

Final Project Report
Navigation Systems for the Visually Impaired
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Abstract

The purpose of our project is to create a product for people with visual impairments that can address some of the shortcomings of navigation systems that are currently on the market, such as the white cane or service dogs. We approached this problem by attaching ultrasonic sensors to a white cane, which is essentially a stick that is held out in front of the user in order to give advance notice if they are to walk into something. Our sensor can pick up on objects that are further from the user than the range of the white cane, and then the arduino code allows the sensor to vibrate a motor in the handle of the cane, thus providing feedback to the user about the various locations of objects. This device will hopefully aid in the day to day lives of people with visual impairments by having the capability to act as a modification to the current white cane that the user is already familiar with. This modification will increase range and data about surroundings to the user, thus improving on the current model of the white cane. Through testing, we were able to assess the durability, portability, and overall function of the smart cane, and we can conclude that it meets our criteria for being a functional product, as it is durable, portable, and allows the user to navigate around objects with ease.

Project Scope

Our clientele includes people with visual impairments. People with visual impairments generally use some sort of aid when navigating a crowded or unknown space. The most common and widely used options available to them include either a white cane or a service dog. A service dog guides the user through the environment, but it has its limitations as it is a breathing animal that requires care. The other, most common option is the white cane. A white cane looks like a stick, and a person using this device would navigate an area by holding this cane out and feeling around for objects in the area (See Figure 1). If the cane makes direct contact with an object, then the user will be alerted and thus avoid the object. The main benefits of using a basic white cane is that it is cheap, easy to use, durable, portable, and the design alerts others in the area that the user has a visual impairment. In order to maximize the effectiveness of our design, we wanted these benefits to apply to our cane as well. Therefore, our design of a white cane modification that utilizes an ultrasonic sensor and a vibrating motor would have the criteria of durability, portability, ease of use, cost efficiency, and also the overall ability to detect objects and convey this data to the user. For our smart cane to be efficient, it would need to meet all of these criteria and therefore be an easy and cheap way to increase user data for someone who requires a visual aid.

Figure 1: People using a white cane

Design Requirements

Our purpose in developing this smart cane has been to aid people with visual impairments so that navigating spaces is easier. The criteria that we have decided on for this product has been for it to be easy to use, durable, portable, reliable, and functional. For our cane to be successfully easy to use, it would be ideal for it to be similar to a traditional white cane in that the user needs to walk with it held out and wait for feedback from the vibrating motor to alert the user of incoming obstacles. This would allow our design to be similar to a device that the user is already familiar with. A way to turn the sensor on and off would also allow for the product to be easy to use and easy to turn off in the event that the user does not need the sensor at a given time. For the product to be durable, we want to ensure that the wiring and electronic components do not break when the product is being used, and that the general wear and tear on the object that comes from use in various environments is kept to a minimum. As far as the portability of the device, it is ideal that our product maintains the ability to fold up in the way that a traditional white cane does without the added electronic components getting in the way. For the reliable and functional elements of our design, we want our design to accurately detect obstacles in the way of the user, and then convey this information to the user via the vibrating handle without any issues or inaccuracies from either the motor or the sensor.

Design Alternatives and Process

Prior to choosing the Smart Cane as our final project, our team considered two other potential options in addition to the Smart Cane and analyzed the best project for our timeframe and skillset to help the visually impaired.

1. Traffic Light Sensor
 - a. Receives signal from traffic light
 - b. Tells visually impaired user when to cross
 - c. Tells visually impaired user what time light will switch

2. Handheld Room Scanner
 - a. Uses LiDAR technology to scan the room/environment
 - b. Notifies user of obstacles in a room after scanning
 - c. Provides audio feedback to inform user where obstacles may be

3. Smart Cane
 - a. Uses an ultrasonic sensor to calculate distance between cane and closest object
 - b. Sends user feedback through vibrating motor in handle
 - c. Interactive button so user can initiate distance calculation

Decision Analysis:

Criteria	Wt, %	Option #1: Smart Cane	Option #2: Light Reader	Option #3: LiDAR Scanner	Existing Product
Capital Cost	10%	< \$50.00	\$100.00	\$200.00	\$30.00
Yearly Operation	10%	\$5.00	\$5.00	\$5.00	\$0.00
Accuracy	30%	9/10	6/10	9/10	5/10
Portability	20%	7/10	10/10	10/10	8/10

