Real-time obstacle detection to assist wheelchair navigation

Acceptance & Delivery Review

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LightSight: LiDAR and sonar-based real-time obstacle detection

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Engineering Goal

A visually-impaired wheelchair user has difficulty navigating obstacles in their environment, Our engineering goal is to build, test, and deliver an obstacle detection device which alerts the user of obstructions to their movement path.

Background

STATISTICS

The American Federation for the Blind estimates 14.86% of individuals who are legally blind or have serious visual difficulties use a wheelchair (Simpson et al., 2005).

THE CLIENT

This product was designed for a visually impaired individual , who uses a manual wheelchair.

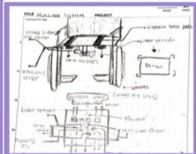
THE SOLUTION

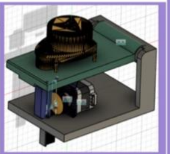
A LiDAR sensor will be mounted on a tilting mechanism above the head of the user. In addition, sonar sensors will be mounted below the wheelchair.

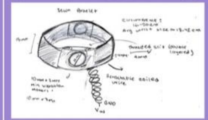
GOALS

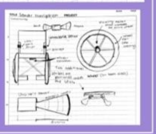
The goal is to increase independence and mobility for visually impaired wheelchair users.

Preliminary Designs









Decision Matrix

Requirement	Level	Type	Verison 1 - SONAR Only	Verison 2 - LiDAR Only	Verison 3 - SONAR and LiDAR
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The device must be able to sense obstacles three-quarters of the way up from the floor to the top of the wheelchair.	2	functional	fail	fail	fail
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Must sense 360° around the user.	2	functional	fail	pass	pass
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The total price of the device must not exceed 125 USD, excluding already obtained and borrowed materials.	1	cost	pass	pass	pass
The user must be physically capable of operating a manual wheelchair.	1	user	pass	pass	pass
The device shall include a user manual detailing the operation and capabilities of the apparatus.	1	documentation	pass	pass	pass
The device will include documentation specifying the design, materials, and data collection/analysis.	1	documentation	pass	pass	pass
The device shall include figures/diagrams regarding its installation.	1	documentation	pass	pass	pass

Results and Testing

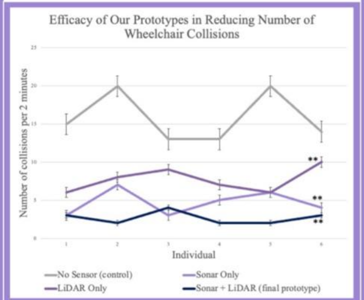


Figure 1: Iterations of prototyping and number of collisions for each. Significant p values for each prototype in comparison with control. Complete system had highly significantly less collisions (**p = 0.000002648).

Final Design

LiDAR sensor mounted above wheelchair, sonar connected to each footrest, two bracelets (left and right) with vibration modules in each.

Bracelets with Vibration Modules

Sonar Sensors on Footrests

LiDAR Sensor

Completed Prototype

Conclusion

Our system was successful in reducing the amount of wheelchair collisions in two minutes. The sonar and LiDAR system reduced collisions significantly (*p = 0.000002648). In addition, the complete system perform significantly better than both other iterations (*p = 0.022963, **p = 0.000053), proving to be the best option.

Our multifaceted approach means we have the ability to make updates and edits more easily. In addition, our Velcro attachment system would make the system more applicable to different wheelchairs.

Process

LiDAR and Tilting Mechanism
A LiDAR sensor was mounted on a tilting mechanism, connected to a stepper motor.

Sonar and Bracelet
Sonar sensors were connected to vibration modules, that were attached to a watch band.

Code and Parameters
Code was written according to desired distances before vibration occurred.

Printing Attachments
3D printing and CAD were used to design attachments for the LiDAR and sonar sensors.

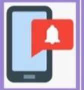
Testing
The subsystems were combined and attached to the wheelchair to begin testing.

Data Collection

Data was collected through a series of tests run on a sample obstacle-filled pathway. Each group member was blindfolded and asked to navigate the path first using the wheelchair only. Then, the process was repeated with the prototype attached to the wheelchair. Number of collisions along with total time were collected for each run.

