Developing turn signal and vehicle detection systems for bicycles

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Introduction

New laws and initiatives across the United States have increased the viability of bicycle travel because it is a more popular form of transportation. Moreover, bicycles are a clean choice in the search for more environmentally sustainable travel methods. Traveling with a bicycle poses risks. According to the Centers for Disease Control (2022), "nearly 1,000 bicyclists die and over 130,000 are injured in crashes that occur on roads in the United States every year." With this high number of accidents and injuries, there is a need and market for safety devices that can improve cyclists' safety. Research by Engbers et al. tested different safety systems, recording cyclist performance and improvement from the systems, finding front and rear detection the most successful (2018).

With recent advancements in technology like faster and better algorithms of object detection and smaller, low-power computers like the Raspberry Pi 4 model B, a new system at a low cost had the potential to be created. This project aimed to create a vehicle detection system that alerted cyclists to a vehicle's presence and implement functional turn signals.

Materials and Methods

Before developing a prototype, some requirements were established. The prototype should not impede cyclist movement, the battery life should last around two hours, the price was cheaper than the market competition, and the function was independent of an internet connection. For hardware, the computer was the Raspberry Pi 4, the system is powered by a battery bank, with a 12,000 milliampere hour capacity, delivering power over USB, and with the camera described in figure 1. Following these constraints, the measurements of mounting points on the bicycle frame were gathered. Then, Partsam two-pack of six-inch oval turn signals and general-purpose two-pin turn signal relays were used to create the turn signals. The parts were tested in a mock turn signal circuit. Although, a voltage booster was used in the final circuit to allow the battery bank to power the signals because the automotive parts needed a 12V source.

2.5 cm

Figure 1 (right): The camera is the Arducam model OV567, with a five-megapixel sensor. The sensor's field of view is 54° and it can record at 1080p with 30 frames per second. This camera has built-in compatibility with the Raspberry Pi 4 and sends data through the CSI interface.
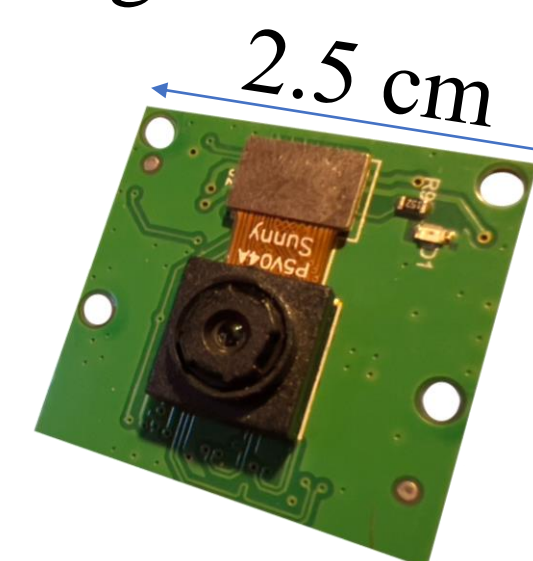
Materials and Methods (continued)

After the acquisition of hardware, the final object detection model was created and trained on vehicles. The development platform Edge Impulse was used following the steps in figure 2.

Set input size of 320 by 320 pixels → 100 local images / 10,000 images from databases → 80/20% split into training and validation → Input images into Faster Objects More Objects algorithm (FOMO)

