ULTRASONIC SENSOR

OBJECTIVE

A key feature of the Proximity Badge requires the intensity of the vibration servo to be varied based on the distance between an obstacle and the user. To do so, it is necessary for us to obtain the mathematical relationship between the time taken for the transmitted ultrasonic waves to be received and the distance travelled by the ultrasonic waves.

RESULTS

Distance (cm)	$Time_1$ (μs)	$Time_2$ (μs)	$Time_{ave}$ (μs)
20	1131	1133	1132
40	2303	2290	2296.5
60	3469	3420	3444.5
80	4590	4660	4625
100	5750	5754	5752
120	6869	6920	6894.5
140	8011	8050	8030.5
160	9278	9308	9293

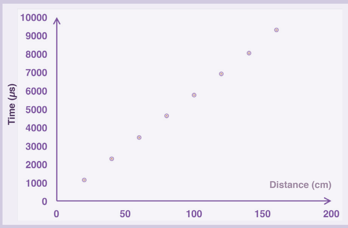
APPROACH

1. Find an open space without unwanted obstacles that may potentially interfere with the accuracy of the experiment.
2. Mark out distance range within our range of consideration at intervals of 20cm (0 to 160cm).
3. Fix the ultrasonic sensor upright at the 0cm mark.
4. Place a flat object upright at the 20cm mark and record the time taken for the receiver to detect the transmitted ultrasonic waves which bounced off the object.
5. Repeat step 4 at the intervals marked in step 2.
6. Use a scatter plot to illustrate the data collected, observe the relationship between time taken and distance travelled.
7. Find the exact mathematical constants relating the two variables.

SCATTER PLOT

Scatter plot suggests that they have a linear relationship. As such, the gradient of the inverse function should give us twice the speed of ultrasonic waves in air under practical conditions.

Gradient of inverse function = (2*distance/time)



LINEAR ALGEBRA

MATRIX SYSTEM

$A\vec{x} = \vec{b}$

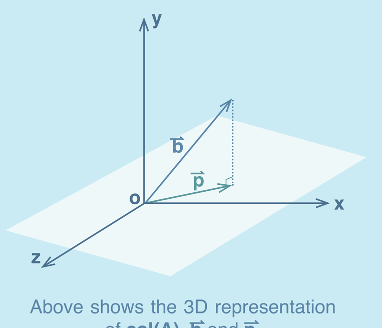
$$\begin{bmatrix} 1132.0 & 1 \\ 2296.5 & 1 \\ 3444.5 & 1 \\ 4625.0 & 1 \\ 5752.0 & 1 \\ 6894.5 & 1 \\ 8030.5 & 1 \\ 9293.0 & 1 \end{bmatrix} \begin{bmatrix} M \\ C \end{bmatrix} = \begin{bmatrix} 20 \\ 40 \\ 60 \\ 80 \\ 100 \\ 120 \\ 140 \\ 160 \end{bmatrix}$$

rref $([A\ \vec{b}])$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Finding the rref of augmented matrix **[A b]** gives no solution for $\vec{x}$ b does not lie in col (A).

PROJECTION



Above shows the 3D representation of **col(A)**, $\vec{b}$ and $\vec{p}$.

To get the approximation of solution for x, we use the projection, p, of b on col(A):

$$P = A(A^TA)^{-1}A^T$$

$$\vec{p} = P\vec{b}$$

APPROXIMATE SOLUTION

$\vec{p} = P\vec{b}$

$$= \begin{bmatrix} 20.0358 \\ 40.1452 \\ 59.9697 \\ 80.3554 \\ 99.8173 \\ 119.546 \\ 139.164 \\ 160.965 \end{bmatrix}$$

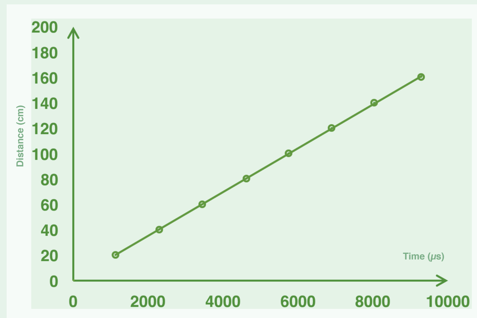
rref $([A\ \vec{p}])$

$$= \begin{bmatrix} 1 & 0 & 0.0173 \\ 0 & 1 & 0.4876 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\vec{x} = \begin{bmatrix} 0.0173 \\ 0.4876 \end{bmatrix}$$

