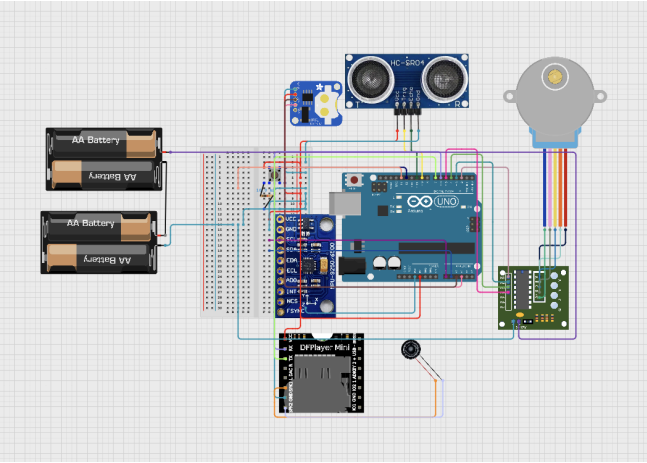
1. Executive Summary
    a. Brief overview of project
        i. Our project is Handl, a smart walking stick that sends vibrations and vocal feedback to visually impaired users if they are getting too close to an object. Additionally, Handl is equipped with a step counter and a fall detector, which provides the user with auditory feedback through a speaker.
    b. Key achievements
        i. As opposed to other walking sticks, Handl ensures the safety of those around the user because it is not required to swing the stick to tap objects, while also letting the user achieve their fitness goals and their physical health when in use. Furthermore, our design makes it so that adding and removing components to our product prototype is relatively easy, which lends to easier product adjustments. Finally, our product can be powered by battery only, allowing further mobility for the user, and implements 6 total Arduino libraries.
    c. Target market and applications
        i. The target market of this is the nearly 300 million people with MVSI, (moderate to severe vision impairment), where users see between 3x to 20x worse than someone with normal vision.

2. Problem Statement
    a. What problem does your project solve?
        i. Handl solves the problem of visually impaired people who need assistance with seeing objects when walking, but present a danger to the people around them from swinging the stick around. Handl also gives the user the option to get audio feedback instead of vibration feedback.
    b. Why is this problem important?
        i. This affects the confidence and independence of visually impaired people. Normally, they would have to depend on another person or might accidentally hurt someone with their traditional walking stick. By negating this issue, visually impaired people can walk around with less stigma around them.
    c. Current limitations in existing solutions
        i. The traditional walking sticks allow the user to tap their surroundings which might be harmful for people standing near them. Additionally, it's recommended for normal blind cane users to go through training first. Handl does not require any official training and can be integrated into daily life without hassle.

3. Target Audience
    a. Primary users/customers
        i. Our product is for people with blindness/who are vision impaired in need of walking assistance. We wish to cater to all ages and will make product adjustments as needed.
    b. Use cases and applications:
        i. Vision-impaired individuals walking around in public alone (e.g. downtown, at supermarket, in a park, etc.)
        ii. Object detection in pitch-black/near pitch-black environments where there's no light available
    c. Market size and potential
        i. Out of the 300 million people with MVSI, 2-8% use a blind cane- that's 6-24 million people. The market price for a blind cane is anywhere from $22-$70 depending on quality. The estimated cost of our product prototype is around $48, which is slightly lower than the typical good-quality cane on the market; with bulk ordering of parts, it can be even cheaper.