Repeated until validation sample is 80% correct

Deploy on Raspberry Pi with Python ← Test model on validation sample and videos ← Train model on Edge Impulse Server
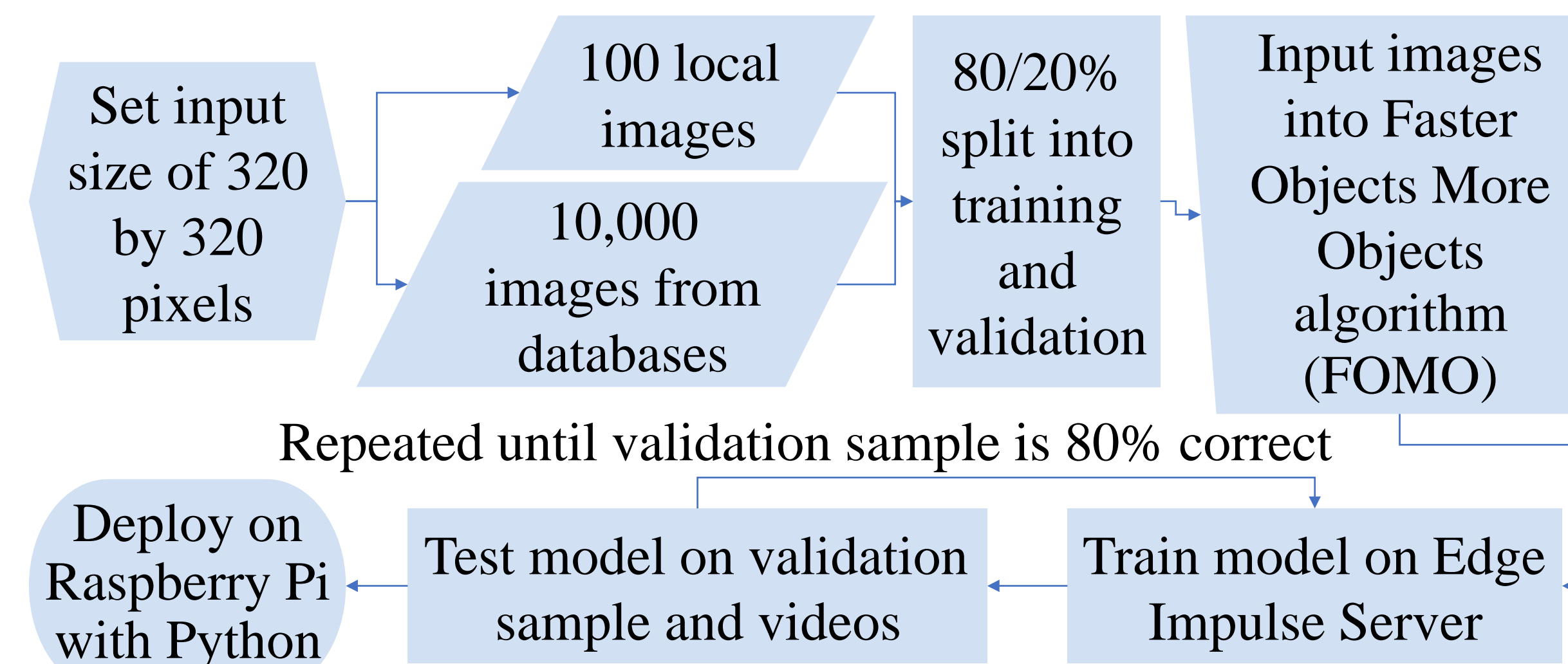
Figure 2 (above): Process that was used on Edge Impulse to create the vehicle detection model. FOMO was a new algorithm created for constrained hardware like the Raspberry Pi. Also, Edge Impulse provided server time to train models. Deployment of the model was done through the Python software development kit provided for Linux by Edge Impulse.

With the completion of the Edge Impulse model, the code in Python was optimized. After that, physical mounting hardware was designed. Figure 3 shows the final design with details of the specific system used to accommodate constraints. This design was then created using the material PETG on the Prusa i3 MK3 3D printer. Figure 4 depicts the system used for mounting the camera to the rear of the bicycle seat, which was also 3D printed. These parts were mounted, and the signals were attached to the final model. Notifications were sent through VNC viewer, a remote monitoring software for phones. Data verification was completed by parsing, photos, and two minutes of footage, producing 4350 unique frames that were analyzed for false positives or negatives.
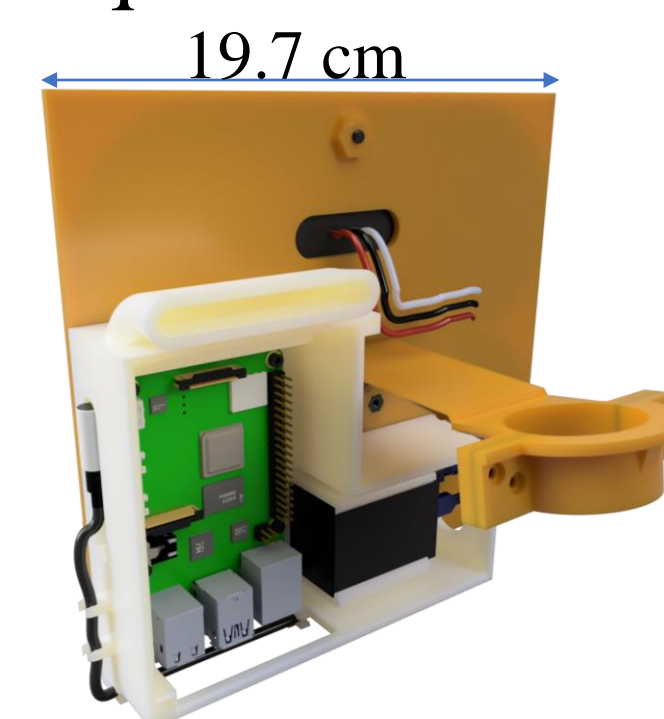
19.7 cm

Figure 3 (left): Fusion 360, a computer-aided design program, was used to create models of hardware. The hardware to the left is the final design. The design used an electronics box, in white, that encapsulated the Raspberry Pi, in green, and an LED flasher relay, in black. Also, a swoop was added to improve the cooling of the Raspberry Pi. There was a bracket arm that held the system to the frame of the bicycle. All the parts were mounted with nuts and bolts.

Figure 4 (right): Camera mounting hardware that used thumb nuts and bolts, one shown in white, allowing for fine position adjustments. The camera was on a ball joint, which created more movement too. Model adapted from *Articulating Raspberry Pi camera mount for Prusa MK3 and MK2* [3D Model], by Sneaks, is licensed under CC BY 4.0.

