Vehicle Detection Cane

Team 42 - ECE445 - Spring 2020 - Design Document

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27 February 2020

1. Introduction

1.1 Objective

In 2016, pedestrian fatalities accounted for 16% of all traffic fatalities [1]. Those who are severely visually impaired are more susceptible to being involved in a traffic accident as they are not able to see oncoming traffic. Instead they either have a guide dog or rely on using a cane and their hearing to determine if an area is safe to walk. Gas fueled vehicles make a loud noise when driving by, but electric vehicles are virtually silent. With electric vehicles becoming more common it becomes more difficult for blind people to navigate as they cannot easily determine if a street is safe to cross.

Our solution for determining if an area is safe to walk is a battery-powered cane attachment that detects and alerts the user when a vehicle is passing in front of them. When activated by pressing a button, it uses a radar sensor to determine if there are cars or other fast moving vehicles in front of the user and alerts the user with vibration if it is not safe to walk.

1.2 Background

In an article by The Telegraph [2] on how a visually impaired woman was narrowly saved by a pedestrian from being hit by an electric vehicle, she mentioned that even her guide dog failed to recognise the car since there was no noise or fumes from the exhaust. This incident has really impacted her confidence of walking outdoors alone. This is just one of the many stories and electric cars are now viewed as a hazard for the visually impaired.

There have been a number of solutions proposed to solve this problem. One of which is making the electric cars emit a warning sound [3]. This hasn’t been implemented yet and might also be expensive to incorporate in the cars.

A number of smart canes have been made to assist visually impaired in walking by themselves. weWalk [4] is a smart white cane that uses an ultrasonic sensor to detect any obstacles above chest level and warns the user by vibrating their handle. It can be paired with smartphones to use voice assistance and google maps with a cost of $500.

UltraCane [5] is also another smart cane that detects obstacles with a dual range, narrow beam ultrasound system.The ultrasound transducers provide range data on the closest potential hazards. It cost around $760 and can detect street obstacles within 2 to 4 metres.

Bat ‘K’ Sonar Cane [6] radiates ultrasonic waves to insonify objects in the path of a blind walker. The reflection from the objects return to the sonar unit and converted electronically into a unique sound based “image” of the landscape that gets transmitted to a set of headphones worn by the blind traveler. It cost $640 and also doesn’t target moving obstacles.

One of the most successful smart cane is the "EyeCane" [7], developed by a team of researchers at The Hebrew University of Jerusalem, which uses infrared rays to detect obstacles within 5 metres, and communicated with the users through sound and vibration. It is relatively faster at detecting obstacles than other similar devices but still focuses on stationary objects.

Our solution is designed for visually impaired people to protect themselves from electric cars and give them more autonomy.

1.3 Visual Aid

Fig 1: Visual Aid: When the user approaches a crosswalk, they can activate the vehicle detection cane attachment (circled in red) which will use a doppler radar to detect oncoming traffic (represented with blue lines). If a vehicle is detected, then the device will notify the user through vibration feedback.