Speed
= 2(gradient) = 2(0.0173)
= 0.0345 cm/μs
= 345 m/s

INVERSE GRAPH

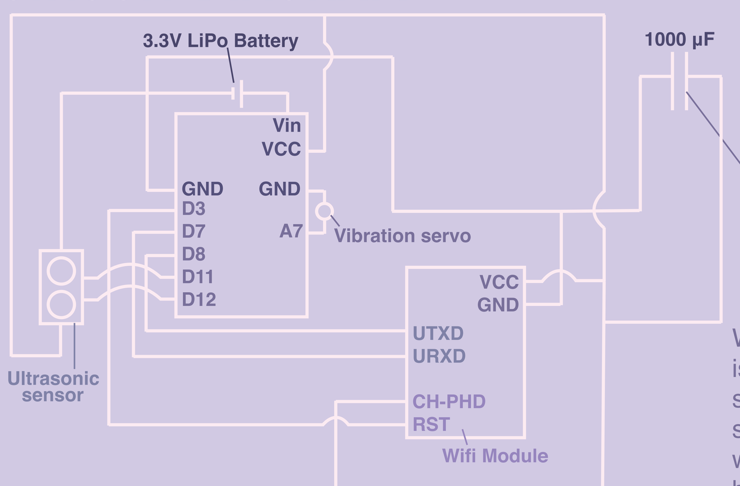


CONCLUSION

The doubled distance between the user and an obstacle (x) and the time taken for the ultrasonic wave to travel twice of this distance (y) can be related by the following equation: $\hat{y} = 0.0173x + 0.4876$ and the speed of ultrasonic waves is waves in air is approximately **345 ms^{-1}**.

PROXIMITY BADGE

CIRCUIT DIAGRAM

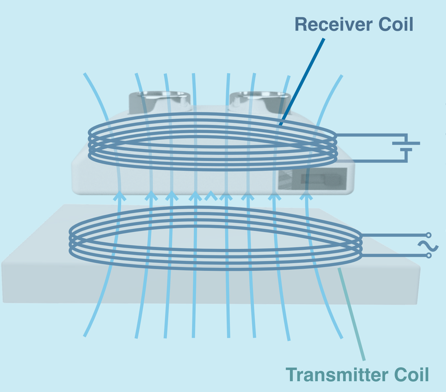


CAPACITOR

When the wifi module pulses, it is not uncommon for the power source to be unable to provide sufficient current to it. Hence, we placed a capacitor there to buffer against this occurrence.

The capacitor is charged to a potential difference of 3.3V. This allows it to provide sufficient power to pulse the wifi module without drawing all the power from the main battery, thereby preventing system resets.

CHARGING PAD

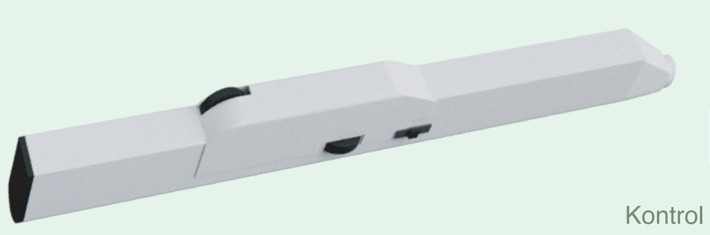


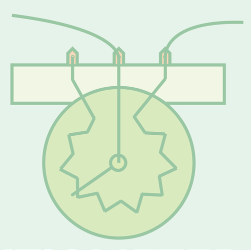
FARADAY'S LAW

The main voltage will be converted into high frequency alternating current (AC) which is then passed through the transmitter coil in the charging pad. AC from the transmitter coil will induce a magnetic field which extends to the receiver coil in the Proximity Badge within a distance of 4cm. Since the current is alternating, the magnetic field extended to the receiver is constantly changing. As a result, the magnetic flux linking the receiver coil will too be constantly changing.

According to Faraday's Law of Induction, the changing magnetic flux linkage would induce an electromotive force (e.m.f.) in the linked conductor. In this case, when e.m.f. is induced in the closed conducting loop, current is induced too. The AC generated in the receiver coil is then converted into direct current (DC), thus charging the battery of the Proximity Badge connected to the receiver circuit.