Ease of Use	20%	7/10	8/10	9/10	8/10
Durability	10%	7/10	9/10	9/10	8/10
Total Score	100%	7.8	7.3	8.0	7.3

Ultimately, our team ended up choosing the Smart Cane because it did not already exist as a product, and we found it to be inexpensive compared to both of our other options. The Smart Cane also allowed us to reach our goals of making a working product while also pushing to challenge ourselves and learn new concepts along the way. While the LiDAR room scanner would have been the most technologically advanced and most revolutionary in terms of creating products for the visually impaired, we realized that we would not be able to create a viable product within our budget or understanding of engineering for the scope of GEEN 1400.

Initial Prototype Pictures:



Description of Final Design Choice

For our final design choice, we developed a modification to a traditional white cane. This modification includes an ultrasonic sensor that is externally mounted to the white cane, and relays information about the objects it detects to a vibrating motor on the handle using Arduino. A 3D printed sensor mount held the sensor at the correct angle near the bottom of the cane (Figure 2), and a 3D printed box (Figure 3) held our electronic components such as the battery and the Arduino nanochip.

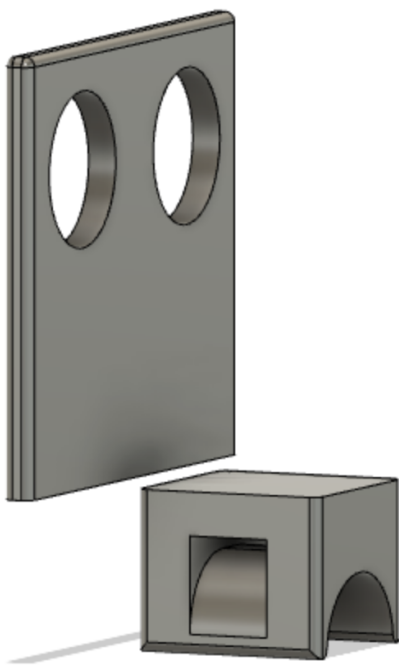


Figure 2: Sensor Mount

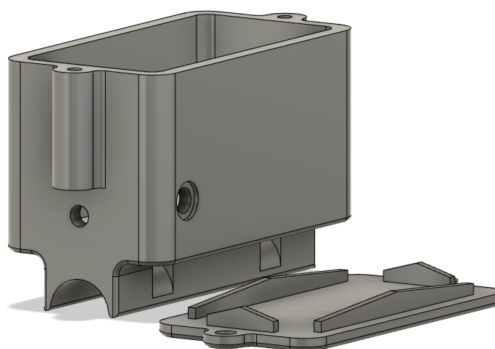
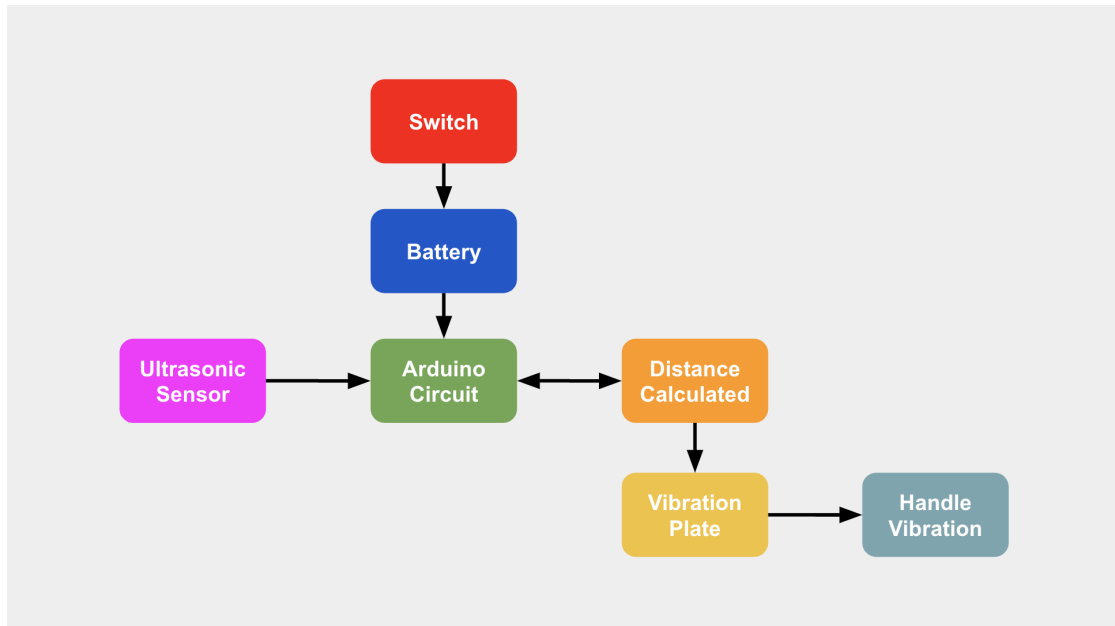


