are several ways to support people with vision trouble walking; First, a cane; Second, a guide dog and a cane. Of course, those two methods are also effective to walk around the outside, but the problem is that both of methods are just to detect unknown objects near a person who uses them. Both methods do not have an ability to prevent accidents from happening. There are many products of comfortable canes or of training a service dog, but there is no such products on the market that protect people with vision trouble from accidents and allow visually impaired people to cross a street safely and to walk around without exposing themselves to a danger. To protect people with visually impairment from any accident, we thought of a device that notifies people with visual impairment when an object with higher speed than people is approaching. Here is a brief explanation of the solution. The solution includes two components. First component is a hat integrated with four doppler radar sensors, and facing four different direction, so that sensors can cover 360 degree. Second component is a bone conducting speaker located in the device. If an object with higher speed than people is coming behind toward people with visual impairment, the device calculates the speed and direction of the object coming, determines level of danger, and sends a signal to the speaker to notify users.

1.3 High-Level Requirement List

- The range of detection component, including doppler radar sensors will be approximately 20 meters
- Four of the doppler radar sensors must be able to detect an object within 360 degree
- The doppler radar sensors must be able to detect a speed of an object from 1.4 km/s to 60 km/h

2. Design

2.1 Block Diagram

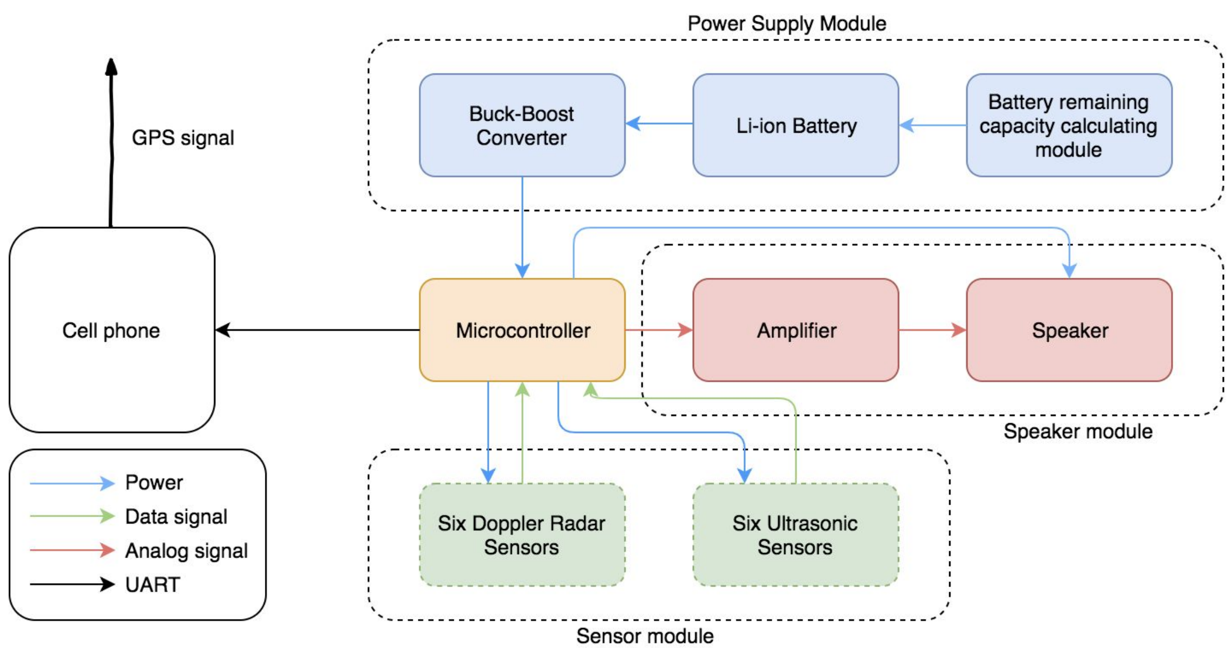

Figure 1. Block diagram of the product

2.2 Block Description

2.2.1 Component description, requirements and verifications

a hat unit manages the battery storage, checks the remaining battery, receives the data input from the Bluetooth module, and alerts the user by calculating speed and distance of an approaching object.