KONTROL DEVICE





POTENTIOMETER

2 potentiometers are used in the Kontrol Device to allow the user to control settings such as vibration intensity and range of the sensor. The potentiometer consists of 3 pins as shown in the figure to the right. The pins are Ground, Digital and Input from left to right. A long resistor forms the connection between Input and Ground. When the wiper is turned, the resistance between the Digital and Input pins changes. This change is then measured by the Kontrol Device. When the wiper is all the way at the Input, the resistance would be minimum, registering a value of 0. Conversely, when the wiper is at the Ground pin, the resistance is maximum, registering a value of 1023.

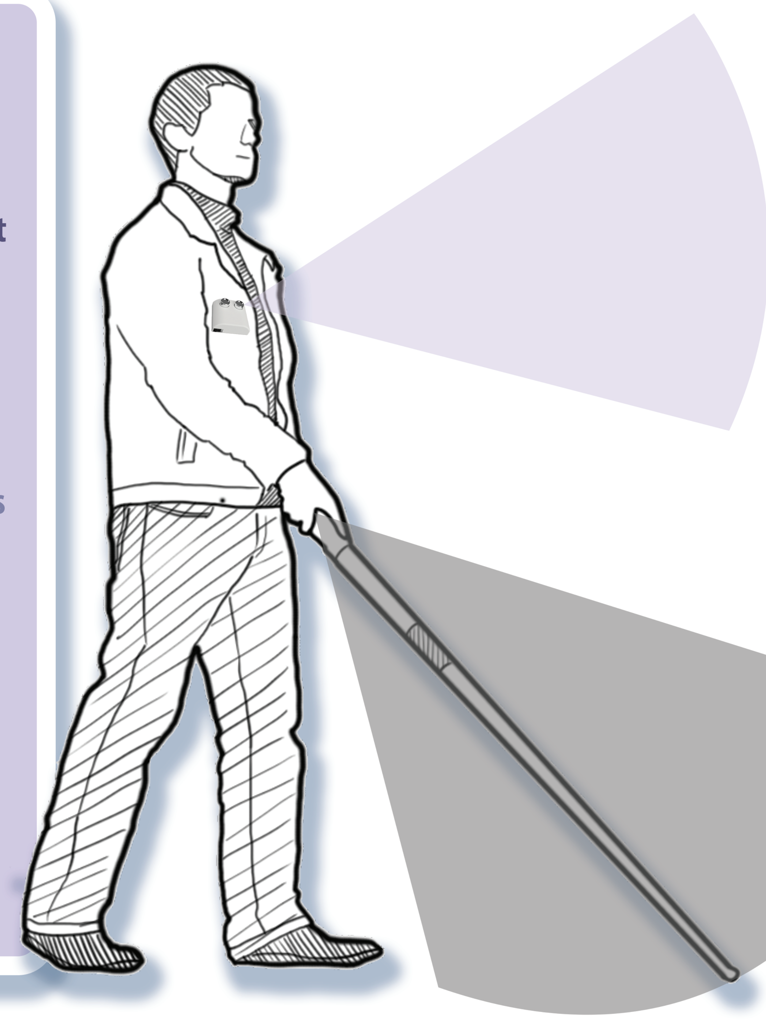
PROXIMITY BADGE & KONTROL DEVICE

PROBLEM STATEMENT

The visually-impaired are physically empowered in their need for daily travel with the advent of assistive technologies. The white cane, the most common of them, is long enough to detect incoming obstacles when contact is made, warning the user of their presence.