Figure 3: Electronic Components Box

A switch located on the box was able to turn the system on and off, and from there, a person could simply walk around a space that contained various obstacles. The ultrasonic sensor would detect these, and vibrate the handle of the cane to alert the user. A diagram of how this works is shown below.



Block Diagram of System

Our initial prototype of this device was a rapid prototype of a simple PVC pipe with weight attached to it. This served to model how it would feel to use a traditional white cane with the added weight that comes with the electronic components. A video of us using this prototype can be seen here: https://drive.google.com/file/d/1y2_dDMsLggfrfly-Ub-y87uEz07gZeY3/view?usp=sharing

From this prototype, we gathered that the weight from the electronics needed to be concentrated at the handle of the cane in order to minimize the torque on the user, so that the user does not become fatigued.

Our second prototype involved a functioning smart cane where the electronic components were taped to the handle, and the wires were not gathered. While this was lighter than our final design, it was less durable due to the electronic components being exposed, and the cluster of wires could potentially snag on something. This prototype also did not include the switch as an option to turn it on or off.



Adjusting this prototype to account for more durability and a cleaner more efficient design overall resulted in the wires being taped together and a box and switch being implemented to hold the electronic components. Therefore, our final design is as shown below.



This then resulted in our final circuit including a 9V battery, a battery regulator, our vibrating panel, our arduino nanochip, our ultrasonic sensor, and transistors. The diagram of this is seen below.

