BLUE TEAM

Success Report

Arush Jain, Aarush Khanna, Tanvi Mavani, Rahul Nair

Academy for Mathematics, Science, and Engineering

Academy Engineering & Product Development III

Mr. DeMiceli and Mrs. Niemo

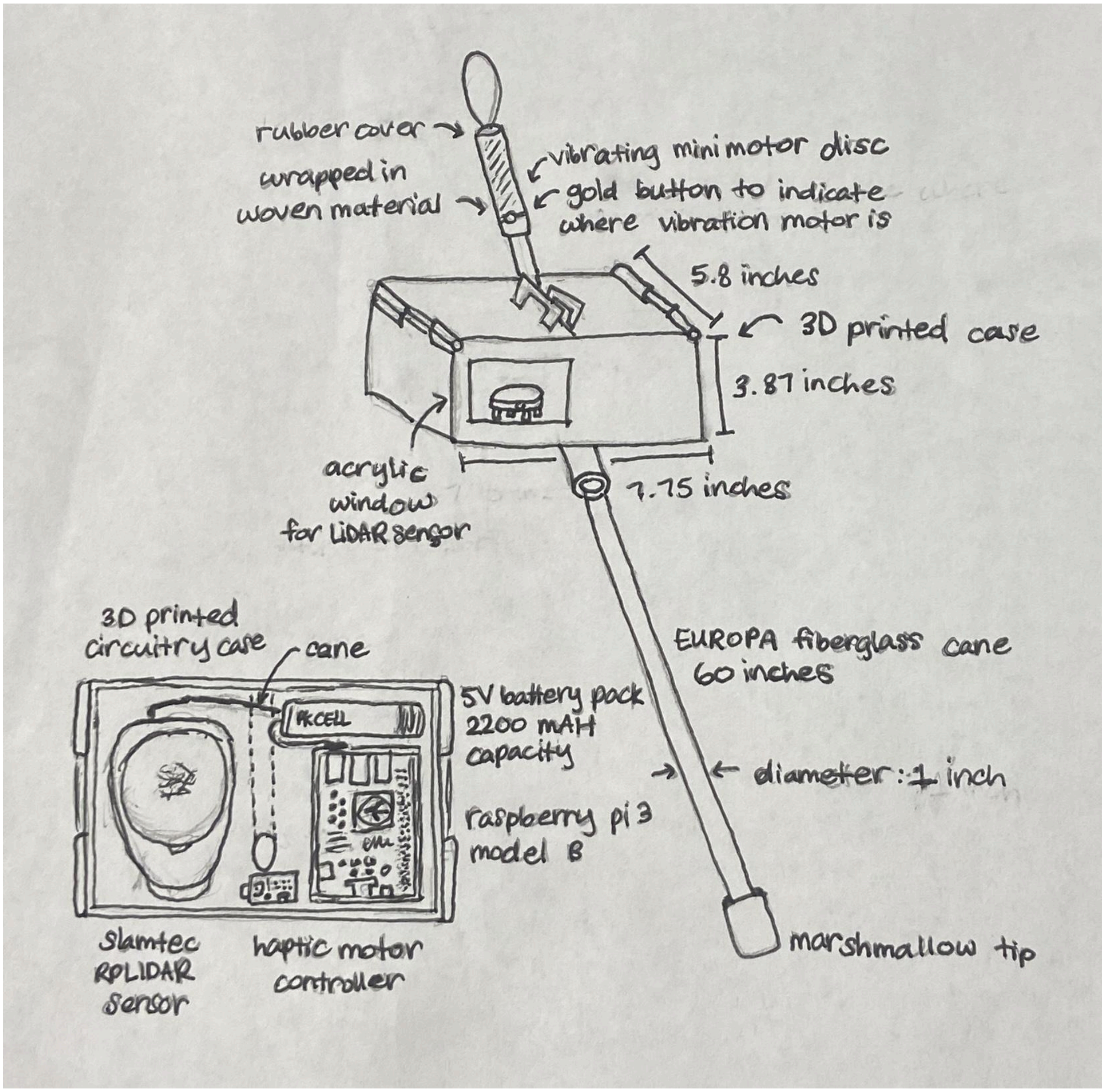
May 8, 2023

BLIND BAT

REVISED PROBLEM STATEMENT

More than 250 million people have “impaired vision and face challenges navigating outside their homes,” negatively impacting their independence and mental and physical health (Slade, et al. 2021). Visual impairment affects mobility, due to changes in “visual acuity, visual fields, depth perception, or contrast sensitivity” (“The Impact of Vision Loss”, 2016). Individuals rely on their vision to interact with their surroundings and know their own position and direction (Real and Araujo, 2019). In a correlational study done in 2016, it was found that 46.7% of visually impaired people had fallen in the past year, compared to only 27.7% of adults without any impairment, showing that visual impairment is related to inhibited physical ability (“The Impact of Vision Loss”, 2016). Visual function, specifically far sighted function, appears to “play an important role in physical function” and mobility (E. Salive, et al. 1994). Existing approaches including simple canes or electronic travel aids do not fully address the challenges and create an effective solution for those with this disability (Slade, et al. 2021). This issue “highlight[s] the need to scale up vision impairment alleviation efforts at all levels” to serve a market of those that are visually impaired, whether that be complete blindness or some other form. The aging population is creating a larger number of people with visual impairment (Bourne, et al. 2017). It is predicted that more than “2 billion people will need at least 1 assistive product by 2030” due to this shift in age among the global population. Assistive technology is useful in reducing the amount of caretakers and health care services needed (“Assistive Technology”, 2018). The market for assisted walking devices was $3.4 billion in 2021 (“Assisted Walking Devices Market Size”, 2022).

SKETCH, PRODUCT DESCRIPTION, SCIENTIFIC SUPPORT, MATERIAL JUSTIFICATION



The Blind Bat is a smart walking stick that can detect obstructing and moving objects within a certain range and then alerts the user through vibrations.

The main components of the walking stick will be a fiberglass cane, a LiDAR sensor, and vibration motor. They will be powered by a 5V battery and programmed using a Raspberry Pi. The sensor we chose is the RPLiDAR A1 sensor because it performs 360-degree scans within a

12-meter range. It will detect stationary and moving objects within this range. It can be configured for 2-10 Hz sample rate. We chose this over an ultrasonic sensor because of the cost-effective option we found, the accuracy that a LiDAR sensor offers, and its ability to measure 3D structures, including small objects (Burnett, 2021).

