Batstick: Ultrasonic Smart Walking Aid

Introduction

According to the World Health Organization, there are over 284 million people in the world who are visually impaired and 39 million people who are classified as blind. Our project seeks to create a device that improves the quality of life of these individuals by converting ultrasonic sensor readings into physical sensations, similar to the echolocation of a bat.

Proposed Solution

- Takes input from an array of ultrasonic sensor readings to output to an array of vibration motors.
- Physically easy to use and reliable in real-world settings.
- Accurate ultrasonic sensor readings and noticeable changes in vibrations for the distances of objects.
- Aids in daily navigation and possesses the ability to distinguish between objects.

Design

Materials
- 5 HC-SR04 ultrasonic sensors
- 5 button vibration motors
- Raspberry Pi computer
- Raspberry Pi power supply
- 6V batteries & battery holder
- Jumper wires
- Breadboard

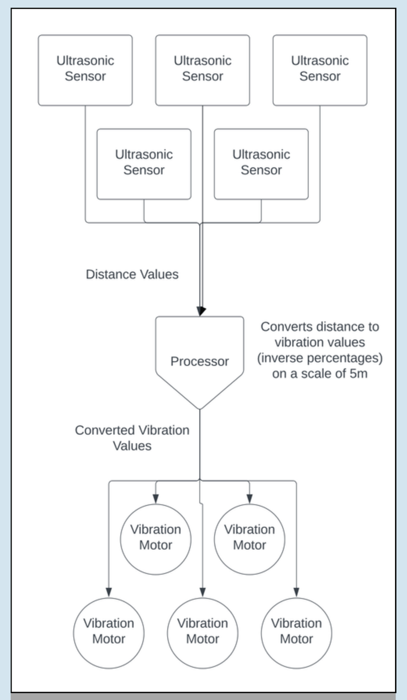


Diagram of sensor-motor connections

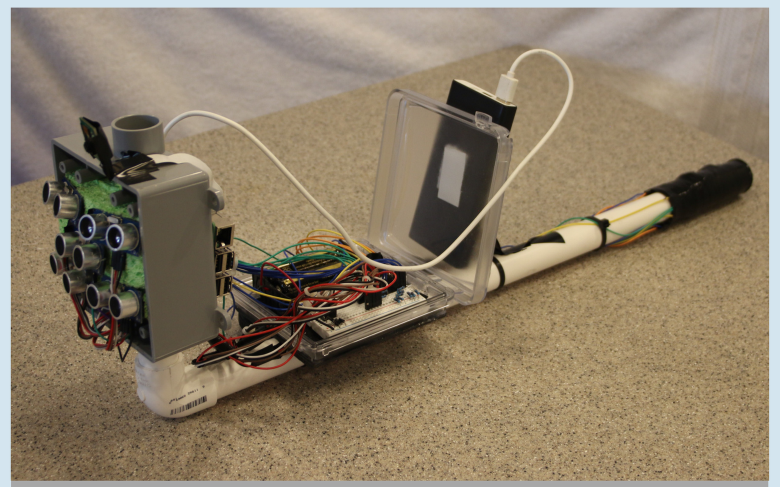
All photos produced by researchers and parents.

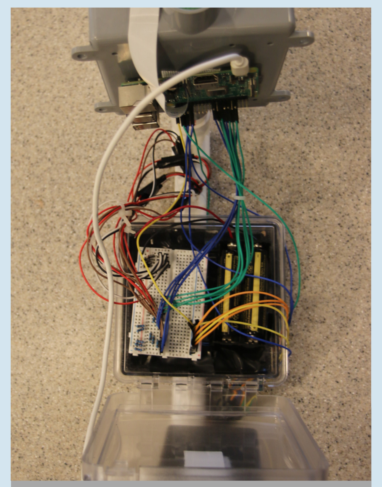
$$Value = \frac{(Distance - minDistance) \times (minValue - maxValue)}{maxDistance - minDistance} + maxValue$$

$$Value = \frac{-(Distance - 0.02)}{3.98} + 1$$

Ultrasound distance to inverse percentage equations

Sensor to Motor Connection
- 5 ultrasonic sensors (front, left, right, bottom left, bottom right) pair to 5 vibration motors, each in the same position.
- Sensor readings are converted to inverse percentages and input to corresponding motors(closer reading = higher vibration intensity).
- Sensors fire in a loop to prevent cross-interference.
- Considered glove, visor, and walking stick design ideas.