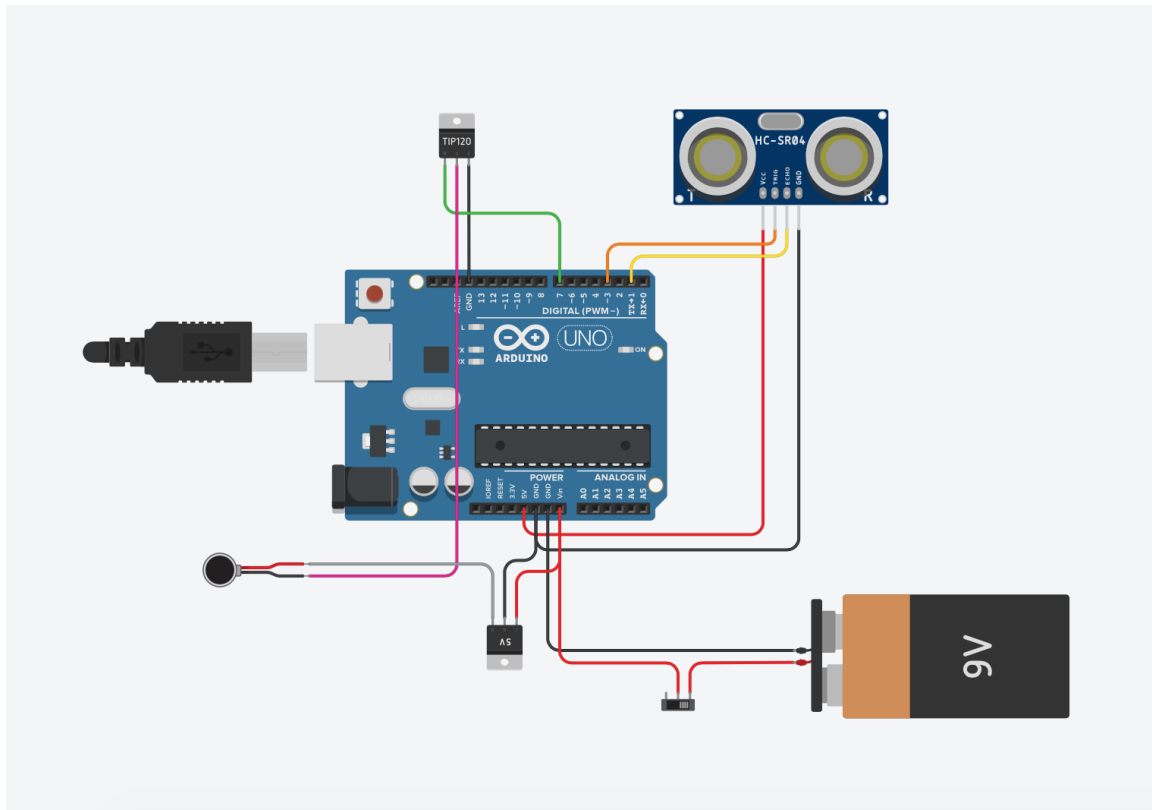


Figure 3: The final circuit

Critical Components

Due to the fact that the smart cane is a modular system that can attach to any white cane, the main part of the project is the electronics. The electronic system was composed of a battery that powers a motor, an ultrasonic sensor, and an arduino nano chip. When the system was changed to be as condensed as possible using a smaller arduino chip, the circuit stopped working. We learned that the nano chip can not supply sufficient current to run the system through testing with the multimeter and a power supply.

In an effort to remedy this, we tried many combinations of components to run the motor before we had success. The power had to be hooked straight to the motor while also being triggered by the board, so we used a voltage regulator to send the correct amount of power straight to the motor from the power supply. Another component was then added, called a transistor, which acts as a powered switch. When hooked up to the arduino board's trigger pin for the motor it would open and close the circuit for the motor. This combination of parts allowed us to bypass the board sending power straight to the motor and still have the motor turn on when it was triggered within the code (Figure 3).

Fortunately, setting up the ultrasonic sensor was a less difficult endeavor. We were able to find diagrams on how to set up the sensor as well as tips on setting up the code for object detection. The code was arranged so that multiple sensors could potentially be incorporated for increased accuracy (Appendix A). To begin, we set up a simple circuit that showed the distance values read by the sensor. This allowed us to find where the cone of detection emitted by the sensors was for the best accuracy as well as gaining a better understanding of the technology itself and the accuracy of it. This testing allowed us to learn where to best place the sensor on the cane and what angle to have it held at for the best results. We also did some testing with the

motor with how powerful the vibration is and how it translates through solid mediums. (Video of vibrating motor seen here:

<https://drive.google.com/file/d/13j8l8oRlww6uCjbH2RjFTCIOk1Ob96kH/view?usp=sharing>

)The original idea was for the user to have the hand on the motor but we were able to push more power to the motor to have a stronger vibration. This allowed us to attach the motor right below the handle which was still easily detectable and have a cleaner finished look.

Final Product Development

To go from our rapid prototype of a simple piece of pvc pipe with a weight attached to the final smart cane design we spent many hours on the development of multiple parts including CAD drawings done of Fusion 360 and circuitry.

We started with the development of our circuit. No one in the group had a very profound understanding of circuitry. We started with a breadboard/ arduino board mock up of the circuit to try our best to figure out the most basic way to connect our ultrasonic sensor to the arduino board. We sourced our code from a reputable arduino website and edited it to fit our uses. We had to change where the code was sourcing inputs depending on where we got plugged in our sensor. And also the distances at which the ultrasonic sensor would activate. We repeated a similar process to plug our vibrating motor into the circuit, and again altered the code so that the motor would turn on when the ultrasonic sensor detected a distance under 3 feet. Finally, we found that a switch would be necessary to avoid the circuit constantly drawing power and to allow the user to turn off the vibrating function to return temporarily to a normal cane. The entirety of the circuit was simulated on TinkerCad before soldering to the arduino nano.

When it comes to the computer aided design side of the product our needs were quite simple. We needed first a way to affix our ultrasonic sensor to the cane, which required a few simple measurements and simple geometric figures to design. And second, a housing for our electronics system. This part was a little bit more technical as it required perforations on the front and back side of the box for wires running up and down the body of the cane. As well as a slot for the switch which also required a thinner body wall in order to hold functionality. Finally, we made the lid semi permanent by allowing it to be fixed with a simple phillips head screw. All while keeping the entirety of the component as small, compact and light as possible.