1.4 High-Level Requirements List

1. Device is able to detect vehicles moving up to 45mph.

2. Device is able to detect vehicles at a distance of at least 110m.

3. Device is able to be powered for at least four hours when not scanning.

2. Design

2.1 Block Diagram

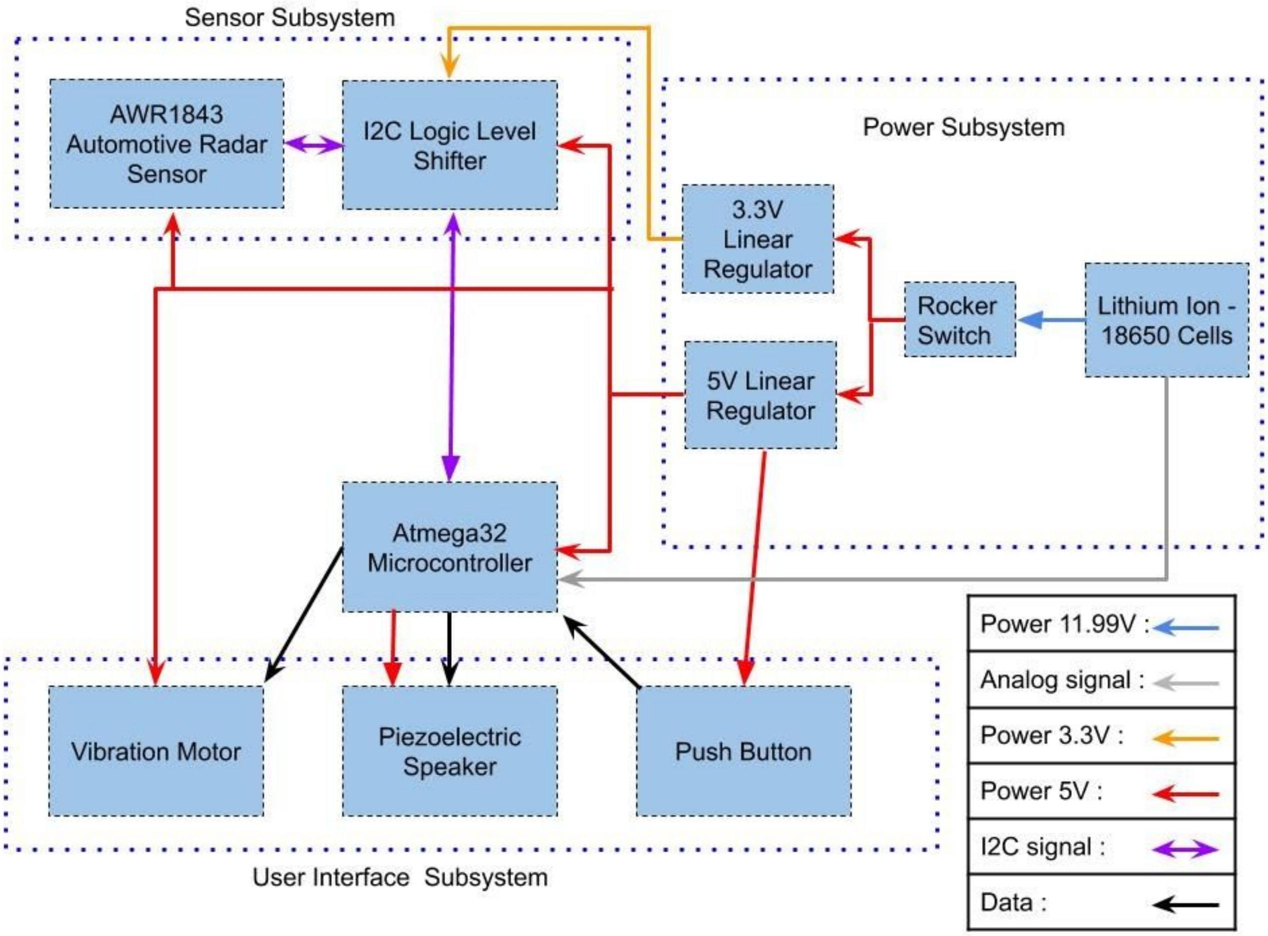

Fig 2: Block Diagram: Our design has four main subsystems for successful operation: a sensor subsystem, the power supply, user interface, and a microcontroller control unit to interface between the other subsystems.

Our design has four main subsystems for successful operation: a sensor subsystem, the power supply, user interface, and a microcontroller control unit to interface between the other subsystems. The sensor subsystem is responsible for sensing incoming vehicles and processing the data received from the sensor to determine if there is an incoming vehicle. The power supply ensures that the system can be continuously powered for four hours while in standby mode. The user interface allows the user to activate the sensor and receive feedback on vehicle detection and the battery state through a vibration motor and piezoelectric speaker. Additionally, the user interface detects the low battery state and reports it to the user. To interface between the three subsystems we use a microcontroller to process all of the signals and direct them to the correct feedback output.