Future Work

- Enable real-time topography analysis and mapping of the user's environment to provide programmed routes
- Utilize mobile notifications to alert caretakers or loved ones of potential collisions
- Deploy electromagnetic or other automated braking system to protect users
- Optimize the apparatus for cost and production scale



Engineering Problem and Goal

Problem

- An individual with a brain injury has difficulty navigating their home in a manual wheelchair due to impaired vision.
- Target Audience
  - Individuals with any degree of visual impairment who use a manual wheelchair.

Goal

- The goal of this project is to design an attachable device for a wheelchair that allows a client with a visual impairment to navigate their home with increased safety and ease.

Requirements

Level 1:

- System can alert user of obstacles
- Feedback system does not rely on vision
- The device is fully attached to the wheelchair
- Device is well-documented
- Cost to group does not exceed 125 USD

Level 2:

- System can detect elevation drops
- Device can function in dark conditions
- Device and all accompanying parts weigh less than 5 lbs

Level 3:

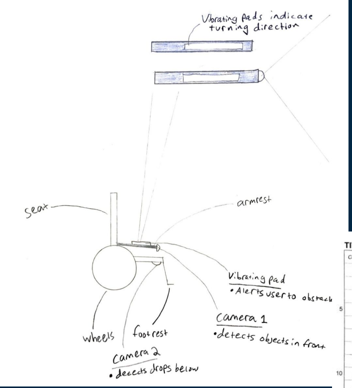
- Feedback is customizable to user
- Device proposes alternate route

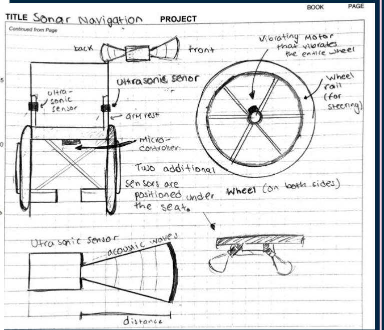
PDR Designs

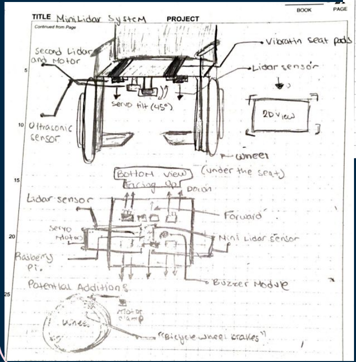
Design 1 Summary:
- Camera on arm rests, buzzer modules

Design 2 Summary:
- Infrared sensor, vibrating motor

Design 3 Summary:
- LiDAR sensor, vibrating pads







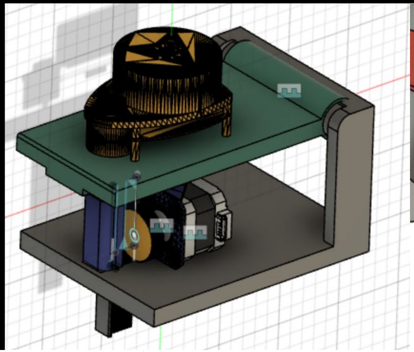
CDR Designs

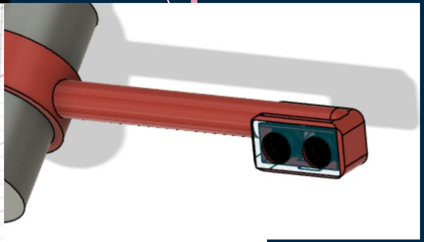
Main Design Presented:

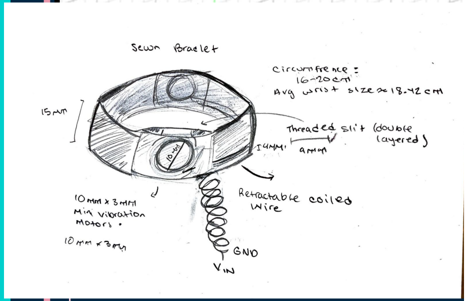
- LiDAR Scanner
- Tilting mechanism
- Sonar
- Bracelet feedback system

Changes from PDR:

- **Combination of LiDAR and sonar**







Build Process

LiDAR Testing

We tested the LiDAR sensor both horizontally and vertically. Then we 3D printed a mount which connects the LiDAR to a stepper motor.