Analysis and Testing

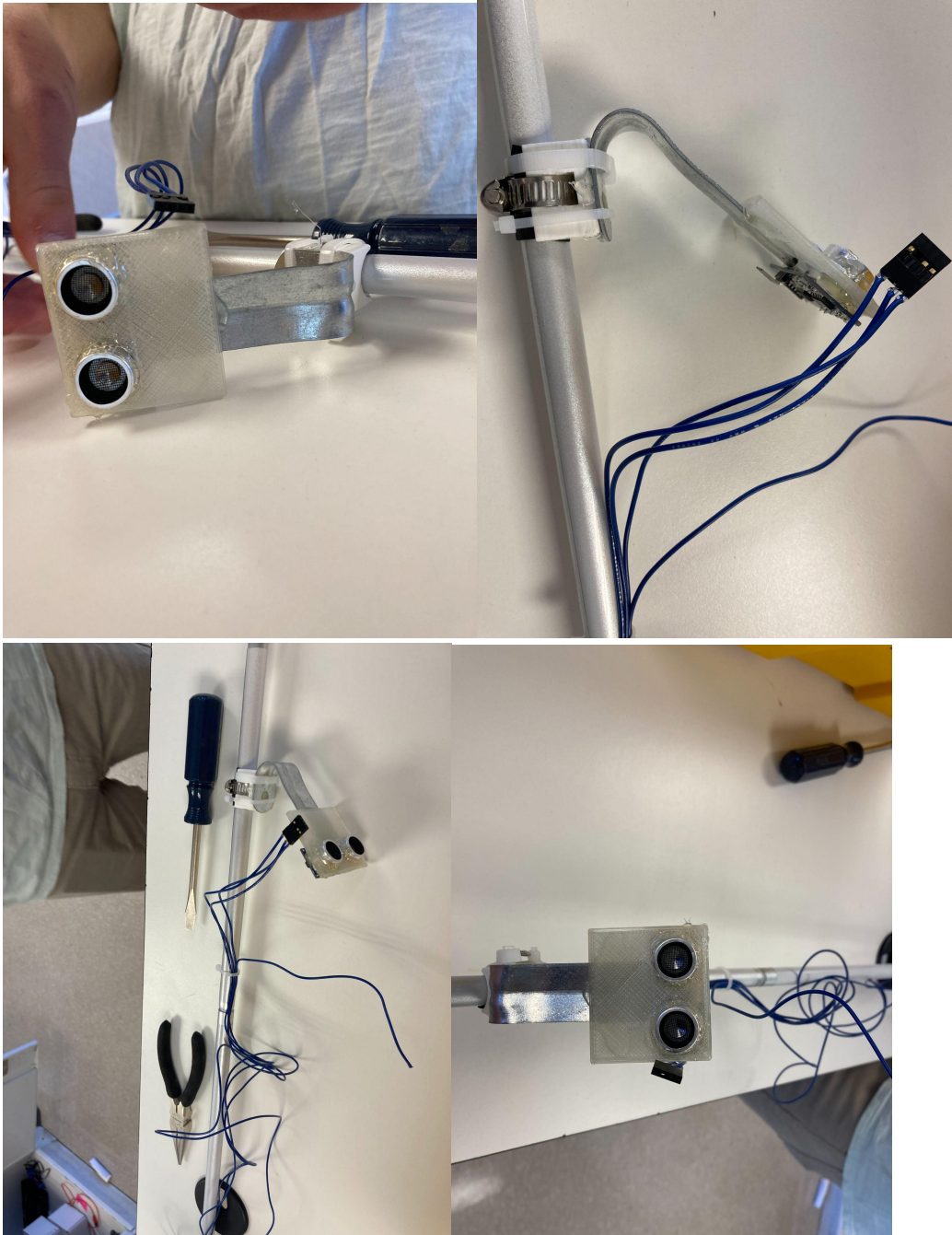
Our purpose in developing this smart cane has been to aid people with visual impairments so that navigating spaces is easier. The criteria that we have decided on for this product has been for it to be easy to use, durable, and reliable. Therefore, various aspects of the cane will be tested, including both how well the electronic components perform as well as the durability of the cane body.