2.2 Physical Design

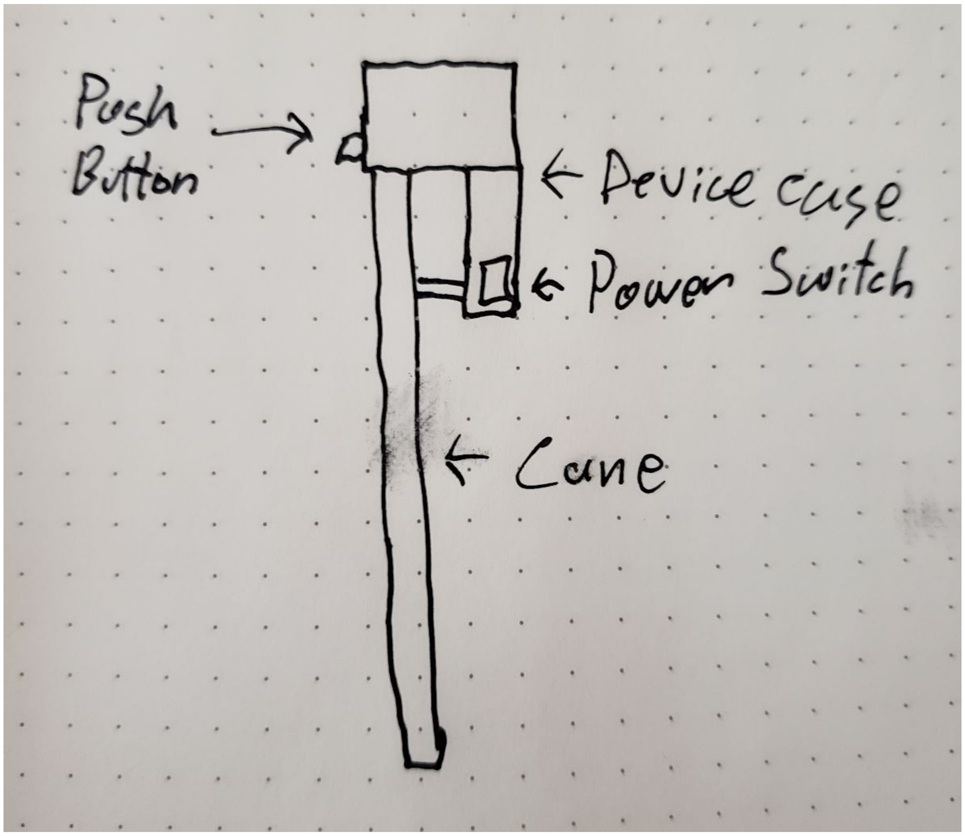

Fig 3 Physical Design: The device attaches to the body of the cane using clamps. The user will hold it in an upright position to scan the environment. The push button is easily accessible on the back of the device facing the user to be easily accessible during operation and serves as a reference for the location of the scanner.

The system is designed to attach to the handle of a cane using clamps. The main body is detached from the cane shaft to allow it to be gripped the same during normal operation. The push button needs to be easily accessible during scanning, so it is positioned at the rear near the user's thumb. The push button's location also serves as a physical reference to aid in aiming the scanner.

2.3 Subsystems

2.3.1 Radar/Control Subsystem

The radar/control subsystem is responsible for detecting vehicles and issuing an appropriate response to the user interface subsystem. Radar technology has been in development in recent years for use in fully and partially autonomous cars. By emitting high frequency microwave "chirps" (above 77GHz) and "listening" for reflections off of objects, their location and speed (the doppler effect) can be determined. Further processing can be performed to get more data on the object such as size and certain material characteristics (useful for differentiating between cars and other moving objects like people). An integrated automotive radar evaluation board (which includes a transceiver, DSP, and microcontroller), will be used to emit and analyze radar data. This information will then be used to determine if there are any incoming vehicles, their distances from the device, and their speed. The microcontroller will then compare these values to stopping distance data to determine if it is safe to cross because of each vehicle. Using I2C this information will be periodically sent to another microcontroller, the Atmega32. Below is a Figure 3 illustrating the above functionality of the sensor.

