Department of Electrical & Computer Engineering

Boston University
Electrical & Computer Engineering
EC464 Capstone Senior Design Project

Final Test Report

OPTICLE

by

Team 3
Opticle

Team Members

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I. Required Materials

A. Hardware:
- Raspberry Pi 4 Model B (with 16 GB MicroCenter SD card)
- Raspberry Pi Zero
- Pi Sugar Power Source
- Charmast Portable Power Bank
- OpenCV AI Kit: OAK-D Camera
- Linear Resonant Actuator
- Switch
- Bone-conducting headphones
- Desktop monitor
- Keyboard
- Mouse

B. Software:
- Python 3 Scripts:
  - Point Cloud Detection (Mode 1) + Obstacle Detection (Mode 2) + Audio Mode
- Motor Control:
  - Raspberry Pi GPIO

C. Other:
- Platinum Extreme Accessory Kit (Chest Mount)
- 3-D Printed Wrist Mount

II. Set-Up

Our set-up was consistent with the final test plan. Prior to the demo, we ensured that the user of the chest mount had a snug fit by adjusting the straps accordingly. We also made sure that the components attached to the chest mount (portable battery, Raspberry Pi 4), were on securely. One of our team members as well as a chair served as obstacles to test the detection of our model with varying distances.

Our set-up includes both software and hardware components: an object detection Python script that is run on a Raspberry Pi 4, which is connected to an OAK-D camera and wired to a linear resonant actuator. The hardware is attached to a chest mount where the camera is mounted to a screw in the middle and the pi and portable battery is attached to the body of the user. Both the Pi 4 and OAK-D are connected to the portable battery to receive power. The actuator is attached to a Raspberry Pi Zero which is housed on a 3-D printed wrist mount. This wrist mount will be meant to be worn like a watch where the actuator is touching the user’s skin. There is also a switch attached to the right strap of the chest mount, near the user’s right side of their collarbone. Both Pis are connected to a keyboard, mouse, and monitor display via HDMI so that the Raspberry Pi Desktop can be used to run the script. Once the scripts are running, both Pis will be unplugged so the user can use the device portably. The python script utilizes the OAK-D camera where it uses point cloud data to determine whether an immediate obstacle is in front of the user. Point cloud data is generated by combining both RGB and depth data. By drawing a cuboid of space in front of the user and looking at the density of data points in that cuboid, the system is able to alert the user of nearby obstacles. When an object is detected, the script will send a detection value via TCP/IP to the Raspberry Pi Zero, which will then send a PWM signal to the appropriate GPIO pin on the Pi Zero. The LRA is wired to this GPIO pin which will allow the LRA to receive the pwm signal and vibrate to alert the user whenever an object is detected. The user will also wear bone-conducting headphones that will output audio from the Pi and will also receive speech input from the user that will be received by the Pi.