The aspects of our product that we will be testing includes the following:

1. Testing the effectiveness of the ultrasonic sensor.
 - Ensuring that distance is measured accurately and in real-time
2. Testing user feedback while the cane is in use
 - Making sure potential users are able to receive vibrations from the cane when within set range of ultrasonic sensor detection
3. Testing durability of cane
 - Using cane in various indoor and outdoor environments and weather conditions
4. Testing portability of cane
 - Ensuring that cane is collapsible without disrupting internal wiring and functionality easily

To test the ultrasonic sensor itself, we will do isolation testing and place objects in front of the sensor alone at a distance of three feet or closer, which will be measured with a tape measure. We will see how well the sensor alone can detect various objects, and this will also test how well the sensor is able to provide feedback to the vibrating motor.

Photos of the ultrasonic sensor attached to the cane can be seen below.



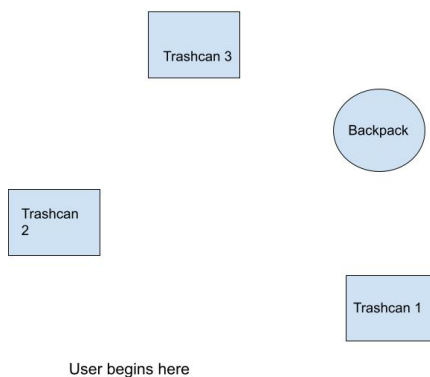
In order to test the effectiveness of the ultrasonic sensor on the cane, we will create an obstacle course containing various objects of different sizes. These objects will also be in various locations relative to the cane, including to the left, right, and off the ground. This will allow us to see how well the cane is able to detect different obstacles of different placements.

To test user feedback, users will be blindfolded and operate a maze-like obstacle course. Navigating the obstacle course solely using feedback given by the cane will allow us to examine how effective the cane is at both detecting the obstacles and communicating this data to the user. The cane will be tested on how well it can give advance notice of an obstacle in order to deter the user from a collision, as well as how fast the user can navigate the course using the aid. The maze will be created beforehand with the testers unable to see what it looks like. First there will be a control that does not utilize the ultrasonic sensor, and then the cane with the ultrasonic sensor will be used in order to navigate the maze.

The durability of the cane will be tested through using the cane in a variety of environments. A user will walk with the cane outside for ten minutes, and inside for ten minutes. After this, the wear and tear on the cane will be assessed by observing if there is any damage to the structure of the cane or to the electronics.

The cane will be collapsed and then uncollapsed several times, the cane will then be inspected to see if any of the electronics on the cane have been disturbed by this process.

Diagram of Obstacle Course Used



1. Test of the sensor alone in addition to the sensor motor system

<https://drive.google.com/file/d/1XJhBbttKoxpqI-ZdBnm6r2pEY1GRXRBo/view>

The sensor is shown to be incredibly accurate and is able to sense obstacles at a distance of exactly three feet.

2. Obstacle Course (First Trial)

Run #	Tester	Objects Hit	Effectiveness Rating (Out of Ten)
1	Chris	1	6
2	Greg	2	5

When testing the obstacle course, both of our users were able to navigate through the course. However, some issues were encountered when one of the obstacles was hit during the trial. The ability of the users to get through the course while avoiding the majority of the obstacles leaves the effectiveness rating of the cane at 6 and 5. It should also be noted that those testing the cane are not blind and therefore are not familiar with a white cane in the way users would be. (Videos of this testing can be seen here:

<https://drive.google.com/file/d/1LgKuwQw3-nSZjbIVVNCIcizKCB59FwG7/view?usp=sharing>

- <https://drive.google.com/file/d/1Bh9Dfi4uw3K5QV5tE8f2NPABBAXiwmb4/view?usp=sharing>)
3. User Feedback (First Trial)

Run #	Tester	Motor Effectiveness Rating	Feedback Rating
1	Chris	8	6
2	Greg	8	6

The data picked up by the ultrasonic sensor was conveyed to the user, and there were no issues with the motor not working. However, the motor appeared to be vibrating constantly during the course, which could be an issue with the sensor or with the code. The motor does not vibrate at different rates for different distances, however, this is something that we would add as a feature to the cane if given the time. The issue with this course was that the motor was vibrating to alert the user of objects, but it also appeared to vibrate even if there was nothing in front of the sensor.