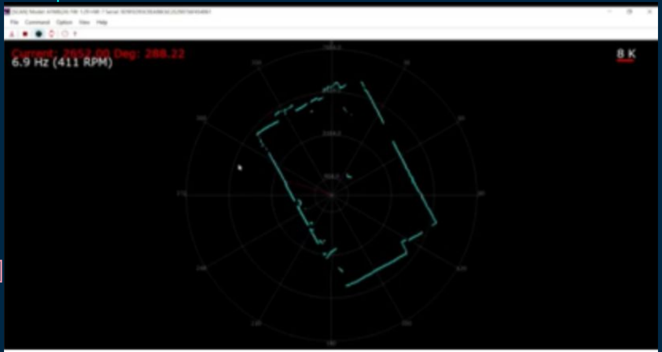
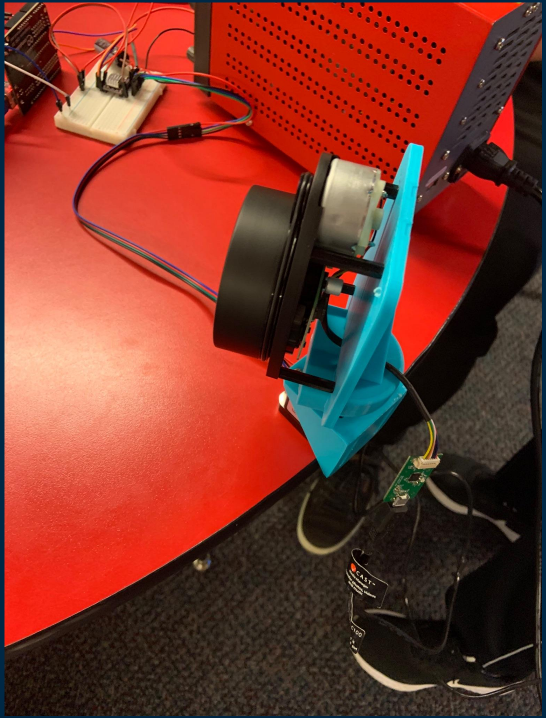
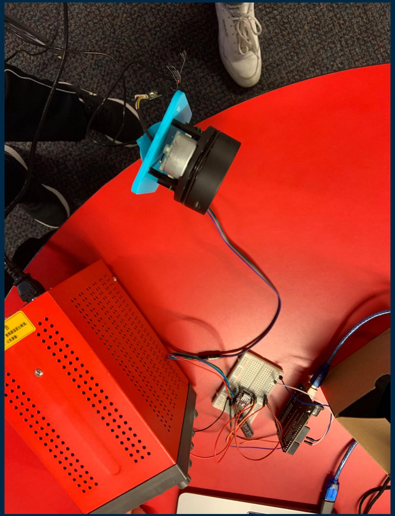


Figure 4: Map of Mass Academy math room, generated by LiDAR sensor.





Build Process

Proof of Concept

We started very preliminary proof of concepting for the LiDAR-wheelchair attachment to see how cardboard would react to someone sitting in the chair.

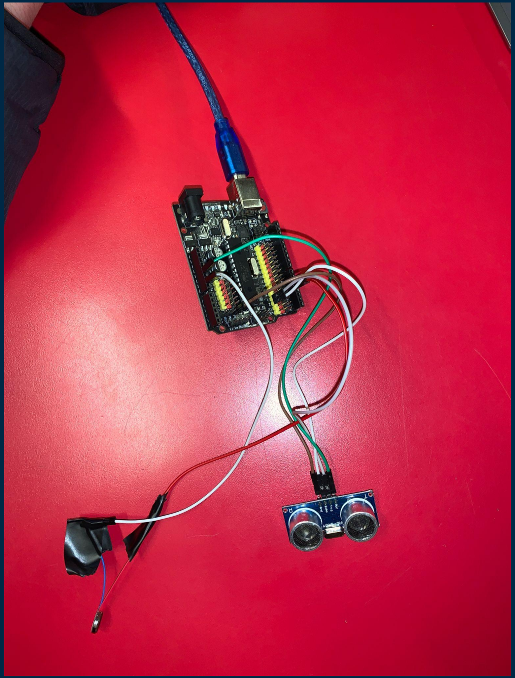
Before sitting in wheelchair

After sitting in wheelchair

Build Process

Sonar Testing

We experimented with sonar sensors and the sensor's code to determine the optimal range settings.