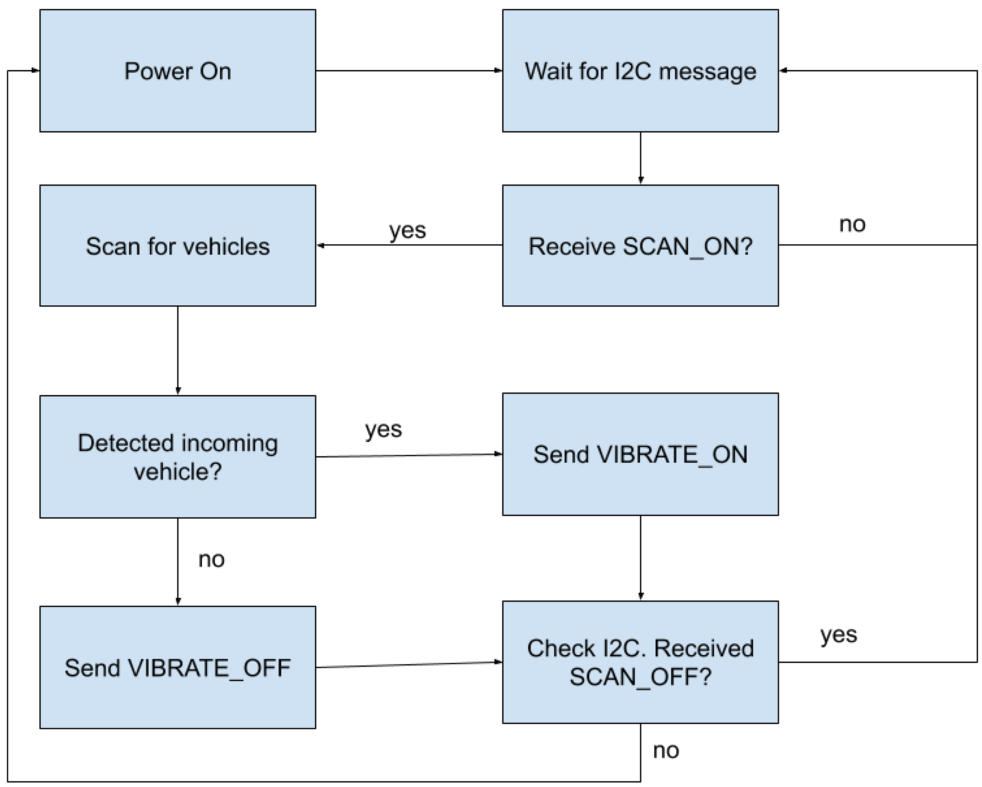

Figure 4 Radar Sensor Program Flow

The Atmega32 has three primary functions:

- It will periodically check the battery level of the device using it's ADCs and warn the user of low battery with periodic beeps from the speaker and disabling scanning.
- When instructed to by the radar sensor, it triggers vibration in the motor.
- When the push button is depressed or released, it triggers scanning in the radar sensor over I2C.

Requirement	Verification
The device detects cars travelling at and above 10mph under 25m away.	1. Program an arduino to mirror I2C data over a serial connection to a laptop and probe the I2C debug pins with it. 2. Mark a spot m away from a designated scanning area on the side of the road. 3. Drive a car at 10mph over the spot while scanning with the device from the side of the road. 4. I2C data should include a VIBRATE_ON message and a corresponding VIBRATE_OFF message. 5. Repeat at 5mph increments up to 45mph.
The device does not detect people.	1. Program an arduino to mirror I2C data over a serial connection to a laptop and probe the I2C debug pins with it. 2. Have a person walk in front of the sensor while it is scanning at 5m, 10m, 15m, 20m, and 25m. 3. I2C data on the laptop should *not* include a VIBRATE_ON message. 4. Repeat at 5mph increments up to 45mph.

2.3.2 User Interface Subsystem

The radar sensor lacks the ability to interface with motors, speakers, and buttons, so a user interface microcontroller will be responsible handling them. This microcontroller will communicate with the sensor subsystem through I2C and an appropriate I2C logic level shifter. This microcontroller will interface with a push button, rocker switch, piezoelectric speaker, and vibration motor to communicate information to the user and receive input. Each component's function is as follows:

- Push button: enable radar scanning when held
- Rocker switch: turn the device on and off
- Piezoelectric speaker: alert the user of low remaining battery, plays different tones to signal device turning on, turning off, and low battery state
- Vibration motor: vibrate when moving vehicles are detected in front of the device