4. Durability

Run #	Tester	Inside Durability	Outside Durability
1	Chris	10	9
2	Greg	10	9

There was no damage to the cane observed when used in a variety of settings, both inside of the ITLL as well as in the 45 degree Fahrenheit weather conditions outside. However, there will still be casing for the electronic parts in case of more incremental weather conditions.

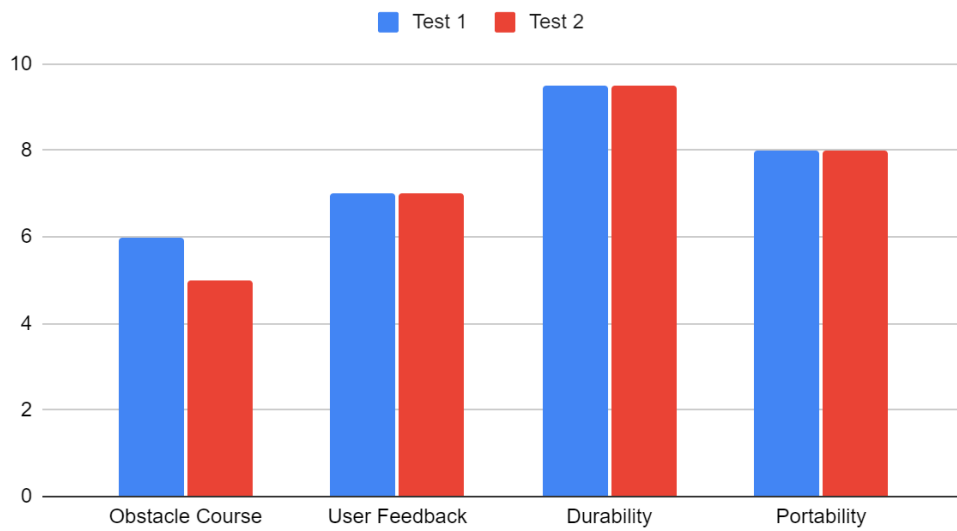
5. Portability

Run #	Tester	Portability Rating
1	Chris	8
2	Greg	8

Folding and unfolding the cane was not incredibly difficult, and nothing appeared to fall out of place, however, the abundance of wires got in the way to a small extent, so mitigating this will improve the portability of the cane. The image below demonstrates the collapsibility of the cane.



Test 1 v.s. Test 2 Effectiveness



The two original tests were fairly similar in the ratings of the elements of the smart cane that we were testing.

As far as final product testing, several users tested the functionality of our final design that included a cleaner look as well as a switch that turned the modular system on and off. This testing went extremely well and the testers were able to report that the cane could detect objects at three feet and convey this data through the vibrating motor in all scenarios. Therefore, our final product was incredibly successful and effective in its purpose of alerting users of obstacles in advance. Test runs by various users can be seen below:

https://drive.google.com/file/d/1e-Zk1iQtZmF-TXy8_Ht9AdofHqNN9ACj/view?usp=sharing

<https://drive.google.com/file/d/1dcX9fyVa0kv0gjVfkIg9o-Iem5UC0shg/view?usp=sharing>

<https://drive.google.com/file/d/1zY0XaK9tNaknX8PMBMO90TFqbL2qB6g4/view?usp=sharing>

<https://drive.google.com/file/d/1I0II9c5rleu3JYZRbIeVc-pxawPVu2YD/view?usp=sharing>

In all cases, these users reported that the cane was easy to use and was able to accurately detect obstacles as well as show a clear path for the user.

Future Directions

If this cane were to be improved upon in the future, our main goals would be to increase the amount of data available to the user as well as increasing how much the user is able to adjust the settings of the cane to their liking. The ideas that we have to accomplish this include an adjustable knob on the handle of the cane that could change the distance that the sensor is set to read at. Therefore, the user could potentially change the distance sensor to detect objects at anywhere between one to six feet depending on user preferences or even based on the environment the cane is being utilized in. Another potential improvement would be adjusting the code for the vibrating motor so that it either vibrates at a certain intensity or a certain amount of times based on how far away the object being detected is. Furthermore, ways to add to the cane's functionality that we have discussed are adding more sensors to the cane, and creating a hinge on the sensor mount so that the user could adjust the angle to gather data from spaces at head or waist level that the bottom of a traditional cane would not pick up. While these are endeavors that we would like to undertake, it was not possible to accomplish all of this given the time and budget constraints of this project.