The sensor only requires 5V power which is why we chose to use a 5V battery. It is better than alternative options at a capacity 2200mAh with a 1 Amp output which is key for powering the Raspberry Pi, wifi adapters, and possibly even small displays if we need to use it. The battery can also charge and power the walking stick at the same time. The USB Battery Pack also is relatively small with dimensions of 25 mm x 91 mm x 25 mm so it will be able to compactly fit into our stick. It is also very lightweight at only 73 grams.

The battery will be housed inside of a 3D printed plastic case that will be attached near the top of the cane. The 3D printed case will be shaped like a rectangular prism with a dimension of 6 inches at the top, 3.50 inches at the bottom, and a total height of 5 inches. We will use the F170 printer and it is estimated to cost $40. We will be making the 3D model using Onshape software. The case will also house the Raspberry Pi 3 Model B. This model of the Raspberry Pi is faster and more powerful than its predecessors. It has improved power management to support more powerful external USB devices and now comes with built-in wireless and Bluetooth connectivity. It uses a next generation Quad Core Broadcom BCM2837 64-bit ARMv8 processor, making the processor speed increase from 900 MHz on the Pi 2 to up to 1.2GHz on the Pi 3. We chose to use a Raspberry Pi as opposed to an Arduino because there is already documentation supporting the usage of the Raspberry Pi in collaboration with the Slamtec RPLiDAR sensor (“Arduino vs Raspberry Pi: What’s the difference?”, 2022) The Raspberry Pi will receive sensor data and be programmed to deliver that data to the user via vibrational feedback (Astels, 2019). Depending on the distance of the object, the handle will vibrate at different intensities.

This will also be connected to a vibration motor. For this motor we decided on a Vibrating Mini Motor Disc because it was cost-efficient and effective. The rated voltage is 2.5 to 3.8V which will be sufficient with our battery. It is very simplistic as all it needs is power from a battery. It will be connected to the DRV2605L Haptic Motor Controller. The controller has the ability to turn the vibration level up and down which will be helpful because the stick will increase vibration as the object nears ("Vibration Module with Raspberry Pi: Wiring Diagram and Python Code", 2022). It is onboard with a 3.3V regulator and logic-level shifting circuitry which makes it compatible with the 5V Raspberry Pi that we will be using. This controller is also lightweight and will be placed under the handle with the vibration motor. This will allow the handle to vibrate anytime an object is within the 12 meter range. There will be three regions with increasing intensity levels, at 4 meters, 8 meters, and 12 meters. We have found research in support of vibrational feedback methods, showing that they are a useful way to alert users (Kim, et al. 2020).