4. Circuit Design
    a. Detailed circuit schematic
        i. Here is our final schematic:

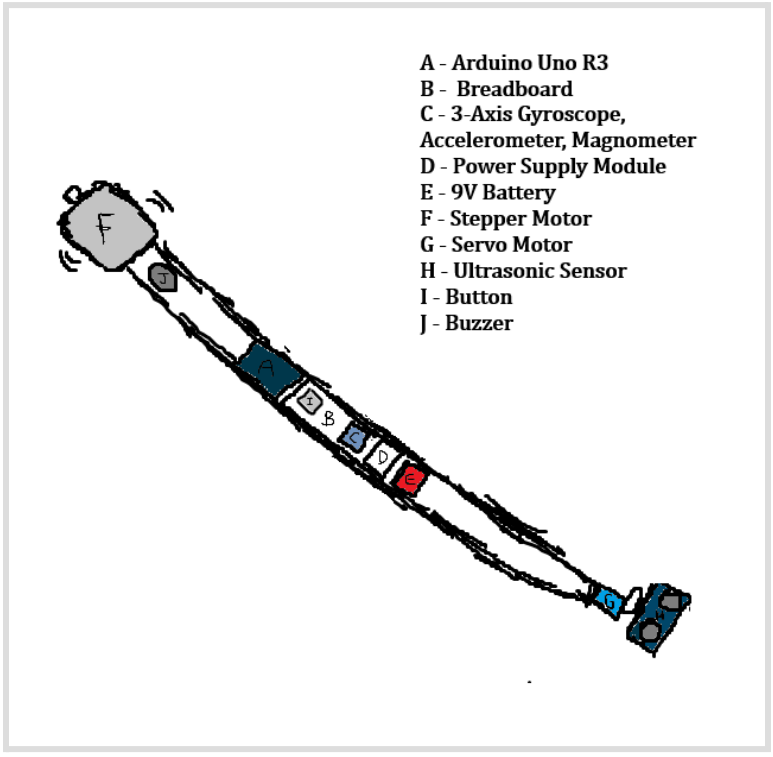


    b. Component specifications
        i. Power:
            1. Two of 2 x AA Battery Holder (with Knife Switch) connected in series to power the Stepper Motor separately. (Knife switch not necessary but good for voltage regulation.)
            2. 9V battery to power the Arduino.
        ii. Inputs:
            1. Ultrasonic Sensor

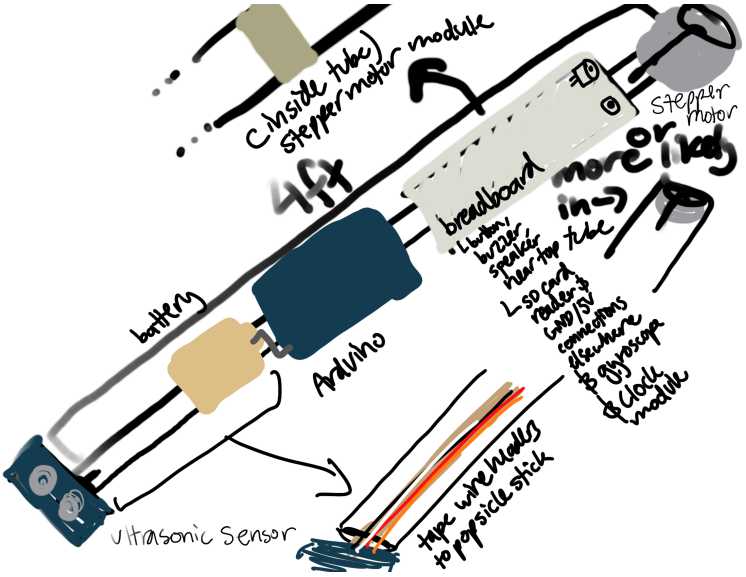
2. Button
3. Gyroscope
4. RTC Clock Module

iii. Outputs:
1. SD Card Reader + Speaker
2. Stepper Motor

iv. Control
1. Arduino UNO

5. Development Process
   a. Design methodology
      i. We picked which components were necessary for Handl and sketched out a prototype for component placement.
         1. 

      ii. After some testing, we adjusted our design and swapped components in and out. We made an updated sketch for component placement.

1. 

iii. When creating the physical prototype, we adjusted component placement to the various constraints that were present (such as wire tension and gravity).

b. Tools and software used
   i. Arduino IDE and Arduino Uno
      1. Scoured GitHub for Arduino library information
      2. YouTube videos to implement sensors
   ii. PVC Pipe to put together the structure of the device

c. Timeline and milestones
   i. Week 1:
      1. Learning about components and Arduino
   ii. Week 2:
      1. Meeting team
      2. Brainstorming Ideas
   iii. Week 3:
      1. Proposal Presentation
      2. Schematic and Wiring
      3. Finding and Solving Issues
      4. Ordering Necessary Parts (such as speaker and PVC pipe)
      5. Starting Code & understanding what each part does
      6. Critical Design Review
   iv. Week 4
      1. Finalize Code and Wiring
      2. Making Final Prototype
      3. Recorded MP3 Audio and Presentation
      4. Final Presentation Editing & Dry Run
      5. Final Event Presentation on Aug 3