Requirement	Verification
The push button triggers the	1. Program an arduino to mirror I2C data over a serial

microcontroller to send SCAN_ON and SCAN_OFF messages to the radar sensor.	connection to a PC and probe the I2C debug pins with it. 2. Push the button. 3. I2C data should include a SCAN_ON message. 4. Release the button. 5. I2C data should include a SCAN_OFF message.
When the battery voltage is read to be less than 10%, the speaker periodically beeps.	1. Use a benchtop power supply in place of the battery cells. 2. Set the voltage to simulate 10% charge. 3. The device should beep periodically.
VIBRATION_ON and VIBRATION_OFF messages sent over I2C trigger the vibration motor.	1. Program an arduino to send a VIBRATION_ON message over I2C 2. Attach Arduino to the I2C debug pins and check if the motor turns on 3. Send a VIBRATION_OFF message over I2C 4. Check if the motor turns off
When the battery voltage is read to be less than 10% the device does not scan.	1. Use a benchtop power supply in place of the battery cells. 2. Set the voltage to simulate 10% charge. 3. Program an arduino to mirror I2C data over a serial connection to a PC and probe the I2C debug pins with it. 4. Pressing the button should *not* generate SCAN_ON messages.

2.3.3 Power Subsystem

The power system is responsible for providing set voltages to the other subsystems. 1.2v, 1.3v, 1.8v, and 3.3v are required by the sensor subsystem and 5v is required by the user interface subsystem. The power is provided by rechargeable battery cells which can be charged via USB.

The system will run off two 3.7v 18650 lithium ion cells running in series. A usb charger pcb (boards sometimes used for making portable phone chargers) will allow the cells to be charged with a usb cable. Voltage regulators will be used to produce the other voltages (1.2v, 1.3v, 1.8v, 3.3v, and 5v). A USB charger PCB will allow the cells to be charged with a USB cable.

Requirement	Verification
All voltage levels remain within 10% of their expected values during a scan.	1. Use a benchtop multimeter to probe the output of each linear regulator 2. Measure the voltage during a scan.
When plugged into USB, the cells are charged.	1. Drain the batteries until the cells reach roughly 3.3v. 2. Use a benchtop multimeter to probe the output of the cells. 3. The cell voltages should begin rising.
The battery lasts at least 4 hours when not scanning.	1. Fully charge the battery 2. Time how long it takes to begin beeping.

2.4 Risk Analysis

The sensor subsystem definitely poses the greatest risk to successful completion of the project. Since if the sensor fails to detect a moving car from a distance of 25m, our main goal of the project wouldn't be achieved.

User-interface block and power subsystem should be able to work well together with the sensor subsystem to give the right inputs to the user. Since, false positives would make our product less reliable and affect the success of our project.

The wires should also be soldered securely and neatly in order to prevent short/open circuit. Since this could make our electric component conductive and be harmful for the user. Also since this attachment will be on the cane, it needs to be able to work through all weather conditions which is why we have to make sure to cover our electrical components to avoid any system failure.

The power subsystem should be able to power the whole system without any power failure. It should allow the user to operate it for around 4 hour without heating up.

2.5 Tolerance Analysis

2.6.1 Vehicle Stopping Distance Tolerance

Detecting vehicles early enough is critical to the safety and effectiveness of our project. A bare minimum required detection range can be established by estimated vehicle stopping distances. It is critical we detect vehicles before they are closer to the user than their stopping distance. A detection within the stopping distance does not allow the driver to stop before reaching the user, which poses obvious safety problems.

Vehicle stopping distances are dependent on vehicle type, environmental conditions, and vehicle speed as shown in Figure 5. To ensure our device is the safest it can be, it needs to be able to detect all types of vehicles and have a safety tolerance for dangerous situations, like brake power assist failure. Accounting for the worst case scenario keeps our users the safest.