We are planning to make modifications to a pre-existing walking cane as this will save time and resources. We decided on using the EUROPA Rigid Fiberglass Cane approximately 60 inches in length perfect for our use. The cane is primarily made out of fiberglass which is lightweight, strong and less brittle. The tip of the cane is also replaceable and provides long lasting support. The cane's handle is a golf grip handle with an elastic wrist loop. We will need to modify the handle to house the vibrating motor. This will be done by adding a cost-efficient rubber grip on top of the motor and haptic controller.

The point of devastation for this product is the Raspberry Pi 3 - Model B. If it fails to take in the information from the sensor and relay that information to the vibration motor, the system to alert the user of an object will not work. Without this system, the cane would become similar to a regular cane without any technology. The microcomputer must successfully be programmed to interpret the information received from the LiDAR sensor and accordingly convey that information to the motor so that it can vibrate to notify the user.

SOLVING THE PROBLEM

Our problem statement addresses the issue that visual impairment decreases mobility because of lack of visual acuity, thus negatively affecting physical and mental health. The Blind Bat increases mobility and physical function for those that have visual impairments.

It is predicted that more than “2 billion people will need at least 1 assistive product by 2030” due to this shift in age among the global population. Assistive technology is useful in reducing the amount of caretakers and health care services needed (“Assistive Technology”, 2018).

Navigating unfamiliar places with impaired vision is challenging because it requires having to avoid obstacles and then recognize a way around them. This device will assist the user in recognizing and maneuvering around obstructing obstacles. It will be able to notify users of approaching obstacles or those in the distance unlike regular white canes. Because of this, the user can gain a better sense of their surroundings and position in relation to surrounding objects.

DEFINING THE SUCCESS

The success of our product will be based on the following two goals:

- The cane can successfully detect 80% of nearby obstacles within a range of 10m in 180 degree radius. We determined the percentage of 80 based on statistical significance and other canes. A detection rate of 80% for the cane, coupled with their existing vision and other senses, would be enough to help the user navigate their surroundings.
- Every time the cane detects an object, it is able to properly notify the user using vibrations.

FUNDAMENTAL KNOWLEDGE

- Programming
    - To program the Raspberry Pi, we will need to know how to work with it and how to code in Python.
    - The Raspberry Pi will also be connected to the sensor, camera, and vibration motor and will be accordingly programmed. The program will have to take in the data from the sensor, interpret it, and relay the information to the motor so that it can accordingly alert the user.
- CAD and 3D Printing
    - Our product will be designed using CAD and then further, the case to hold the Raspberry Pi, sensor, and camera components will need to be created with correct fitting and proper tolerances. We will also need to know how to use the 3D printer because this case will need to be printed.
- Circuity
    - In order to properly use the Raspberry Pi, we will need to know how to connect the sensors, camera, and motor to the correct inputs.

- We have to be able to develop a complete circuit that is capable of sending information to the vibration motor in the handle.

MATERIALS AND COST

MATERIAL	PRICE	Quantity	LINK
Slamtec RPLIDAR A1 - 360 Laser Range Scanner	$99.95	1	https://www.adafruit.com/product/4010
Adafruit DRV2605L Haptic Motor Controller - STEMMA QT / Qwiic	$7.95	1	https://www.adafruit.com/product/2305
Vibrating Mini Motor Disc	$1.95	5	https://www.adafruit.com/product/1201
EUROPA Rigid Fiberglass Cane - 60 inches	$22.95	2	https://www.maxiaids.com/europa-rigid-fiberglass-cane-60-inches
Plastic case to hold the Raspberry Pi	Brought From Home	1	N/A
Raspberry Pi 3 - Model B - ARMv8 with 1G RAM	$17.50	1	https://www.adafruit.com/product/3055
5V 2.5A Switching Power Supply with 20AWG MicroUSB Cable	$8.25	1	https://www.adafruit.com/product/1995
USB cable - USB A to Micro-B - 3 foot long	$2.95	1	https://www.adafruit.com/product/592
USB Battery Pack - 2200 mAh Capacity - 5V 1A Output	$14.95	1	https://www.adafruit.com/product/1959