6. Challenges and Solutions
    a. Technical challenges encountered
        i. Sophia 1: The 9v battery, by itself, was not powering the Arduino and letting the device run properly.
        ii. Sophia 2: At one point, my computer couldn't upload code to the Arduino.
        iii. Kazimir 1: My zipties kept sliding down by stick because they were only secured by gravity.
        iv. Sujitha 1: I had trouble with securing the wires on the board because whenever I tried to fix one wire another wire would come loose.
        v. Bailey 1: I had an issue where the battery packs from the stem kit were not providing power to the stepper motor, despite me verifying that they were working to an LED
        vi. Jazmine 1: I had trouble with the ultrasonic sensor giving inaccurate readings.
        vii. Jazmine 2: I overloaded the serial monitor the first time I wired up all components on the final prototype at the same time.
        viii. Jazmine 3: My 9V battery ran out of power before I was able to finish filming the demo video for our product.
    b. How were they resolved
        i. Sophia 1: I connected the arduino USB to my power bank, which worked!
        ii. Sophia 2: Google => Arduino forum helped a lot, spammed arduino reset button & uploaded simple "blink" example code a bunch
        iii. Kazimir 1: I anchored all my zipties to the top of the stick with twine.
        iv. Sujitha 1: I rearranged the wires so they can be separate and not tangled with each other.
        v. Bailey 1: I had to put the ground wire in both the arduino and the battery pack before connecting it to the stepper motor
        vi. Jazmine 1: The incorrect readings were due to incorrect wiring, which I fixed.
        vii. Jazmine 2: I simplified the code.
        viii. Jazmine 3: I used the charger from the arduino kit instead of the 9V battery, so it's at least partially portable.
    c. Lessons learned
        i. Sophia: Having backups for every component is good & Google is my best friend.
        ii. Kazimir: Tension is strong but not that strong.
        iii. Sujitha: Make a schematic of what you're going to do beforehand.
        iv. Bailey: If you feel stuck, just try everything you can think of.

v. Jazmine: Test parts of the final product individually, in pairs, and in small groups before putting them together.

7. Test Methodology
    a. Testing approach and criteria
        i. First, test whether all components work as intended with their individual code. The Serial should output what we expected and the sensor outputs should perform as expected.
        ii. Next, test all components together as one whole system, with one program that connects to all parts.
        iii. Finally, test that the system can perform when powered by battery, not by computer USB.
    b. Test environments and conditions
        i. Stationary part testing: parts lie on a desk, connected to the breadboard & a computer.
            1. Ultrasonic Sensor + Buzzer + Button
            2. Stepper Motor
            3. SD Card Reader + SD Card + Speakers
        ii. Stationary product testing: after a physical prototype is made, it lies on the desk or floor, connected to a computer.
        iii. Movement testing: product used as intended, connected to battery
            1. Fall detection: simulate dropping Handl to trigger the accelerometer & speakers
            2. Step counter: walk around with Handl to increase the step count

8. Future Work
    a. Potential improvements
        i. Moving the button closer to the top/stepper motor would definitely be more user-friendly; however, such would be a struggle to implement.
        ii. Minimization, less wires, maybe PCB for a neater, less electrical overall look; also wouldn't have to worry about components randomly not responding to the Arduino.
        iii. Making Handl foldable like the normal white cane would greatly improve mobility.
        iv. App integration for smoother control
        v. GPS function
        vi. Have water level detector when running into body of water
    b. Next-generation features
        i. Wire management/hiding would improve the aesthetic and feel of the device.

ii. Coding so that when rotated (around yaw axis) Handl can say whether obstacles are on left or right.
iii. Maybe add a potentiometer so user can decide how far something has to be to be considered “obstacle”
iv. Voice commands integrated into features such as step count
v. On/Off button for power

9. Conclusion
    a. Summary of achievements
        i. Created an object detection system which broadcasts findings through vibration and audio
        ii. Integrated a fall tracker + announcement system
        iii. Improvised a step counter for health-minded individuals
        iv. Ease of adjustment for future product developments
        v. Product is an independent running battery-powered device
    b. Impact and significance
        i. Handl, as a concept, is an invaluable resource for the visually impaired community. Although what we were able to create in these four weeks is nothing more than a prototype, the idea behind the product is an impactful step in technologically advanced disability aids for a more modern world.
    c. Final thoughts
        i. Handl is our team’s first attempt at a blind-assistive technology. Although we were able to achieve our planned visions for this product, Handl requires a lot more development in order to achieve full usability.
10. References
    a. Academic papers and sources
        i. https://iovs.arvojournals.org/article.aspx?articleid=2465334
        ii. https://www.visionaustralia.org/news/2019-10-15/white-canes-what-you-need-know#:~:text=Cane%20training,effectively%20when%20out%20and%20about.
    b. Technical documentation
        i. Link to google drive folder with videos: https://drive.google.com/drive/folders/1-27r8jBvKRK3HEo5gRAtQK1hixzDRgtK?usp=sharing
        ii. https://github.com/asukiaaa/MPU9250_asukiaaa/blob/master/src/MPU9250_asukiaaa.cpp
        iii. https://github.com/DFRobot/DFRobotDFPlayerMini/tree/master
        iv. https://github.com/adafruit/RTClib?tab=readme-ov-file