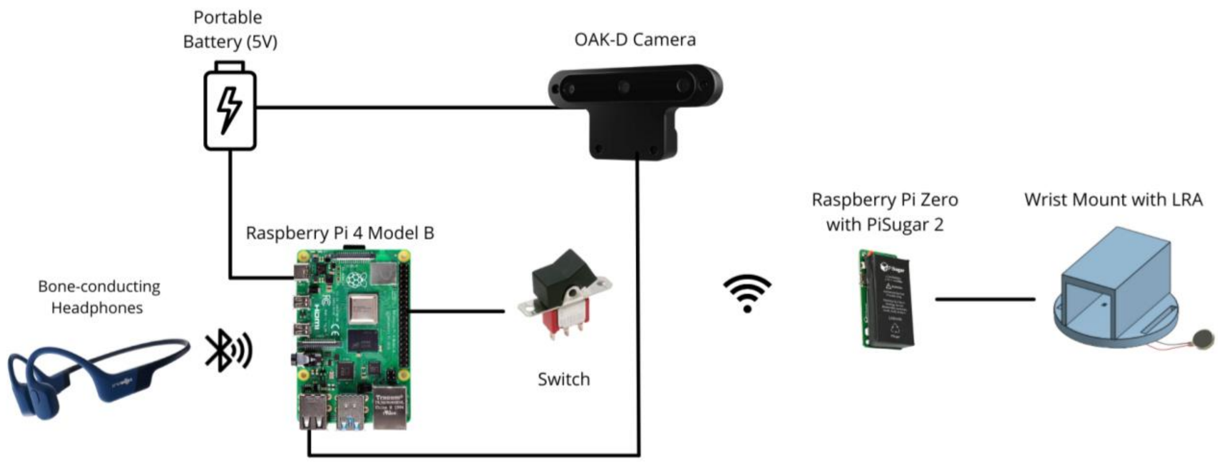

Figure 1. Illustration of Setup

III. Measurements

This table shows the criteria for success that we developed for testing.

Mode 1

Object	**Distance**	**Motor Vibration Correct?**
Person	+1.7m	Y
Person	0.5-1.7m	Y
No Person	N/A	Y
Chair	0.5-1.7m	Y
No Chair	N/A	Y
Result		5/5

Mode 2

Object	**Distance**	**Motor Vibration Correct?**	**Audio Output Correct?**
Person	+1.7m	Y	Y
Person	0.5-1.7m	Y	Y
No Person	N/A	Y	Y
Result		3/3	3/3

1. We started the demo by running the file *spatial_tiny_yolo.py* on the Pi 4 and *piserver.py* on the Pi Zero and ensuring that the OAK-D camera was running properly. This was satisfied as the laptop screens showed the terminals running on each Pi since we SSHed into them.
2. Based on the objects detected, if there was an object present within the cuboid, we ensured that the linear resonant actuator produced a vibration to alert the user. One of our teammates simulated an obstacle.
3. Several tests were performed with varying distances and different positions in the camera frame. First, one person stood nearby the user. This was followed by the user moving toward the person until the motor vibrated. Both the motor vibrated and the terminal showed the motor vibrating showing the device detected the person.
4. The user then attempted to walk arround the obstacle. The monitor showed that the motor stopped vibrating and the user no longer felt any vibrations.
5. We then tested a much larger distance of detection by asking a person to stand 5m away from the OAK-D camera. The user faced the person and showed that the motor was no longer vibrating.
6. A chair was then placed near the user. The user then walked toward the chair and showed that the motor was vibrating to show the system detected an object. The user then walked around the chair so that it was no longer in the user's path and showed the motor no longer vibrated.
7. The switch was then pressed to switch the device into mode 2. This prompted the device to only look for people at the moment.
8. The user then faced and walked toward the obstacle that was a person and listened for the audio output. The headphones then prompted the user that a person was found as well as giving the relative distances from the user. It was also demonstrated that the device would not prompt the user again unless the distance from the obstacle changed or 15 seconds have passed.
9. The user then faced away from the obstacle toward a wall showing that the motor still vibrated but no audio feedback was given since a person was not detected.

IV. Conclusions

Since the second prototype testing, our team was able to make significant improvements on our system. We were able to make our system wireless by having our two Raspberry Pis communicate over Wifi and using a barrel to USB plug to power our OAK-D camera. We also sewed on loops onto the chest mount to consolidate the wires better on the chest mount, making it less cluttered. Our team also was able to integrate a switch to toggle between two modes, one for detecting immediate obstacles and one for navigating to a specific object/person.

Based on the results of our testing, we can conclude that our proof of concept works when it comes to detecting obstacles and vibrating actuators based on whether an obstacle is present in the cuboid of the space. Our switch also was successful in allowing the user to change modes and our system outputted the correct audio directions to the bone conducting headphones, indicating to the user how far the object they were looking for was.

Since our last iteration, the design of Opticle is significantly more robust and portable now with the additions of the 3D printed watch mount along with 3D printed holders and covers for the Raspberry Pi and the portable power source. The chest mount is snug fit with no interference in the arm movement of the user which solves an important safety issue. Furthermore, the watch mount has a mold for the motor to sit in that amplifies the vibrations so that it is much easier to feel. This was a significant improvement on the motors being placed on the chest as that is very dependent on the clothes that the user would wear. The ability to switch modes also allows more flexibility for the user, and allows them to use the system in multiple environments. To build on the new mode, we hope to incorporate the detection of car handles and doors to guide the user to a specific vehicle.