Fabric Weatherproof Cut Sheet, 9 x 12 Inches, Assorted Color, Pack of 270	$36.89	1	https://www.schoolspecialty.com/cut-sheet-1468237
SUPER GLUE Epoxy Adhesive: Instant Setting Epoxy, Ambient Cured, 29.5 mL, Syringe, Light Yellow	$20.70	3	https://www.grainger.com/product/SUPER-GLUE-Epoxy-Adhesive-Instant-Setting-3EHR4
Aluminum Heat Sink for Raspberry Pi 3 - 14 x 14 x 8mm	$24.95	1	https://www.adafruit.com/product/3083
9V battery holder with switch & 5.5mm/2.1mm plug	$3.95	1	https://www.adafruit.com/product/67
JST PH 2-Pin Cable (Male Header), 200mm	$3.75		https://www.adafruit.com/product/3814
ESTIMATED TOTAL:	$257.37		

CONCLUSIONARY REPORT

Step by Step procedure

1. Use Morris Hills road to Teacher's lot as the testing site because it is vacant during PED which eliminates possible interference from other cars and people.
2. The 5 volt battery will be completely charged before testing.
3. Turn on Raspberry Pi, where the program will be executed automatically on startup.

4. Test the Lidar sensor & Vibration Mechanism
    a. Test whether each intensity (low, medium, high) is detected at its distance range for each object in the testing procedure and assign a point value of 1 if yes or 0 for no.
        i. For the objects, we will begin with the cone, placing it 4m away from the curb - directly in front of the user. The user will begin at the curb and move closer to the cone at walking pace. As the user walks toward the cone, all of the vibration intensity data is being recorded by the program. After the user reaches the cone, the data recorded by the program will be written to a file on the raspberry pi and temporarily stopped, before the person will return to the curb. This process will then repeat, but now instead of the cone, the next obstacle will be Tanvi. Tanvi will be 4m forward and 4m left of the user. The trial will start with Tanvi and the user starting to walk at the same time (the program recording all of the vibration intensity data and Tanvi will be walking perpendicular to the user) until the user walks 6ft forward. Once this is done the user will return to the curb and the same process will be repeated with the Sedan Audi A6 and then Minivan Toyota 2014 Sienna LE, each moving at 10 mph. Both cars will start at the same place as Tanvi - 4m to the left and 4 m forward as to the user.
    b. We will move forward, with the starting point always at the curb. Test whether the haptic motor vibrates at the intensity of the programmed distance of lidar object

detection by assigning 1 if the correct intensity is activated for the corresponding distance and 0 if not.

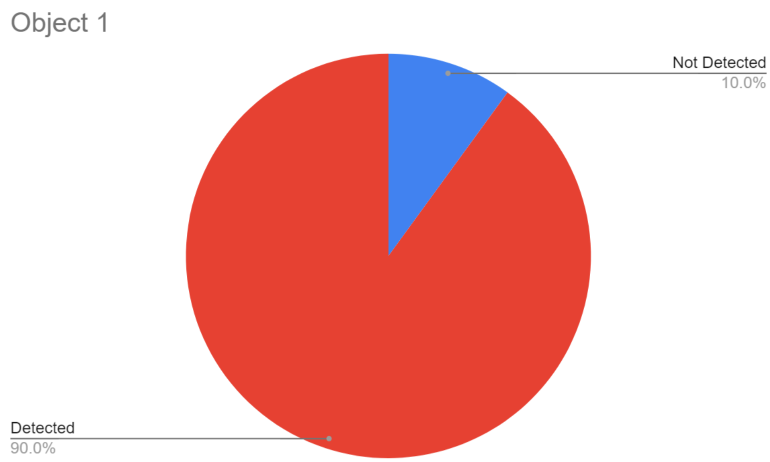
i. Corresponding distances will be printed on the Raspberry Pi IDE at the same time of the change in vibration to provide an accurate measurement of the distance.

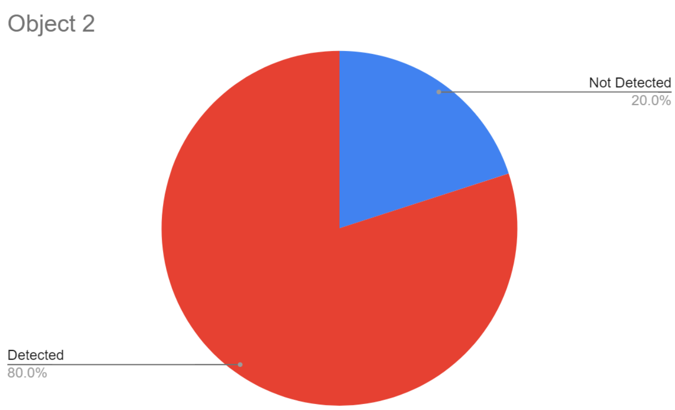
c. The program will constantly be returning an output of what intensity the vibration motor is at (OFF, LOW, MED, HIGH) along with the distance from the nearest object.