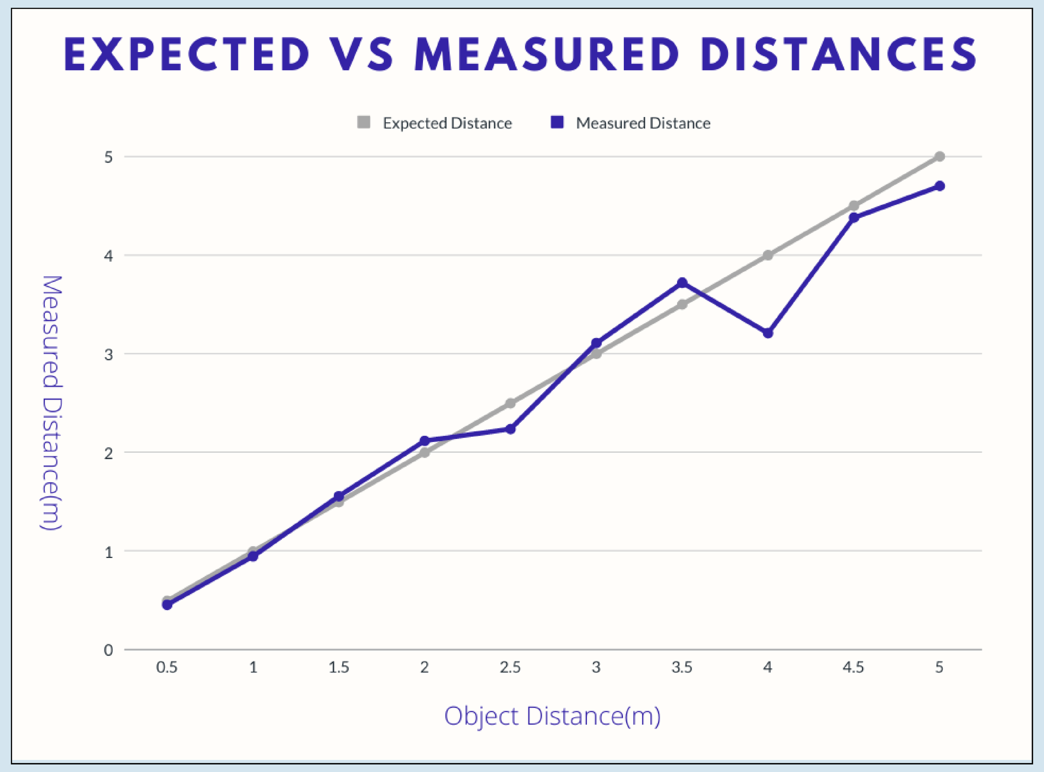

Batstick Side Profile(Sensors, Breadboard, Grip)


Batstick(Top View)

Results

Methodology
- A flat object will be placed at varying distances in front of the device.
- Three trials(object on left, right, middle) per distance conducted incrementing 0.5m up from 0 to 5 meters.
- 2 left sensors measure for left objects, 2 right sensors for right objects, and the middle sensor for middle objects.
- Distance measurements were taken for 2 seconds and averaged to compare to the actual distance and measurement of the testing accuracy of the sensor array.
- A blindfolded user guesses the object's location based on vibrations felt for each trial. Trials are conducted three at a time, and locations are chosen at random.
- Data is collected on correct guesses to determine the effectiveness of the vibration motor array.


Testing both measurement distance averages and guessing the side the object is located on