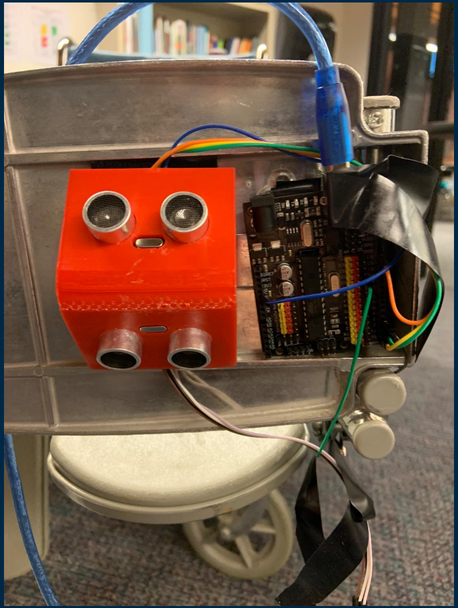


```
// --------------------------------------------------------------- //
// Arduino Ultrasoninc Sensor HC-SR04
// Re-writed by Arbi Abdul Jabbaar
// Using Arduino IDE 1.8.7
// Using HC-SR04 Module
// Tested on 17 September 2019
// --------------------------------------------------------------- //

#define echoPin 2 // attach pin D2 Arduino to pin Echo of HC-SR04
#define trigPin 3 //attach pin D3 Arduino to pin Trig of HC-SR04
#define outPin 4
// defines variables
long duration; // variable for the duration of sound wave travel
int distance; // variable for the distance measurement

void setup() {
  pinMode(outPin, OUTPUT);
  pinMode(trigPin, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPin, INPUT); // Sets the echoPin as an INPUT
  Serial.begin(9600); // // Serial Communication is starting with 9600 of baudrate speed
  Serial.println("Ultrasonic Sensor HC-SR04 Test"); // print some text in Serial Monitor
  Serial.println("with Arduino UNO R3");
}
void loop() {
  // Clears the trigPin condition
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  // Sets the trigPin HIGH (ACTIVE) for 10 microseconds
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration = pulseIn(echoPin, HIGH);
  // Calculating the distance
  distance = duration * 0.034 / 2; // Speed of sound wave divided by 2 (go and back)
  // Displays the distance on the Serial Monitor
  Serial.print("Distance: ");
  if(distance < 50){
    analogWrite(outPin, 256);
    delay(500);
    digitalWrite(outPin, LOW);
  }
  Serial.print(distance);
  Serial.println(" cm");
}
```

Build Process

Connecting Sonar to Vibration Modules

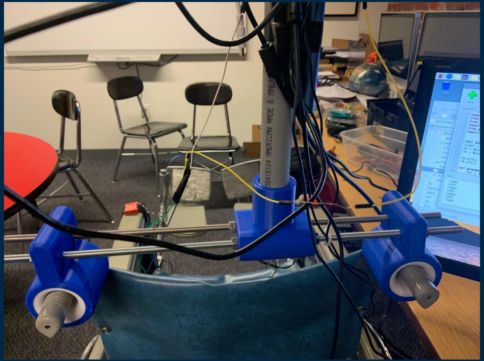
We connected the sonar sensor to buzzer modules and 3D printed casings for each. Then we were able to attach the buzzers to wristwatch straps.



Build Process

LiDAR Mount and Assembly

We attached the LiDAR to its mount, connected it to the wheelchair, and continued testing. Then we attached all cords and batteries to their positions.