TABLE II - STOPPING DISTANCES

Vehicle Test Speed (miles per hour)	Stopping Distance in feet for tests indicated																
	I-1st (preburnished) & 4th effectiveness; spike effectiveness check				II-2d effectiveness				III-3d (lightly loaded vehicles) effectiveness					IV-Inoperative brake power and power assist unit; partial failure		
	(a)	(b)	(c)	(d)	(a)	(b) & (c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)	(a)	(b) & (c)	(d) & (e)
30	[1]57	[1,2]65	[1,2]69 (1st) [1,2]65 (4th and spike) [1]72	88	[1]54	[1]57	78	[1,2]70	51	57	65	84	70	114	130	170
35	74	83	91	132	70	74	106	96	67	74	83	114	96	155	176	225
40	96	108	119	173	91	96	138	124	87	96	108	149	124	202	229	288
45	121	137	150	218	115	121	175	158	110	121	137	189	158	257	291	358
50	150	169	185	264	142	150	216	195	135	150	169	233	195	317	359	435
55	181	204	224	326	172	181	261	236	163	181	204	281	236	383	433	530
60	[1]216	[1]242	[1]267	388	[1]204	[1]216	[1]310	[1]280	[1]194	[1]216	[1]242	[1]335	[1]280	[1]456	[1]517	[1]613
80	[1]405	[1]459	[1]510	NA	[1]383	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
95	[1]607	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
100	[1]673	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1] Distance for specified tests. [2] Applicable to school buses only. NA = Not applicable
Note: (a) Passenger cars; (b) vehicles other than passenger cars with GVWR of less than 8,000 lbs; (c) Vehicles with GVWR of not less than 8,000 lbs and not more than 10,000 lbs; (d) vehicles, other than buses, with GVWR greater than 10,000 lbs; (e) buses, including school buses, with GVWR greater than 10,000 lbs.

Figure 5: National Highway Traffic Safety Administration vehicle stopping distance test results indicate a maximum stopping distance of 358ft (109m) for vehicles travelling below 45mph [8]

Using medium range radar techniques, we can reasonably expect our radar sensor to detect objects at up to 150m (492ft). Allowing for a 20% safety tolerance, our device will safely detect objects at 120m (394ft). Using the data from Figure 5, this range allows our device to detect all vehicles travelling under 45mph, even in the case of power assisted braking malfunction, at a distance greater than their stopping distance.

Considering our device's use case being urban environments, where facilities exist to enable cane users to navigate walkways and street crossings in the first place, 45mph doesn't significantly limit its use. In Illinois, urban streets have a speed limit of 30mph unless otherwise posted [9], 15mph lower than our maximum rating. It is reasonable to expect crossings above this limit to either have facilities in place to allow for safe crossings (eg. signals that stop all cross traffic to allow pedestrians to cross safely) or have an available alternate route.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Parts

Item	Part # or Manufacturer	Count	Price

AWR1843 EVB	AWR1843BOOST EVM RevB	1	$300
I2C Logic level shifter	TCA9406	1	$0.12
3.3v linear regulator	TLS850B0TEV33ATMA1	1	$1.57
5v linear regulator	TLS850B0TEV50ATMA1	1	$1.57
Dual 18650 cell holder	SACKORANGE	1	$6.99
18650 charger and 2 cells	EBL	1	$11.99
Microcontroller	Atmega32	1	$5.46
Vibration Motor	ROB-08449	1	$2.15
Piezoelectric speaker	CPT-1625-80-SMT-TR	1	$1.53
Rocker switch	KGC2ANB1BBD	1	$5.36
Push button	KFB2ANA1BBB	1	$3.85
Total Cost	**$340.59**		

3.1.2 Labor

From the ECE Illinois website, the average starting salary for a student graduating with a degree in computer engineering is $84,250 [10]. If working 52 weeks a year for 40 hours a week that salary is equivalent to earning $40.50/hour. We estimate our work period to be 16 weeks with an estimated work week of 15 hours per week. For three people this would lead to a total cost of:

3 people x $40.50/hour x 15 hours/week x 16 weeks x 2.5 = **$72,900**.

3.1.3 Total Cost

$340.59 (Parts) + $72,900 (Labor) = **$73,240.59**

3.2 Schedule

Week	Neva	Aditi	Nick
2/24	Complete Design Document		

	Initial conversation with machine shop		Research antenna design
	Purchase radar sensor	Research microcontroller to use	Component List
3/02	PCB Design and order		
	Purchase Components		
	Power Subsystem Testing		
3/09	Solder		
	I2C debugging	Microcontroller Programming	Radar Testing
3/16	Spring Break		
3/23	Radar Testing and Debugging		
	Finalize Machine Shop Design		
3/30	Radar Testing and Debugging		
4/6	Radar Testing and Debugging		
	Final Assembly, Report, and Presentation		
4/13	Final Report and Presentation		
4/20	Mock Demo		
4/27	Demonstration		
5/4	Final Presentation		

4. Ethics and Safety

There are a few safety hazards that must be taken into consideration with our product. As an electrical device designed to be used outdoors, the device will be subjected to conditions such as potential water damage or being accidentally stepped on. Our component could also be conductive if there is any short or open circuit. Thus to avoid all these problems we'll make sure the electrical component is well covered to protect the system and the user.

