# IoT-Enabled Smart Mobility Device for Aging and Rehabilitation


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## Abstract


Technological enhancements for mobility aids such as smart walkers have improved throughout the years. However, individuals who have both visual and mobile impairments are not covered in these advancements. We designed a smart walker that reacts and informs about detected obstacles on the user's path. The user will be alerted to change the path to avoid collisions through a haptic feedback device on the walker's handles.


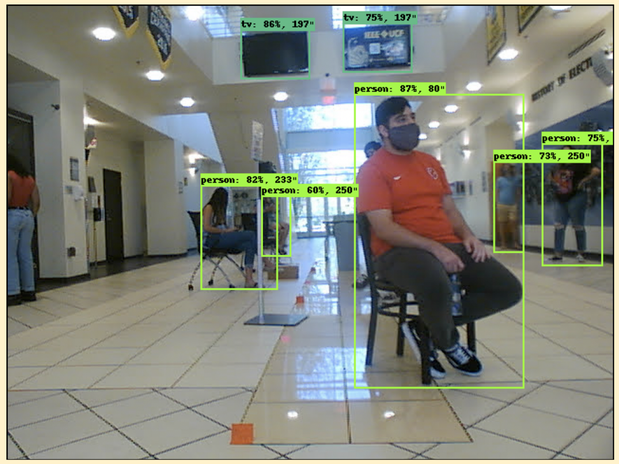


**Figure 1.** Data Collection Environment.

## Goals

- Design an approach suitable for an indoor environment
- Implement haptic feedback alerts to avoid obstacles in path
- Create an inexpensive solution

**Figure 2.** Walker with camera & RaspberryPi.

## Background

- This project improves on the previous prototypes [1-3]
- Raspberry Pi 3i model B is a small and affordable computer. This portable and energy-efficient computer will power and stream the USB camera mounted on the walker
- The PlayStation Eye is a digital camera device with usb connectivity. Captures video at 60 hertz at a 640x480 res
- EfficientDet-D5 is an object detection/classification model that achieved state-of-the-art 55.1 mAP on COCO test-dev [4]

## Methodology

### Data Collection

- Hall with obstacles such as tables, chairs, and people, simulating a busy environment (see Figure 1)
- We recorded 3 data sets with total of 1,933 objects

### Testing Variables

The input data includes the coordinates of the object and the confidence value. Each object is centered at (0,0) using the formula $f = (y_{max} - x_{min})/2$

| parameters | RMSE | r2 | MAE |
|---|---|---|---|
| ['y_max', 'x_min', 'y_min', 'x_max'] | 31.82 | 0.77 | 19.06 |
| ['y_max', 'x_min', 'y_min', 'x_max', 'class_number'] | 31.78 | 0.76 | 18.42 |
| ['y_max', 'x_min', 'y_min', 'x_max', 'class_number', confidence] | **29.52** | 0.79 | **17.02** |
| ['f1', 'f2'] | 35.72 | 0.71 | 21.86 |
| ['f1', 'f2', 'class_number'] | 33.16 | 0.75 | 20.00 |
| ['f1', 'f2', 'class_number', 'confidence'] | 29.55 | **0.80** | 17.21 |

### Testing Model

- Training various machine-learning models to predict distance given the best set of parameters
- Each objects' actual distance is manually measured
- Dataset: 1,639 objects with filter distance ≦ 250"
- Condition: 20/80 split test, polynomial degree = 3, KNN n = 10

## Results

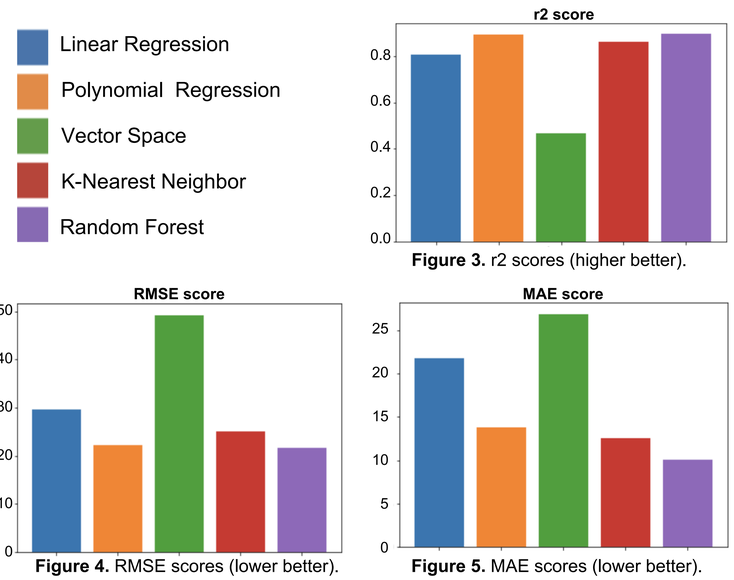


**Figure 3.** r2 scores (higher better).

**Figure 4.** RMSE scores (lower better).

**Figure 5.** MAE scores (lower better).

## Object Avoidance

### Avoiding Obstacles

- Closest objects to user will be tested to see which margin it falls under $y > -1.5x + 960$ and $y > 1.5x$
- Haptic sensors will vibrate according to the region the obstacle appears in, as shown in Figures 7, 8 and 9

### Process

- Camera begins video live-stream to external server
- Detected objects' label, coordinates, and certainty are obtained by the EfficientDet-D5 model
- Our model predicts the distance of the objects
- The objects in danger zone are determined through obstacle avoidance algorithm
- User receives haptic feedback

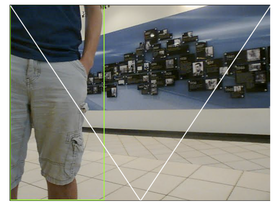

**Figure 7.** Obstacle in left zone; left handle vibrates.

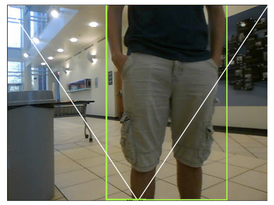

**Figure 8.** Obstacle in center zone; both handles vibrate.

**Figure 9.** Obstacle in right zone; right handle vibrates.

## Conclusions and Future Work

- The Smart Walker is able to successfully instruct the user about the direction of the detected obstacle.
- The best performing machine learning model was Random Forest Regression
- Future directions include:
  - improving the accuracy of object detection
  - improving the speed of object detection to allow for higher frame rates
  - better handling corner cases

## Acknowledgement


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