- **Microcontroller** : a microcontroller, chosen to be ESP 32, communicates with cell phone using the bluetooth module integrated in the microcontroller. This microcontroller is able to communicate with a cell phone via UART. And also it is able to process signals using DAC to alert the user. Furthermore, the microcontroller has enough number of GPIO pins. To detect an approaching object toward a user correctly, the product might need some more sensors to enhance accuracy, or to add extra features later.

Requirement	Verification
1. The microcontroller must be able to output 5 V ± 5% and 15 ~ 30 mA 2. The microcontroller must be integrated with Bluetooth module in order to communicate with any android cell phone.	1. A. Connect the sensors to the microcontroller. B. Measure the output voltage and current using a multimeter C. Check if the voltage and output current of HB-100 sensor are approximately 5 V and 30 mA, and of HC-SR04 sensor is approximately 5 V and 15 mA. (Both voltage and current of ultrasonic and microwave sensors can have ± 5% error) 2. A. First prepare, ESP 32, a laptop and a cell phone, and download ESPblufi app on the cell phone. B. Power on the microcontroller, and open the app. Then BLUFI_DEVICE will appear on the list. C. Connect the device by simply clicking yes, and successful connection message will appear on the interface.

Table 1. Requirement and verification table of microcontroller

- **Doppler radar sensor** : Four HB-100 has been chosen for doppler radar sensor. This sensor is able to operate in the harsh environment. The doppler radar sensor detects the speed of an object approaching, and sends the data to the microcontroller. The detection range of the sensor is more than 20 meters.

Requirement	Verification
1. The microwave sensor should detect an object at least 20 meters away 2. The microwave sensor must be able to detect an object that is moving from 1.4 km/sec to 60 km/hour	1. A. Prepare HB-100 sensor, and power up the sensor B. Check whether the sensor is able to detect any movement of 3 meters away 2. A. After checking first requirement, prepare HB-100 sensor, and a automotive. B. Connect the microwave sensor to the power source. C. Set the vehicle and the sensor 100m apart, and drive the car toward the sensor. D. Measure the velocity of the vehicle E. Repeat the steps C and D to measure at least five different different velocity(minimum 1.4 km/s and maximum 60 km/s). F. Collect the data and analyze the accuracy of the sensor

Table 2. Requirement and verification table of microwave sensor

- **Power supply module** :The power supply module must be included with a rechargeable battery and a Buck-Boost converter. The rechargeable battery included in the module will feed power into a Buck-Boost converter. The power supply module must be able to supply power continuously over 6 hours when the device in active mode. That is why 5 V Li ion battery is chosen. And the Buck-Boost converter, included in the power supply module, must be able to convert 5 V to 3.3 V± 5% to run the microcontroller.

Requirement	Verification
1. The Buck-Boost converter must be able to supply 3.3 V± 5% and 500 mA ± 5% from 4.2 - 5 V source 2. The battery must last over 6 hours	1. A. Connect the battery to the converter, feed power to the Buck-Boost converter, and draw 500 mA B. Measure the output voltage using a multimeter 2. A. Connect the battery to the converter, connect the converter to the microcontroller and 6 sensors, and feed power to the Buck-Boost converter, then draw 500 mA B. Measure the time of operating duration

Table 3. Requirement and verification table of power supply

- **Speaker** : a speaker that can fit inside of the product. That is why Bone Conductor Transducer with wires is chosen. The dimension of the speaker is 14 mm x 21.5 mm. This speaker consumes 1 watt.

Requirement	Verification
1. The speaker should be able to conduct the vibration that is equivalent to loudness of 60~65 decibel.	1. A. Prepare a speaker and a decibel meter B. Check the loudness of the speaker by using the decibel meter. Check the loudness of normal conversation (60~65 decibel)

Table 4. Requirement and verification table of speaker

- **Cellular Phone and GPS signal** : We Need a database that stores the user email address and location information in the backend. For the database, we are going to use SQLite, which is the standard database for Android DB. We are using Google Map Android API v2 to get current GPS location, and needs to program the chip to send the GPS information via internet.