We are using rechargeable batteries to power all our other subsystems so we need to make sure that the power subsystem is secure and doesn't heat up with long duration of use since it could be uncomfortable for the user and harmful to the other subsystems.

Since our product caters to the need of visually impaired, we must be realistic in stating claims about the features and success of the product, in accordance with IEEE Code of Ethics #3 [8]:

'to be honest and realistic in stating claims or estimates based on available data'.

We will make sure we vigorously test our product with different parameters each time to get a better accuracy of the success of our product.

Since we'll need to test the product with an actual vehicle approaching at different speed and distance we need to ensure the safety of our team which adheres to ACM Code of Ethics #3.1 [9]:

'Ensure that the public good is the central concern during all professional computing work'.

This covers the point that we create the most optimum design for the safety of our target customers as well.

For the success of this product we will consider all the constructive criticism and suggestion on improving the performance which adheres to the IEEE Code of Ethics #7 [8]:

'to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others'.

We understand the difficulty of our project and that it'll require a great level of testing and modification to be finally used as a product that visually impaired can rely on.

5. Citations and References

[1] NHTSA, “Travel Safety Facts”, 2018 [Online]. Available: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812493. [Accessed: 13-Feb-2020].

[2] M. Write, ‘Electric cars are 'silent killers' visually-impaired woman warns after near miss’, *The Telegraph,* 2019. [Online]. Available: https://www.telegraph.co.uk/news/2019/11/20/electric-cars-silent-killers-visually-impaired-woman-warns-near/. [Accessed: 13-Feb-2020].

[3] SINTEF, ‘Electric cars are a hazard for blind people’, *Phys.org*, 2018. [Online]. Available: https://phys.org/news/2018-10-electric-cars-hazard-people.html. [Accessed: 13-Feb-2020].

[4] K. Marchese, “blind inventor creates 'smart cane' that uses google maps to navigate visually impaired people”, *Design Boom,* 2019. [Online]. Available: https://www.designboom.com/technology/wewalk-smart-cane-google-maps-visually-impaired-09-12-2019/ [Accessed: 27-Feb-2020].

[5] UltraCane, “UltraCane”, *UltraCane*, 2011. [Online]. Available: https://www.ultracane.com/ultracanecat [Accessed: 27-Feb-2020].

[6] B. Dybwad, “BAT ‘K’ Sonar Cane”, *Engadget*, 2005. [Online] Available: https://www.engadget.com/2005/04/07/bat-k-sonar-cane/ [Accessed: 27-Feb-2020].

[7] S. Yin, “Why is creating electronic canes for the blind so hard?”, *Whyy*, 2019. [Online] Available: https://whyy.org/segments/why-is-creating-electronic-canes-for-the-blind-so-hard/ [Accessed: 27-Feb-2020].

[8] Federal Register, “Federal Motor Vehicle Safety Standards; Stopping Distance Table”, 1999. [Online] Available: https://www.federalregister.gov/documents/1999/09/07/99-23226/federal-motor-vehicle-safety-standards-stopping-distance-table [Accessed: 27-Feb-2020].

[9] *2020 Rules of the Road*. Office of the Illinois Secretary of State. Available: https://www.cyberdriveillinois.com/publications/pdf_publications/dsd_a112.pdf [Accessed: 27-Feb-2020]

[10] ECE Illinois, “Salary Averages”, *ECE Illinois*, 2014. [Online]. Available: https://ece.illinois.edu/admissions/why-ece/salary-averages.asp. [Accessed: 27-Feb-2020].

[11] IEEE, "IEEE Code of Ethics", 2020. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html/. [Accessed: 13-Feb-2020].

[12]ACM, “ACM Code of Ethics and Professional Conduct”, 2020. [Online]. Available: https://www.acm.org/code-of-ethics [Accessed: 27-Feb-2020].