Figure 1 mounted in device
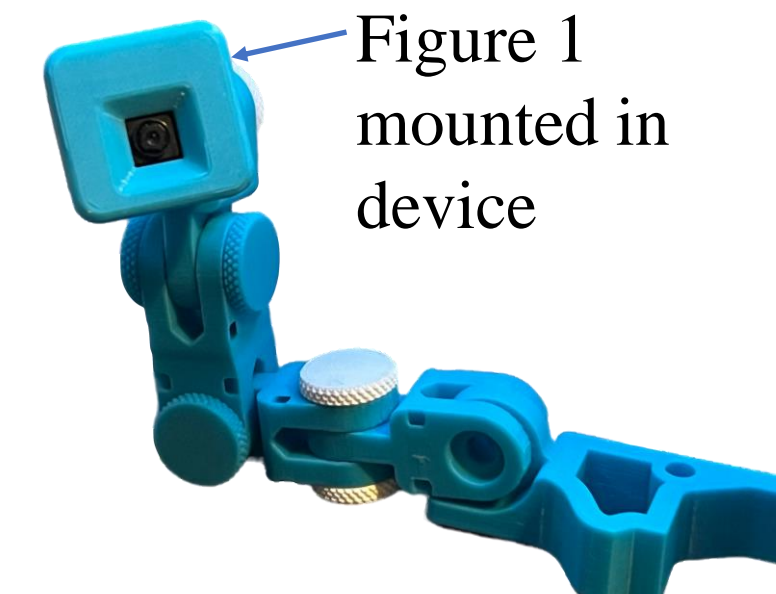
Results

The final attached model can be seen in figures 5 and 6. The maximum distance for vehicle detection was 171 feet, although, this distance decreased to 117 feet with direct glare from the sun. The distance was tested at nine feet intervals until failure, in a parking lot. The final price was $158 at the Raspberry Pi 4 manufacturer's suggested retail price of $75. Also, false positives occurred with dumpsters being misidentified as a bus. While testing battery life was recorded at over three hours.
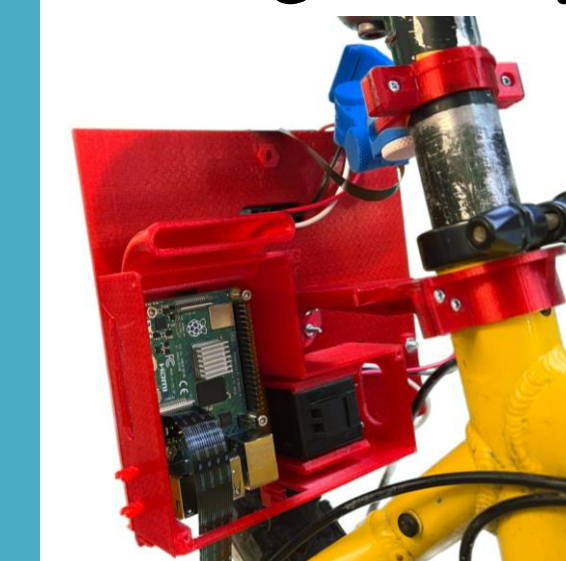
Figure 5 (left): The finished mounting hardware and electronics box in red PETG. Also, the camera mounting bracket can be seen at the top in red.

Figure 6 (right): The turn signals and camera are shown mounted. The turn signals did not function as they were not completely wired to the voltage booster.

Conclusion

The purpose of the project was partially met, the vehicle detection worked, but the turn signals did not. The system functioned well for the first iteration with a detection distance that allowed for time to maneuver to avoid a collision, at 30 frames per second. However, the model had no recognition of motion, meaning stationary vehicles and traffic moving in the opposite direction were detected. This led to extraneous detections that could be improved by implementing a motion detection system.

Moreover, potential future revisions with more sensors, and a different computer could improve performance. Sensors that are used in cars, like LiDAR, could improve detection distance; whereas a more powerful computer like a Jetson Nano with a graphics card can decrease latency, increasing the time to react.

References

Centers for Disease Control. (2022, May 4). *Bicycle safety*. CDC. https://www.cdc.gov/transportationsafety/bicycle/index.html#:~:text=Nearly%201%2 C000%20bicyclists%20die%20and,the%20United%20States%20every%20year.&text =The%20costs%20of%20bicycle%20injuries,the%20United%20States%20each%20y ear

Engbers, C., Dubbeldam, R., Buurke, J. H., Kamphuis, N., de Hair-Buijssen, S.H.H.M, Westerhuis, F., de Waard, D., & Rietman, J. S. (2018). A front-and rear-view assistant for older cyclists: evaluations on technical performance, user experience and behavior. *International Journal of Human Factors and Ergonomics*, 5(4), 257–276. https://doi.org/10.1504/IJHFE.2018.096099

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