Important Decisions Made

NOT USE STEPPER MOTOR

Very loud, made data hard to read

USE TWO SEPARATE ARDUINOS

Allows us to control left and right separately

CONNECT THE LiDAR TO RASPBERRY PI

Easier to program, better to have sonar, LiDAR on separate systems

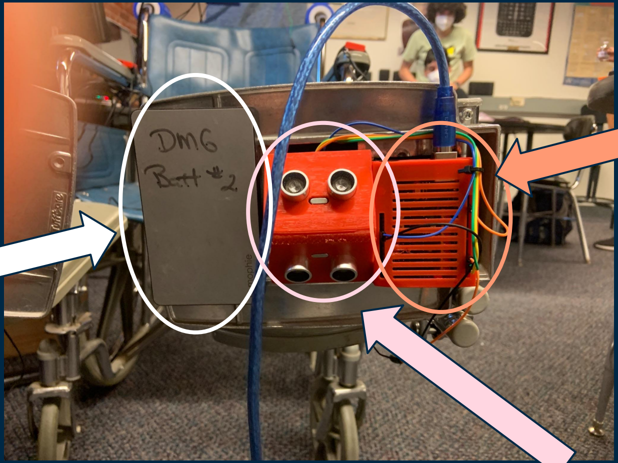
ORIENT LiDAR HORIZONTALLY

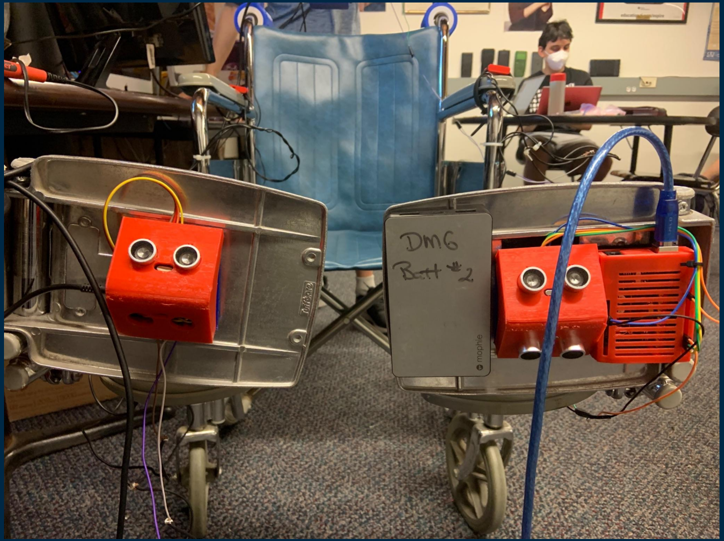
Easier to mount, better for reading data

Final Prototype

Sonar

Two sonar sensors, one on each foot rest. Able to be moved (Velcro attachment).





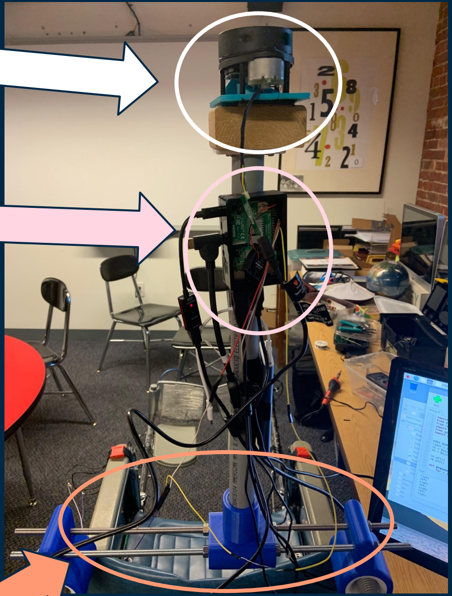
LiDAR

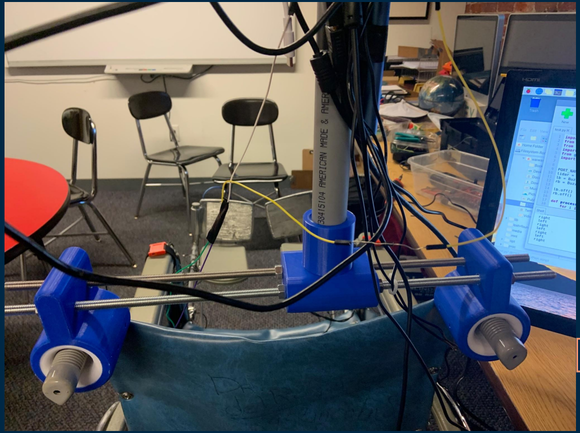
LiDAR Sensor

Raspberry Pi 4

One LiDAR sensor mounted above head of user.

Attachment System





Feedback System

One bracelet for each side (left and right) connected to each sonar sensor with influence from LiDAR.

Vibration Bracelets

Decision Matrix

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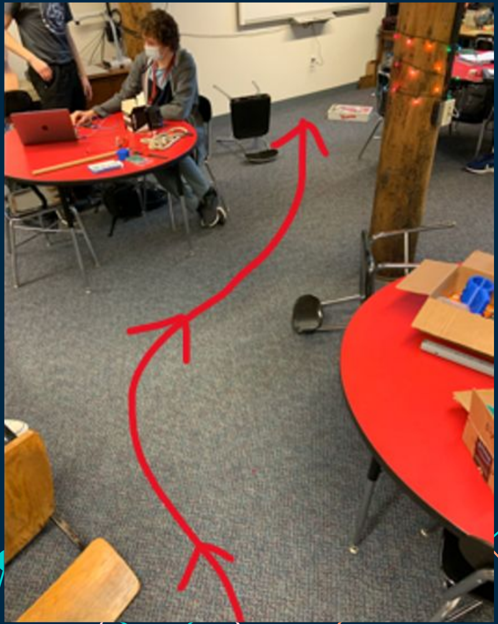
Testing

To test we set up a sample route and tested 6 individuals with no sensor, only one sonar, and the whole systems.



