IoT-Enabled Smart Mobility Devices for Aging and Rehabilitation

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Abstract

Elderly individuals often develop disabilities and require the aid of devices in order to perform everyday tasks. Specifically, elderly visually impaired individuals will need to use conventional aids, such as walkers or canes in order to navigate their surroundings. However, in a complex, unfamiliar environment, these devices won't be useful in avoiding obstacles. We designed a smart walker which detects and classify obstacles in the user's path and return information about the distance of that obstacle. The smart walker will guide the user to the best possible path that will avoid obstacles through an audio and haptic interface.

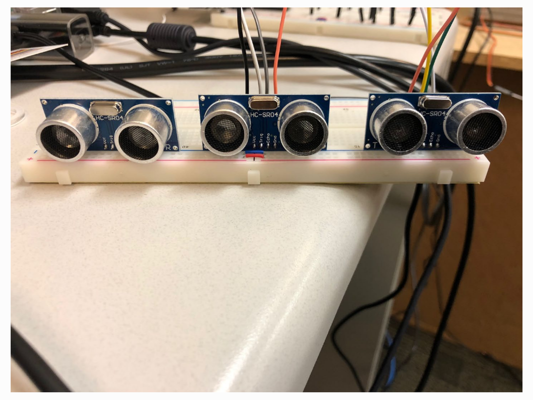
Objectives

1. Design an approach suitable for a sunlit environment.
2. Provide feedback to the user about what direction to take to avoid collision with obstacles.
3. Warn users of massive obstacles, such as doors or stairs.
4. Provide feedback through audio and haptic interface.
5. Create inexpensive solutions.

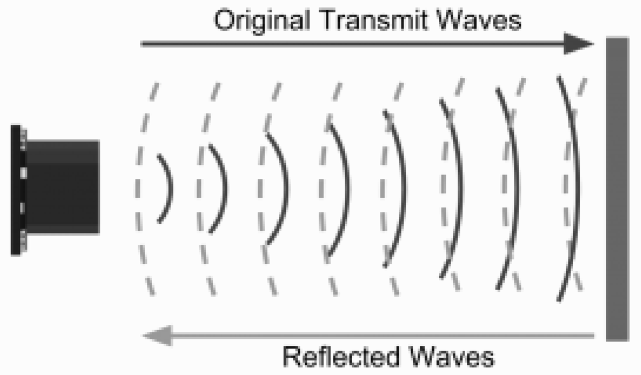
Background

This project expands on Feltner et. al. [1]

- Approach 1: An HC-SR04 sensor is an ultrasonic sensor that generates a sound wave with a frequency above 40 kHz and transmits it forward. If there is an obstacle present, the waves will bounce back off of it and the sensor will receive this bounce as an echo and process it to return the distance.
- The Raspberry Pi is a highly efficient, small computing device used for portability in our *Approach 1*.



HC-SR04 Sensors



The wave path of the sensor [2]

- Approach 2: Google's TensorFlow framework is an open source platform for machine learning models. It can train and run deep neural networks for object classification. We use a pretrained model with TensorFlow to detect and classify obstacles for the user.

Methods

Approach 1 : HC-SR04 Sensors

Detecting Obstacles' Distances [3]

- Attach multiple sensors across the width of the walker
- Sensors will transmit a sound wave by sending out a trigger signal and receiving the echo signal sequentially
- Records the duration of the signal and calculates the distance in centimeters using the formula: $Distance = Speed \times Time$

Navigation System

- Find the smallest distance from an obstacle detected by one of the sensors-indicates the closest obstacle in the path
- Check the sensors' distances to the left and right
- Whichever sensor returns the greater distance, the corresponding handlebar of the walker will vibrate.
- Greater distance indicates an obstacle-free path to take