2.3 Physical Design of the product

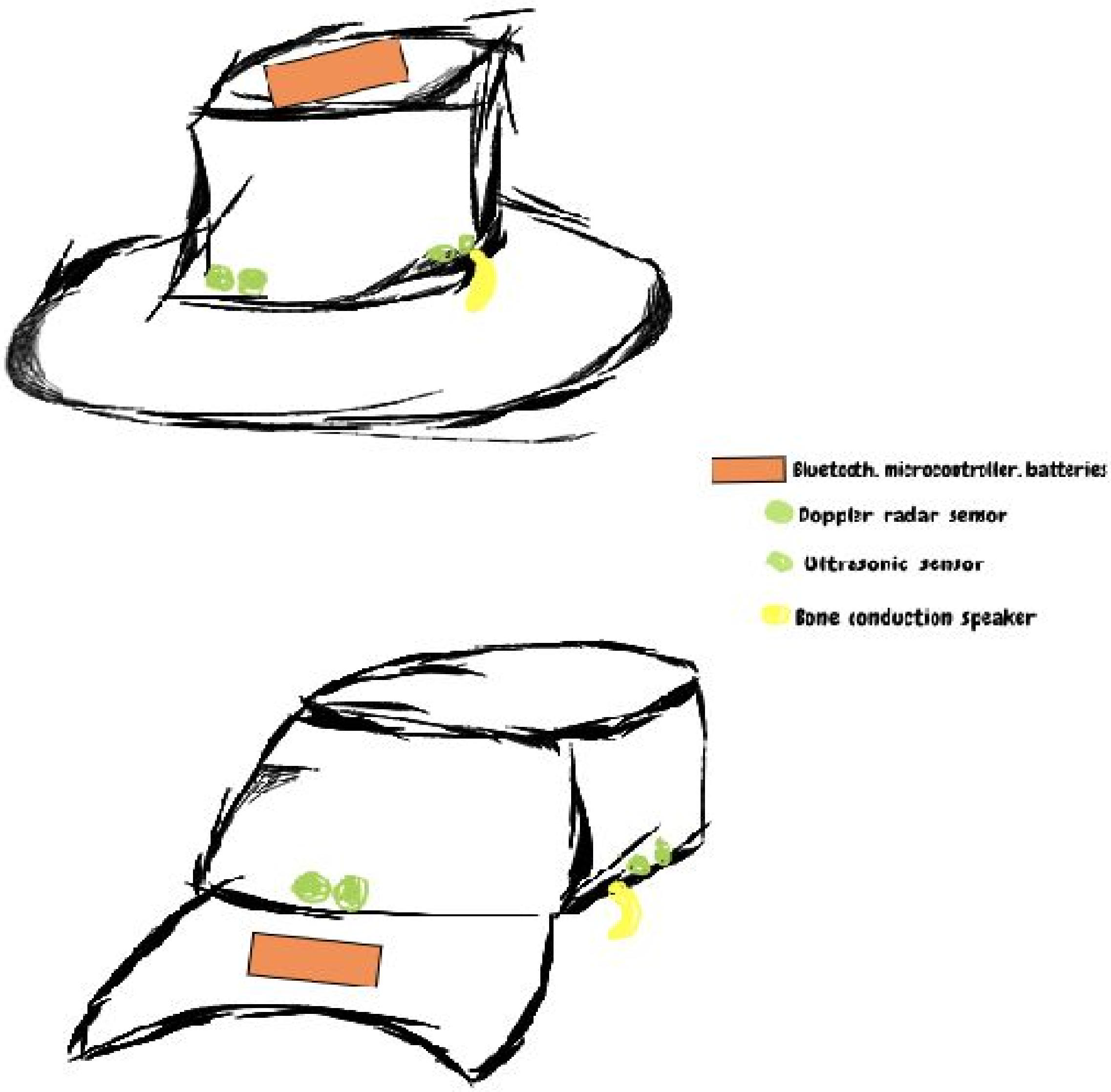

Figure 2. Physical design sketch

The physical design, shown above, will consist of a hat, a bone conduction speaker, 4 doppler radar sensors, 4 ultrasonic sensors, bluetooth module, battery, and a microcontroller. The speaker, sensors, battery, microcontroller and a bluetooth module would be protected from water and dust. Bluetooth, battery and a microcontroller would be placed beneath the top part of the hat if we go with the first sketch and they would be placed under the brim of a cap if we go with the second sketch.