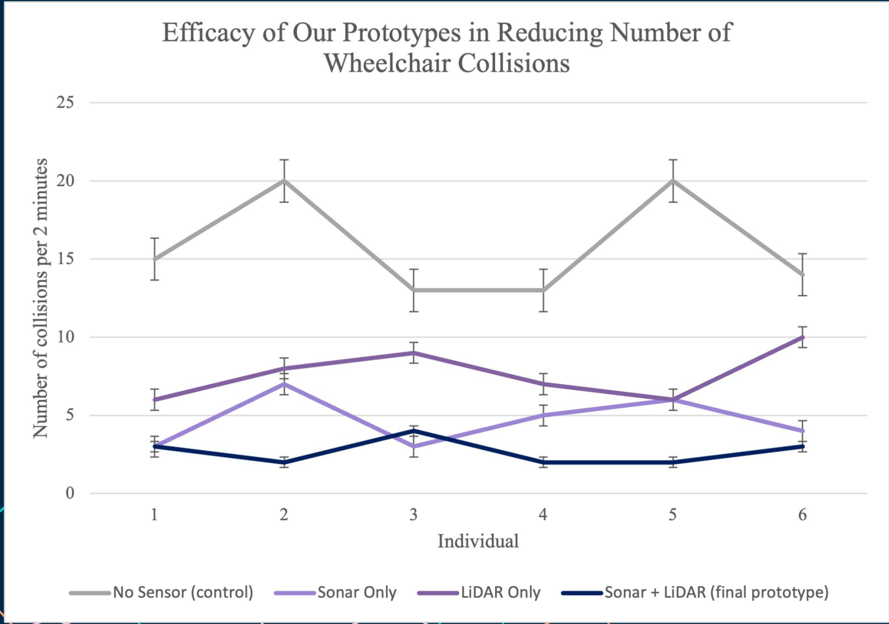


Figure 1: Iterations of prototyping and number of collisions for each. Significant p values for each prototype in comparison with control. Complete system had highly significantly less collisions (**$p < 0.01$).

Demonstration

Future Extensions

- Organize our different sensors in a way that they are able to work together
- Add more detailed information to our feedback system (for example right or left, or a voice system that provides more detail)
- Make the LiDAR mount more universal and mobile
- Potentially connect our system to an automatic wheelchair

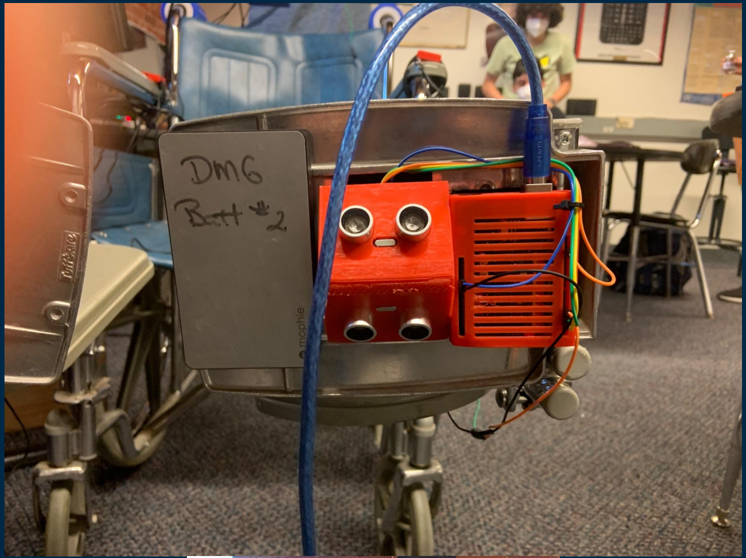
Lessons Learned

Throughout this project we:

- Learned the importance of teamwork
- Gained a greater appreciation for assistive technology and individuals with visual impairment
- Time-management
- Presentation and communication skills

Thank You

Any Questions?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