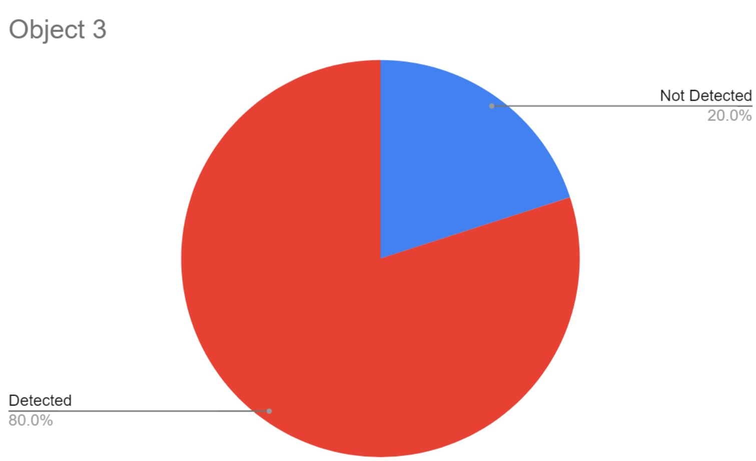
Testing Data

Blind Bat Testing Data

	A	B	C	D	E	F	G	H	I	J
1		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9
2	Obstacle 1									
3	Low	Not Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected
4	Medium	Detected	Detected	Detected	Detected	Not Detected	Detected	Detected	Detected	Detected
5	High	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected
6	Obstacle 2									
7	Low	Not Detected	Detected	Detected	Detected	Detected	Detected	Detected	Not Detected	Detected
8	Medium	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected
9	High	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected
10	Obstacle 3									
11	Low	Not Detected	Detected	Not Detected	Detected	Detected	Detected	Detected	Detected	Detected
12	Medium	Detected	Detected	Detected	Detected	Detected	Not Detected	Detected	Not Detected	Detected
13	High	Detected	Not Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected
14	Obstacle 4									
15	Low	Detected	Not Detected	Not Detected	Not Detected	Detected	Detected	Not Detected	Detected	Detected
16	Medium	Not Detected	Detected	Detected	Detected	Detected	Detected	Detected	Detected	Not Detected
17	High	Detected	Detected	Detected	Detected	Not Detected	Detected	Not Detected	Detected	Detected







\

Data Analysis

1-Sample T-Test for Mean (1 Tailed)

H_0: $\mu = 0.8$ H_a: $\mu > 0.8$ $\alpha = 0.05$

μ = The true mean of accurate detections of an obstacle by the Blind Bat

$\bar{x} = 0.8417$

$Sx = 0.3658$

$n = 240$

$df = 239$

$$t = \frac{\bar{x} - \mu_0}{S \div \sqrt{n}} = 1.7645$$

p-value = 0.0395

Since the p-value (0.0395) is less than the alpha level of (0.05) we can reject the null hypothesis. We have statistically significant evidence that concludes that we can accept the alternative hypothesis: that the accurate detection rate of an obstacle by the Blind Bat is greater than 0.8.

A more in-depth look at the data showed that while the overall rate of success was greater than 0.8, the successes were most concentrated with the first two obstacles whereas most of the failures were concentrated with the last two obstacles. This demonstrates that our prototype works incredibly well with stationary or slow moving objects, but did not work as well when trying to detect a fast moving object.

Sources of Error/Biases	**Solutions**
The vehicle moving at different times could create imbalances in the way the distance	We could have the Cars set at a moving speed of 5 mph and then mark tape when it is (for

measurement is calculated.	example) 900 mm away and then calculate vibration and see if it was detected.
Inconsistent walking speed or movement, could affect the results of the testing.	The person obstacle will move with the same pace every time, starting from the same area, and at the same time every trial.
Representative of real-world scenarios or account for individual differences	The test will will take place on a road with obstacles that our users would confront when using this obstacle in a real environment
Measurements are off due to human error or equipment error (rulers are off on measurements, human error in measuring using the rulers)	The distances will be recorded by the lidar sensor itself and written directly to the file on the Raspberry Pi.