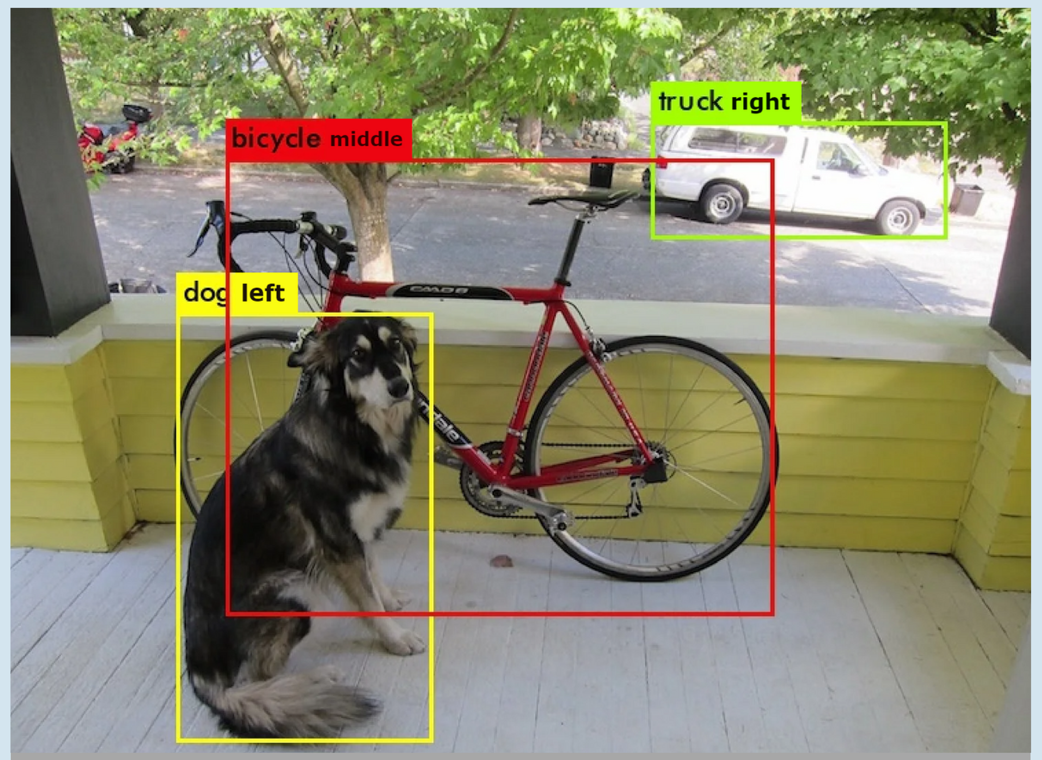


Distance(m)	Correct Guesses(out of 3)
0.5	3
1	3
1.5	2
2	2
2.5	2
3	2
3.5	2
4	1
4.5	2
5	1

All graphs produced by researchers.

Object Detection

- Decided to implement object detection to easily identify entities being viewed from a distance and to assist in distinguishing between multiple spatially recognized visuals.
- Object detection uses YOLOv3 with text-to-speech vocalizing objects and what side of the device's camera they are on.
- Object detection's accuracy at correctly naming objects and what side they were on was tested on images of common objects(cars, signs, beds, chairs, food, etc.) from the MS COCO image dataset.



Example of object detection identifying the side objects are located on

	One Object	Two or More Objects	Overall
Correctly Identified	5/6(83.3%)	23/28(82.4%)	28/34(82.4%)

Analysis

Sensors and Motors
- Ultrasonic readings became less accurate the farther the object was from the device, likely a result of the distance and cross-interference of multiple ultrasonic sensors.
- It was difficult to accurately feel where farther objects were, partially a result of lower vibration intensities.
- The Batstick was still effective in allowing users to detect distant objects and view close objects and their distances accurately.

Object Detection
- Object detection was 82.4 percent successful(28 out of 34 objects) in its trials stating which side objects were on.
- When paired with sensors and motors, the Batstick becomes effective in aiding a visually impaired or blind individual in navigation and daily activities.

Conclusion

The Batstick was highly consistent in trials involving the detection of objects and mapping environments to the vibration sensors. Object detection was also accurate and could detect objects and their positions to vocalize them effectively. As such, the object detection paired with the consistent mapping of the ultrasonic sensors creates an effective smart walking aid that provides a visually impaired user the ability to view the area in front of them by accurately identifying what objects are and their positions in relation to the device. Overall, the Batstick could be used in the daily activities of a visually impaired person, and it fulfills the engineering constraints and goals set.

Application

- The Batstick is easy to use, cheap to create, and sturdy enough for daily use. It improves upon the current standard for common usage, the white cane.
- It is effective in aiding a visually impaired or blind individual in navigation, obstacle avoidance, object location, and other issues related to mobility and quality of life.
- The Batstick also has potential applications in navigating low-visibility environments, such as during nighttime and in caves.
- In the future, CPU and memory could be upgraded, a GPS and smartphone app can be added, and the length of the Batstick can be shortened to improve comfort during long sessions of use.

References

Carullo, Alessio & Parvis, Marco. (2001). An ultrasonic sensor for distance measurement in automotive applications. Sensors Journal, IEEE. 1. 143 - 147. 10.1109/JSEN. 2001.936931.

Raspberry Pi. "See like a Bat." Projects.raspberrypi.org, 2016, https://projects.raspberrypi.org/en/projects/see-like-a-bat/0.

Yahaya, Suleiman & Jilantikiri, Lydia & Oyinloye, Gbenga & Zaccheus, Jesuloluwa & Ajiboye, Joy & Akande, Kareem. (2019). Development of Obstacle and Pit-Detecting Ultrasonic Walking Stick for the Blind. FUOYE Journal of Engineering and Technology. 4. 10.46792/fuoyejet.v4i2.398.