2.4 Risk Analysis

There are three parts that pose the greatest difficulty to implement this project. First is finding a way to protect the device from water and dust. In other words, because our device is for outdoor activity, it has to be water and dust proof. Second is a way to identify joggers from bicycles and automotives.

- Water and dust proof : Since the device needs to be operated, the device has to be water and dust proof in order to protect the user from electrocution, and to prevent the device from malfunctioning. Therefore, the whole circuit except the sensors will be covered with insulating rubber to protect from water and dust. And the sensors will be covered with thin transparent plastic boxes.

- Identification : It will be difficult to distinguish joggers from bicycles, automotives and bikes. Of course, average people walking pace is 1.4 m/s, but there is a special situation that some people sprint or run. Changing a range of speed detection of doppler radar sensors can solve the problem.

- Overlapping detection region : The problem with the doppler radar sensor is that the sensor emits the microwave in 360 degrees. Of course, the actual detection range is 60 degrees, but it still does emit the microwave in 360 degrees. This aspect of the sensor might lead to significant failure of the device. Multiple doppler radar sensors will be integrated into the device. One sensor might receive the signal from the other sensors. Or multiple sensors might detect one object in same time. In order to solve this problem, thin copper plates will be placed around sensors' microwave emitters so that the copper plates reflect non-changed and not attenuated microwave back to the sensor and the microcontroller filter those non-changed and not attenuated reflected microwave out. And the sensor can only detect an object in 60 degree range.

2.5 Tolerance Analysis

A microwave sensor, HB-100, is a sensor that is based on the doppler effect. Before going in depth into the details of one important tolerance of our device, the doppler effect has to be elaborated carefully first. The doppler effect is named after Christian Doppler, who first came up with the idea in 1842. The doppler effect causes the difference in the frequency. The received frequency is different from the sent frequency if the receiver is moving away from or toward the source. If the distance between the receiver and the source is decreasing, the transmitted frequency seem to be increased from the perspective of the receiver. And if the distance between the receiver and the source is increasing, the transmitted frequency seem to be decreased from the receiver's view. Based on the doppler effect, HB-100 sensor detects the speed, or motion of an object by transmitting microwave and analyzing the reflected microwave. Our main concern was that if there is a distinct difference in frequency when an object is passing by the sensor, and when an object is moving toward the sensor. In order to check the fact that if there is a distinct difference in frequency between an object, passing by the sensor, and an object, moving toward or away from the sensor, our group measured the reflected frequency from a source that is moving in different speed in different direction. Figure 3 shows that there is a difference in reflected frequency between an object that is passing by, and is walking by. The reflected frequency of an passing by object is similar to the reflected frequency of an object moving away from the sensor.

Figure 3. Received frequency of a passing by object(Left) and an approaching object(Right)

If the reflected frequency of a passing by object is similar to that of an approaching object, the speed of a passing by object has to be extremely fast, according to the doppler equation below. In this case,