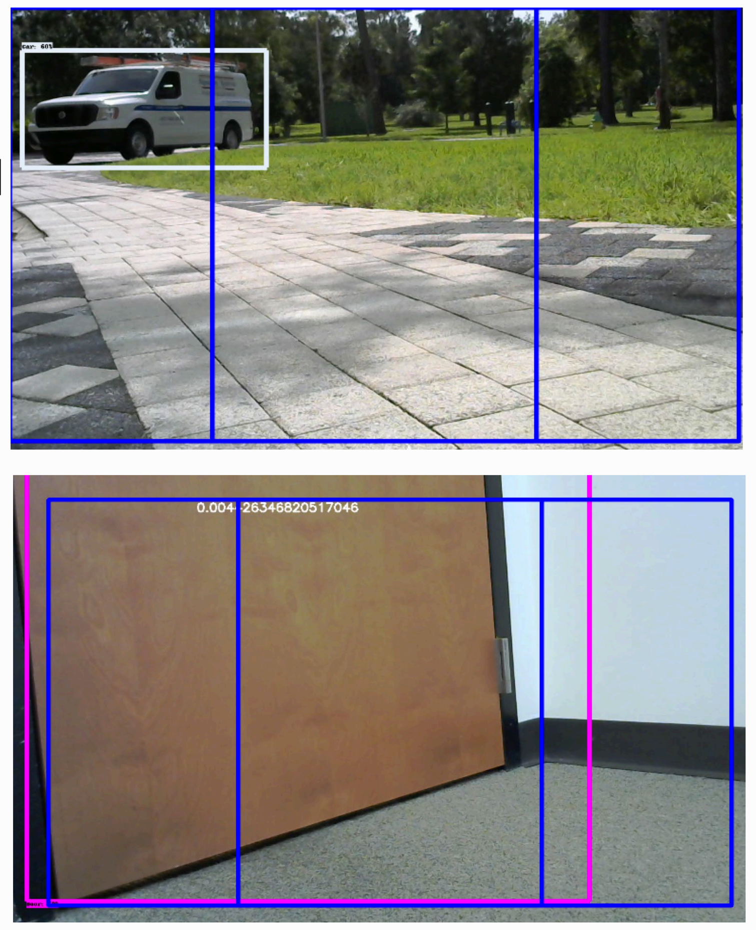
HC-SR04 sensors attached to walker

Approach 2: Image Classification with TensorFlow

Detecting Obstacles

- Pretrained TensorFlow model with all the classified objects is loaded
- Define the graph, detection boxes, scores, and classes from the model to be used
- Create the coordinate "Region of Interest" to detect obstacles in the user's vicinity; obstacles outside this region will not be detected.
- Verbal warning for detected obstacles will be played
- Each classified obstacle' bounded box coordinates is used to estimate the object's width and to determine the obstacle's distance with the formula [4]:

$$Distance = \frac{Object\ Width \times Focal\ Length}{Pixel\ Width}$$



Images of TensorFlow's Image Classification

Navigation System

The closest obstacle to the camera in the "Region of Interest" will send a warning to the user. If the obstacle is located on the right side of the region, a verbal warning to go left will be played.

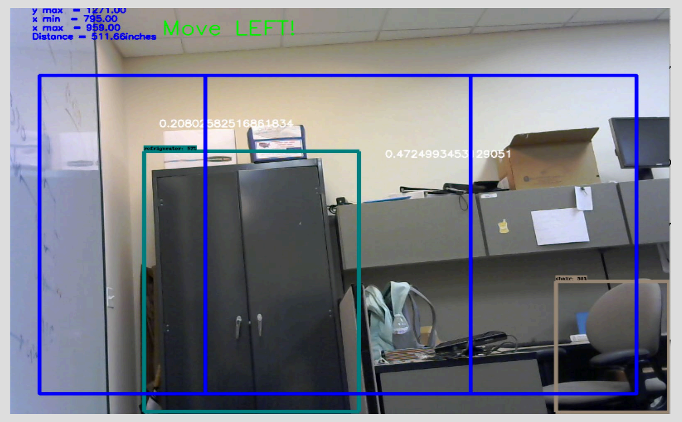


Image of Region of Interest

Results

We evaluate our approaches using:

- Distance detected of obstacles at known distances
- Navigational time through various scenarios
- Number of obstacle collisions
- Comparing haptic vs audio feedback

Image of Obstacle-Filled Environment

Distance Detection Accuracy

Obstacle	HC-SR04 Sensors	TensorFlow	Actual Distance	Percent Error (HC-SR04 Sensor)	Percent Error (TensorFlow)
Wall	92.3 cm	82.9 cm	91.9 cm	0.4%	9.8%
Door	54.6 cm	40.3 cm	53.7 cm	1.7%	25.0%
Person	110.2 cm	120.9 cm	110.3 cm	0.001%	9.6%
Stairs	52.3 cm	54.9 cm	51.8 cm	1.0%	6.0%
Curb	86.9 cm	100.3 cm	87.3 cm	0.5%	14.9%
Backpack	42.6 cm	39.5 cm	42.5 cm	0.2%	7.1%
Empty Hallway	No obstacle	No obstacle	No obstacle	NA	NA

Navigation Time (min:sec)

Environment	HC-SR04 Sensors w/ Haptic	TensorFlow w/ Audio
Empty Hallway	2:21	2:15
Empty Outdoor	3:40	3:30
Obstacle-Filled Hallway	2:33	2:32
Obstacle-Filled Outdoors	4:02	3:50

Navigational Guidance System (obstacles hit)

Environment	HC-SR04 Sensors w/ Haptic	TensorFlow w/ Audio
Empty Hallway	1	0
Empty Outdoor	1	0
Obstacle-Filled Hallway	3	1
Obstacle-Filled Outdoors	4	2

Conclusion

- HC-SR04 sensors were able to detect distances within a 2 cm range. TensorFlow approach was able to navigate through various environments faster with less collisions using audio feedback.
- Future improvements include: increasing the distance accuracy of TensorFlow, adding more image classifications to pretrained model, and decreasing the false positives detected by HC-SR04 sensors.

Acknowledgements

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