Conclusion

Our goals for this project were to create a modification to a traditional white cane that is able to provide increased information on the location of objects without taking away from the durability, portability, and ease of use that is seen in a traditional white cane. Through user testing, we are able to conclude that our goals have been met as the cane is clean and easy to fold down, durable due to the protected electronic components, and effective as user testing shows that the cane is able to detect objects and provide accurate feedback to the user via the vibrational plate in the handle. Therefore, our cane is still low-cost while allowing a user to navigate an area in a more efficient manner without infringing on the benefits of the original white cane, which is shown through the various videos of users utilizing the cane to interact with their surroundings. While more sensors and knobs for user adjustment would be ideal if more work were to be done on this project, the effectiveness of our basic design of the smart cane is able to open avenues for further improvements on navigational aids for the visually impaired using technology, as these sensors could be used in a variety of ways to help people with visual impairments navigate various environments. Ideally, the smartcane would be user-adjustable for the angle and distance that the ultrasonic sensor reads at, while also incorporating multiple sensors for a more comprehensive understanding of the surroundings that would be communicated via the handle. While this could not be accomplished during the time period given, these additions would further improve the range of data that is available to the user, thus being a more effective navigational aid to our clientele.

Budget and Bill of Materials

MATERIALS (on cane)	COST	SOURCE
Arduino Nano	\$6	www.amazon.com/ELEGOO-Arduino-ATmega328P-Without-Compatible/dp/B0713XK923/ref=sr_1_1_sspa?keywords=arduino+nano&qid=1638645379&sr=8-1-spons&psc=1&sp
Ultrasonic sensor	\$4	https://www.sparkfun.com/products/15569
9 volt battery	\$3	https://www.amazon.com/ Energizer-Alkaline-General-Purpose-Battery/dp/B00003IE4E/ref=sr_1_8?crid=2S93OUHQUIOYZ&keywords=9v%2Bbatteries&qid=1638646104&s=hpc&sprefix=9v%2B%2Chpc%2C418&sr=1-8&th=1
Vibrating motor	\$2.15	https://www.sparkfun.com/products/8449
Switch	__\$	ITLL electronics center
transistor/ voltage regulator	__\$	ITLL electronics center
wires	__\$	ITLL electronics center
PLA (3D print material)	__\$	Previous project
Clamps	__\$	ITLL consumables
Zip tie	__\$	ITLL consumables
Shrink wrap	__\$	ITLL consumables
	TOTAL \$15.15	

After taking into account the materials we got for free and the bulk prices we would be able to put our product out on the market for **\$20**

(a high quality folding white cane can cost between \$10-\$15)

For clarification, the above chart describes the items which were placed on the actual cane. Our team was forced to spend slightly more because items like the arduino nano were bought as a 3 pack, and we did not include the cost of the cane because our final product only includes the modular attachment we attach to customers' current cane. The breakdown of what we spent is below.

MATERIALS (bought)	COST	SOURCE
Arduino Nano	\$17.99	www.amazon.com/ELEGOO-Arduino-ATmega328P-Without-Compatible/dp/B0713XK923/ref=sr_1_1_sspa?keywords=arduino+nano&qid=1638645379&sr=8-1-spons&psc=1&sp
Ultrasonic sensor	\$3.95	https://www.sparkfun.com/products/15569
9 volt battery	\$6.99	https://www.amazon.com/Energizer-Alkaline-General-Purpose-Battery/dp/B00003IE4E/ref=sr_1_8?crid=2S93OUHQUIOYZ&keywords=9v%2Bbatteries&qid=1638646104&s=hpc&sprefix=9v%2B%2Chpc%2C418&sr=1-8&th=1
Vibrating motor	\$2.15	https://www.sparkfun.com/products/8449
Foldable Smart Cane	\$12	https://www.amazon.com/gp/product/B08DJDB33X/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1
	+ Shipping	
	TOTAL \$60.00	

Timeline

Week #1

Sketch and create digital prototypes

Week #2

Order materials and start first draft prototype

Week #3

Prepare for critical design review

Week #4

Finish first prototype and asses performance

Week #5

Start building Smart Cane shell and hardware components

Week #6

Work on electrical wiring and software components of the Smart Cane

Week #7

Perform testing and fix potential problems regarding target clientele

Week #8

Add final touches and finish final product

Week #9

Prepare for final expo and finalize report