$$F_d = 2V\left(\frac{F_t}{c}\right)\mathrm{Cos}\,\theta$$

Figure 4. Doppler equation

2.6 Circuit Schematic

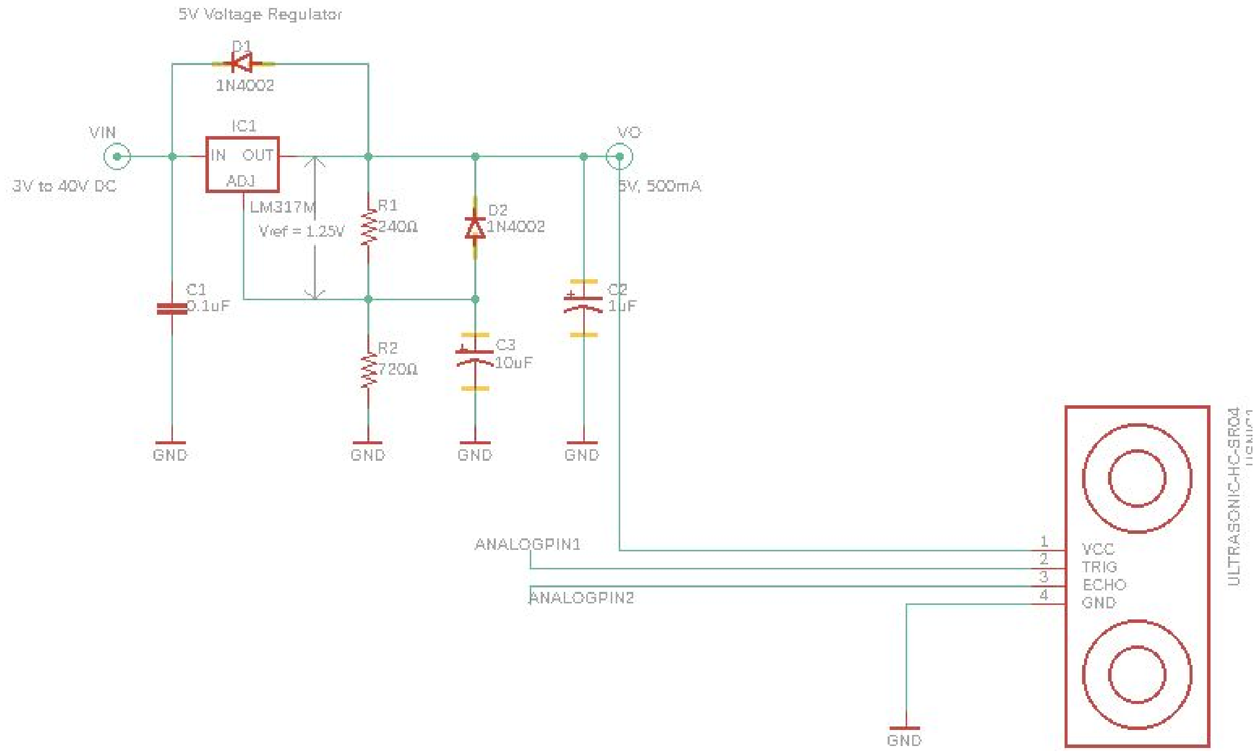

Figure. 5 Schematic of ultrasonic sensor

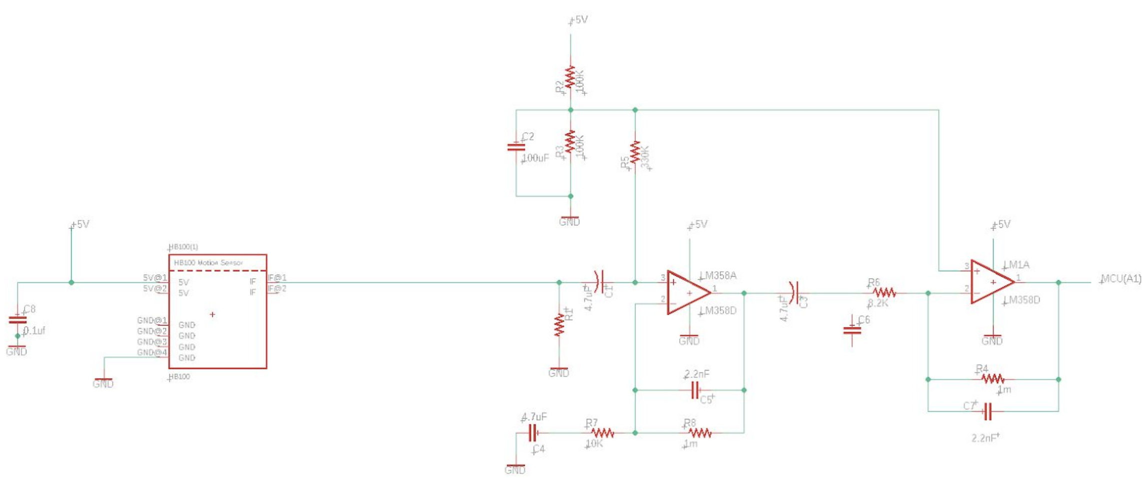

Figure. 6 Schematic of doppler sensor

2.6 Flowchart of object detection

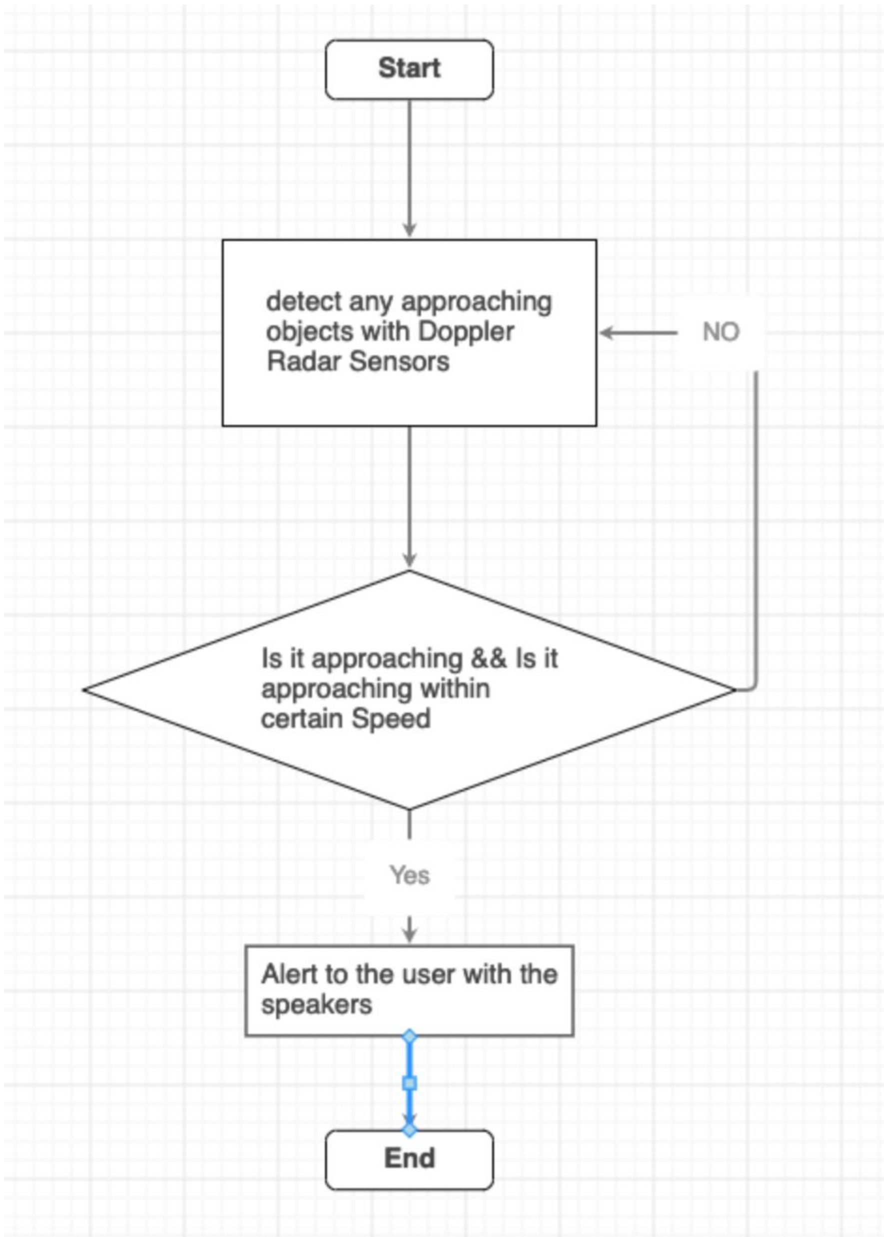

Figure. 7 Flowchart of object detection

2.7 Flowchart of GPS information transmission

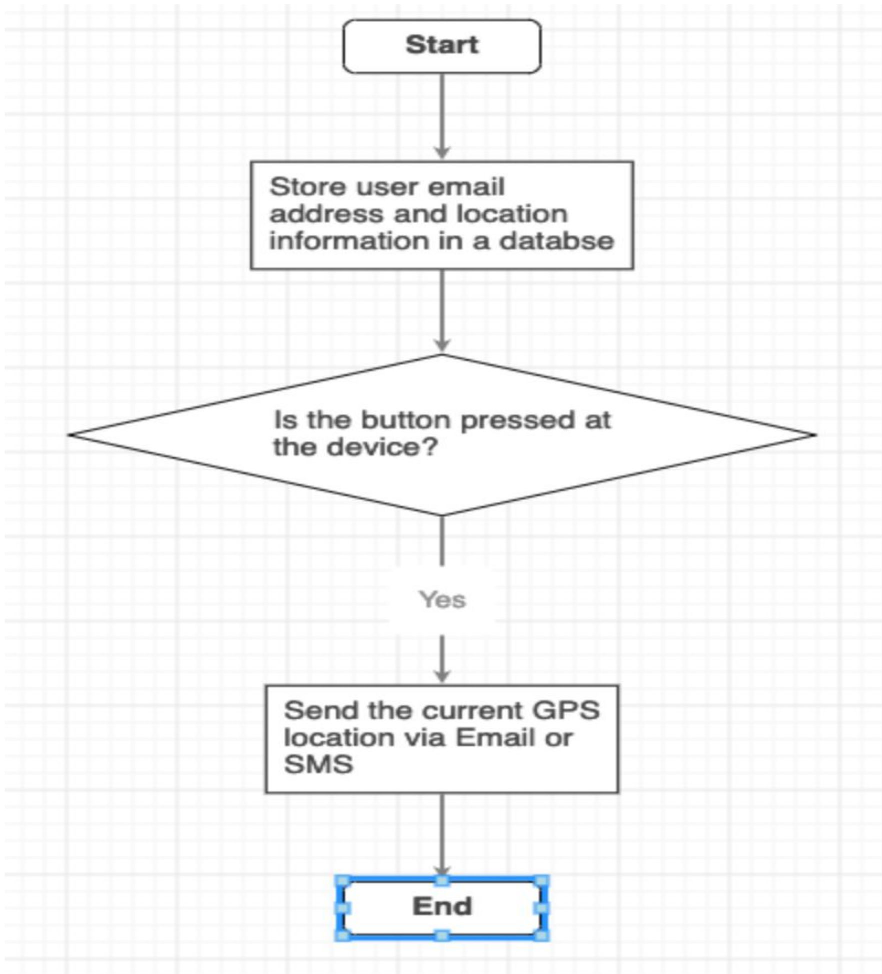

Figure. 8 Flowchart of GPS location transmission

3. Ethics

We, the members of IEEE, acknowledged the 7.8 IEEE code of ethics, and are not going to do any acts that violate the ethics code. The project is to protect visually impaired people from accidents occurring, to provide more safety to people with vision trouble, and to give them more mobility outside. We believe that out product is designed "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger" the people with visual disability.