Materials/Location	Explanation
Morris Hills road to Teacher's Lot	Close proximity to Morris Hills makes it easier to reach to test in and it is usually free allowing for enough space to properly create the course with all the obstacles. Additionally, the road will allow for the cars that will be used to move and serve as obstacles for the blind bat.
Traffic Cone	The traffic cone will be our first obstacle as it is stationary and also something that is present in the actual conditions the product will be used in: our user would need to be able to detect the traffic cone to move around any cordoned off areas in a real situation
Person	The person will be used to see if the can can detect people in crowds. Tanvi will be the person who will be used as the testing object.
Rahul's Minivan - Sienna LE 2014	Used to test if the cane can detect a large, moving vehicle.
Arush's Sedan - Audi A6 2018	Used to test if the cane can detect a small, moving vehicle.

References

Arduino vs Raspberry Pi: What's the difference? InterviewBit. (2021, November 11). Retrieved December 5, 2022, from https://www.interviewbit.com/blog/arduino-vs-raspberry-pi/

Assisted Walking Devices Market Size, Share & Trends Analysis Report By Product Type (Canes, Crutches, Walkers, Gait Trainers), By Region, And Segment Forecasts, 2022 - 2030. (n.d.). Grand View Research.

Astels, D. (2019, March 19). *Using the SLAMTEC RPLIDAR on a Raspberry Pi*. Adafruit Learning System. Retrieved December 5, 2022, from https://learn.adafruit.com/slamtec-rplidar-on-pi?view=all

Burnett, R. (2021, April 27). Ultrasonic Sensors vs. LIDAR: Which one should you use? MaxBotix Inc. Retrieved December 5, 2022, from https://www.maxbotix.com/articles/lidar.htm

Bourne, R., Flaxman, S. R., Braithwaite, T., Cicinelli, M. V., Das, A., Jonas, J. B., Keeffe, J., Kempen, J. H., Leasher, J., Limburg, H., Naidoo, K., Pesudovs, K., Resnikoff, S., Silvester, A., Stevens, G. A., Tahhan, N., Wong, T. Y., Taylor, H. R., & Vision Loss Expert Group (2017). Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. The Lancet. Global health, 5(9), e888–e897. https://doi.org/10.1016/S2214-109X(17)30293-0

Kim, M.-Y., Kwon, H., Yang, T.-H., & Kim, K. (2020, October 12). Vibration alert to the brain: Evoked and induced Meg responses to high-frequency vibrotactile stimuli on the index finger of dominant and non-dominant hand. Frontiers. Retrieved December 5, 2022, from https://www.frontiersin.org/articles/10.3389/fnhum.2020.576082/full

Making Eye Health a Population Health Imperative: Vision for Tomorrow. (2016). Impact of Vision Loss - NCBI bookshelf. Retrieved October 31, 2022, from https://www.ncbi.nlm.nih.gov/books/NBK402367/

Real, S., & Araujo, A. (2019). Navigation Systems for the Blind and Visually Impaired: Past Work, Challenges, and Open Problems. *Sensors (Basel, Switzerland)*, *19*(15), 3404. https://doi.org/10.3390/s19153404

Salive, M. E., Guralnik, J., Glynn, R. J., Christen, W., Wallace, R. B., & Ostfeld, A. M. (1994). Association of visual impairment with mobility and physical function. Journal of the American Geriatrics Society, 42(3), 287–292. https://doi.org/10.1111/j.1532-5415.1994.tb01753.x

Slade, P., Tambe, A., & J. Kochenderfer, M. (2021). Multimodal sensing and intuitive steering assistance improve navigation and mobility for people with impaired vision. *Science Robotics, 6* (59). https://doi.org/10.1126/scirobotics.abg6594

Vibration module with Raspberry Pi: Wiring diagram and python code. peppe8o (2022, August 6). Retrieved December 5, 2022, from https://peppe8o.com/vibration-module-raspberry-pi/

World Health Organization. (2018). Assistive Technology. World Health Organization. Retrieved October 31, 2022, from https://www.who.int/news-room/fact-sheets/detail/assistive-technology#:~:text=Assistive%20technology%20reduces%20the%20need,%2C%20their%20family%2C%20and%20society.

YouTube. (2022). YouTube. Retrieved December 5, 2022, from https://www.youtube.com/watch?v=-BObt8inVs8.