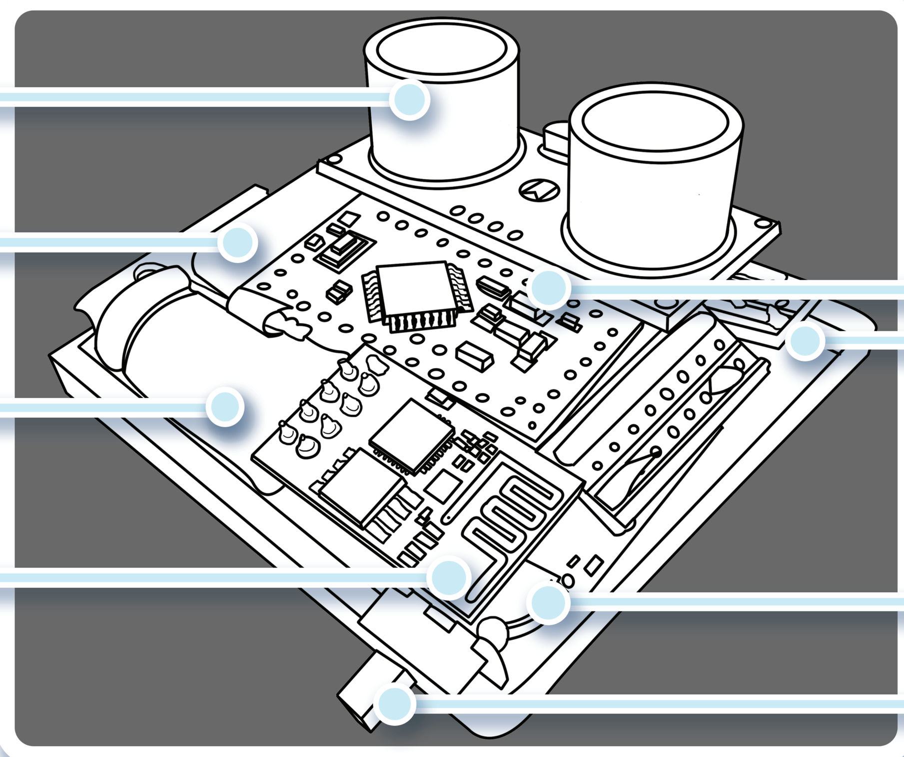
Obstacles above waist-level pose particular challenges for a user's commute due to the cane's sweeping motion resulting in inability for quick detection. Correspondingly, large proportions (>40%) of them get into outdoor head-level collision accidents annually (Fig. 1), leading to serious head injuries. Majority of these accidents were due to tree branches (the majority), poles and signs, construction equipment, and trucks.

26% of the respondent's reported decreased confidence as an independent traveler, avoiding certain areas and opting for a sighted travel companion; posing a potential drawback on the independence of their travel.



PERSONALIZABLE
Versatile design, Adjustable settings.

EASY TO USE
Clip on the PB, switch the KD, turn them on and go.



Ultrasonic Sensor
- Provides obstacle detection capabilities
- Range: 4cm - 400cm

Battery (3.7V 800MA)
- Provides sufficient power for a day's use

Capacitor (1000μF)
- Prevents wi-fi module from using all the power

Wi-Fi Module
- Enables wireless connection and signal feedback from KD

Arduino Pro Mini
- Provides computing power to implement code on device

Wireless Charger Receiver
- Provides wireless re-charging capability

Battery Charging Board
- Regulates battery voltage to prevent burnout from overcharging