(IEEE Code of ethics, #1) “To avoid injuring others, their property, reputation, or employment by false or malicious action,” we will definitely address any possible risks, harms, or dangers to end users in details, so that our product does not put any people with visual disability in a harm’s way. (IEEE Code of ethics, #9) In order to act in accordance with IEEE Code of ethics, #7, our team is also going to take notes thoroughly on the procedure of the development and implementation “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.” Furthermore, to be more adhered to IEEE ethics code, every team members are willingly going to help each other even if it is not his own task to work on. For these reasons, we believe that there is no ethical concerns.

4. Safety Issue

Our project has few risks needed to be taken care of. The device is designed to be a outdoor-purpose device, dust and moisture could damage the device, which is consisted with microcontroller, several sensors, batteries, and a small circuit. In other words, the device for our project has to be dust and waterproof. That is the reason that the circuit will be covered with rubber in order to protect the circuit from water and dust, and the doppler wave sensors will be covered with transparent plastic boxes to protect the circuit from water and dust. The transparent plastic box is chosen because microwave can pass through without any attenuation.

Another safety issue is concerned with rechargeable Li-ion batteries. Li-ion batteries may explode and cause fire if mishandled. If the batteries are mishandled when it is being used or being charged, internal short circuit can cause enough heat to damage the components around and even hurt users. To prevent possible safety hazards, batteries will thoroughly be checked and tested in the manufacturing process.

5. Cost and Schedule

5.1 Cost

Labor

We consider the University of Illinois at Urbana Champaign ECE graduate average starting salary is $45/hour. We have three group members in total and we estimated 10 hours/week as a weekly time effort.

$$3 \ * 2.5 \ * \ \$45/hour \ * 10 \ hour/ \ week \ * \ 12 \ weeks \ = \ \$ \ 40,500$$

Parts

Part	Cost
Microcrontroller x 2 : ESP 32 (3.3 V, 500mA, *Espressif Systems)*	$\$3.96 * 2 = \$7.92$
Doppler radar sensor x 6 : HB100 (1.2mA~4mA with 3 to 10% duty cycle pulse at 5v, *ST Electronics*)	$\$5.83 * 6 \ = \$34.98$
Li-ion Battery x 4 : (<5V and 100mA, last over 6 hours, rechargeable, LiFePO4 3.2V 1500mAh, *AA Portable Power Corp*)	$\$3.75 * 6 \ = \ \$22.5$
Speaker (Bone Conductor Transducer with Wires - 8 Ohm 1 Watt, *adafruit*)	$8.95
Total	$74.35

Table 5. Cost of circuit components

The total development cost becomes $\$40,500 \ + \$74.35 \ = \ \$40,585.93$.

5.2 Schedule

<table>
<tr><th>Week</th><th>TaeHwa Kim</th><th>YongJun Lee</th><th>WooYoung Choi</th></tr>
<tr><td>2/11</td><td colspan="3">Research on the project</td></tr>
<tr><td>2/18</td><td>Power test for sensors</td><td colspan="2">Research on Bluetooth module and modify design</td></tr>
<tr><td>2/25</td><td colspan="2">Begin schematic design</td><td>Research on bluetooth API</td></tr>
<tr><td>3/4</td><td colspan="2">Finish schematic design and order PCB</td><td>Research on bluetooth API</td></tr>
<tr><td>3/11</td><td></td><td>First round PCB order</td><td>Start programming for bluetooth module</td></tr>
<tr><td>3/18</td><td colspan="2">Second schematic design (if needed) & work on building up the device</td><td>Continue on programming and debugging</td></tr>
<tr><td>3/25</td><td>Final PCB order</td><td>Continue on building up the device</td><td rowspan="2">Programming and merge the circuit with software</td></tr>
<tr><td>4/1</td><td colspan="2">Work on finalizing circuit and sensors</td></tr>
<tr><td>4/8</td><td colspan="3">Mock demo prep/ debug</td></tr>
<tr><td>4/15</td><td colspan="3">Mock demo / Bug fix</td></tr>
<tr><td>4/22</td><td colspan="3">Prepare for the presentation and write final report</td></tr>
<tr><td>4/29</td><td colspan="3">Final presentation/Final report</td></tr>
</table>

Table 6. Brief schedule

6. Citations and References

1. Shirin E. Hassan, “Are Normally Sighted, Visually Impaired, and Blind Pedestrians Accurate and Reliable at Making Street Crossing Decisions?,” 2012. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3358127/#i1552-5783-53-6-2593-b04

2. Wilmer Eye Institute, “Traffic gap judgment in people with significant peripheral field loss,” 2008. https://www.ncbi.nlm.nih.gov/pubmed/18174838

3. Matt Pressman, “Over 3 Million Electric Cars On The Road — You Driving One Yet?,” 2018.https://cleantechnica.com/2018/07/03/over-3-million-electric-cars-on-the-road-you-driving-one-yet/

4. Statista, “Number of participants in bicycling in the United States from 2006 to 2017 (in millions),” 2017. https://www.statista.com/statistics/191204/participants-in-bicycling-in-the-us-since-2006/

5. Theorycircuit, 2018. http://www.theorycircuit.com/hb100-microwave-motion-sensor-interfacing-arduino/

6. https://www.youtube.com/watch?v=H9TdEP94LeI

7. ST Electronics, “X-abnd Microwave Motion Sensor Module,” https://www.limpkin.fr/public/HB100/HB100_Microwave_Sensor_Application_Note.pdf

8.https://www.amazon.com/Generic-Surface-Conductor-Transducer-Exciter/dp/B00Y8ISYHG

9. Espressif Systems, 2019, https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf

10. Espressif Systems, 2019, https://www.espressif.com/sites/default/files/documentation/esp32_bluetooth_networking_user_guide_en.pdf

11. https://www.healthline.com/health/average-shoulder-width#the-takeaway