2 x Vibrator Servo
- Provides tactile vibratory feedback

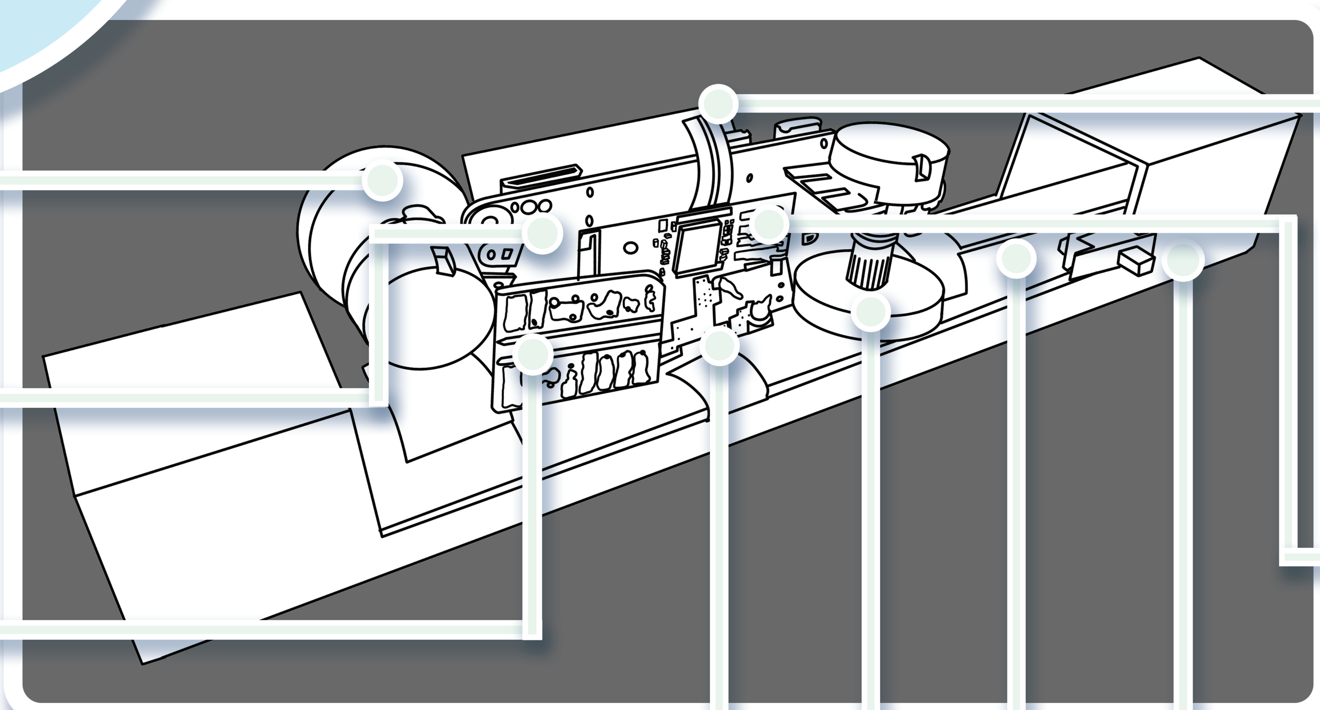
Switch

PROXIMITY BADGE

The PB is a portable detection device to be fitted on the upper torso to detect obstacles above waist-level. It sends vibrations to the user when an obstacle is approaching, increasing in intensity as the distance closes. Multiple can be used at the same time to improve directionality (e.g. one PB on each side of the chest). It is a wirelessly chargeable device, enabling extra convenience.

KONTROL DEVICE

The KD is a control device for the PB that is integrated with the handle of a white cane. It allows adjustments of the vibration frequency and sensitivity of the ultrasonic sensor (i.e. range of obstacle-detection) for different environments and to the user's preferance. It is also wirelessly chargeable.



Potentiometer 1
- Varible resistor to control range of obstacle detection

Raspberry Pi
- Communicates with multiple PBs for adjustment of settings

MCP3008 Analog-Digital Converter
- Acts as interface between potentiometer (analogue) and raspberry pi (digital)

Power Bank Circuit Board
- Acts as a portable power source for the raspberry pi

Potentiometer 2
- Variable resistor to control intensity of vibration

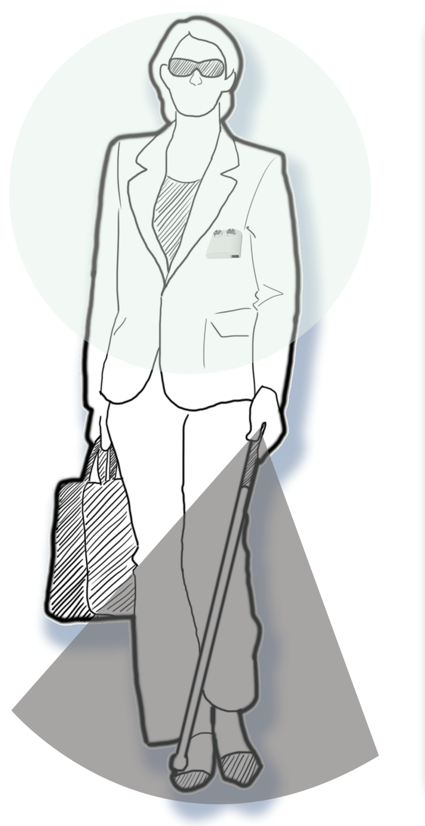
3 x AA Battery
- Provides sufficient power for a day's use

Wireless Charger Receiver
- Provides wireless re-charging capability

Battery Charging Board
- Regulates battery voltage to prevent burnout from overcharging

Wi-Fi Module
- Enables wireless connection and signal feedback for PB

Switch



A BETTER WORLD BY DESIGN

The visually-impaired face great degrees of difficulty in their interactions with the environment. Through understanding and incorporating the accumulation of shared contact from their continuous feedback on head-level obstacles, contextuailzing their interaction through our research provided the design principles behind the formulation of the PBKD.

Utilizing technological advances in sensors and computing capabilities allowed the materialization PBKD. Its inception will serve to enhace the physical and social interactions of the blind and their environment.

By utilizing design principles, our team has created a better world for the visually-impaired, through design.

FUTURE WORKS

1. Adding water resistance to PBKD using latex lining.
2. Allowing KD to enter power saving mode by coding the Raspberry Pi Zero to auto shutdown upon 15 mins of inactivity and turn on upon scrolling of the potentiometers.
3. Making PB more compact by sourcing for smaller, lighter electrical components and exploring other arrangements.
4. Alternative attachments to the current cane tip.
5. Allow KD to be attached to other daily accessories.
6. Modification of ultrasonic sensors.