Department of Electrical Engineering and Computer Science

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EECE 404: Senior Design II

Instructor: Dr. Charles Kim

Spring 2025

CTRl-B
Submitted By Team Ctrl:

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Date Assigned: April 1, 2025 **Date Submitted:** April 23, 2025

Abstract

Scooters and E-bikes are commonly used in large cities and high-density areas to provide an efficient alternative form of transport for commuters. The typical top speed of an e-scooter ranges from 15 to 25 mph and can pose serious threats to safety if users are not able to avoid unexpected obstacles in a timely manner. Therefore, non-motor vehicles in high-density areas pose increased safety risks to riders.

The motivation behind this design comes from a woman in Los Angeles riding on an e-scooter who collided with a man unexpectedly after he stepped onto the sidewalk. The force from the impact caused the man's head to hit the pavement, ultimately leading to his death. Imagine riding an e-scooter or on a non-motor vehicle equipped with an added layer of protection in obstacle avoidance that would reduce the likelihood of similar scenarios.

This report proposes a design for a cutting-edge braking system that helps riders avoid unexpected obstacles. The objective of this project is to address the need to enhance safety measures and provide a more reliable approach to collision prevention for non-motor vehicles. The following will cover the solution design of the developed product and discuss the design process taken to achieve a working prototype.

Problem Statement

Limited visibility on non-motor vehicles can make it difficult to detect incoming objects or pedestrians in time to prevent collisions. The developed system will be equipped with portable, mobile sensors that utilize object detection to assist riders in braking when approaching objects at high speeds. When attached to scooters, this device will reduce the likelihood of collisions in low-visibility conditions.

Design Requirements

Team Name	Ctrl B	
Team Advisor	Dr. Charles Kim	
Project's Goal/Scope	A portable braking mechanism for non-motor vehicles that has the ability to detect and respond to objects within its projected path.	
Team Members	Clarice Yekeh, Trey Wilson, and Ryan Haynes	
1-sentence problem statement	Limited visibility on non-motor vehicles can make it difficult to detect objects or pedestrians in time to prevent collisions. The developed system will be equipped with portable, mobile sensors that use object detection to assist in braking when approaching objects at high speeds. This device when attached to scooters/bikes will reduce the likelihood of collisions in low-visibility conditions.	
Requirements	**Items**	**Quantity**
1. Product (or Software) Specification	Rasberry Pi Object Detection Camera,12-megapixel camera sensor, an RP2040, AI capabilities	1
	Rasberry SC15184 Pi 4B+ Quad Core 64-Bit	1
	TF-Luna Lidar Sensor, continuous scanning, finite distacnce data, signal strength	2
	Lithium-Ion Battery Source: PiSugar, ckt board compatible w/ Pi, portable, rechargeable	1
	Protective outer casing/shell that can securely attach to vehicle	1
	Jumper Wires	May vary
	Mounting Screws	May vary
	Servo Motor: 20+ N of force, attachable to cinching cable, compact in surafce area	1

Constraints

Environmental Constraints	The developed system must be compatible with existing braking mechanisms on scooters and bikes. Additionally, the device should be able to attach and detach securely to the body of the non-motor vehicle. The power source of the device must be rechargeable as well.
Socio-Cultural Constraints	System should be simple to attach to vehicle for user feasiblity. The device should have a compact design that does not interfere with the functionality or usability of the vehicle.
Compliance (Rules, Regulations, and Standards)	**General Data Protection Regulations (GDPR)**: If the sensors or cameras collect data on individuals, especially if linked to identifiable personal information, the collection and storage of that data may fall under regulations like the GDPR, which requires clear consent and strict data protection measures. **The Consumer Product Safety Commission (CPSC)** sets federal safety standards for bicycles. The CPSC does not have specific federal regulations for e-scooters like it does for bicycles, but it monitors their safety under its general consumer product safety authority. The CPSC focuses on issues like battery safety, mechanical components (brakes, wheels, etc.), and may conduct recalls if products are found to be hazardous.

Solution Design

Component Level Schematic (Figure 1)

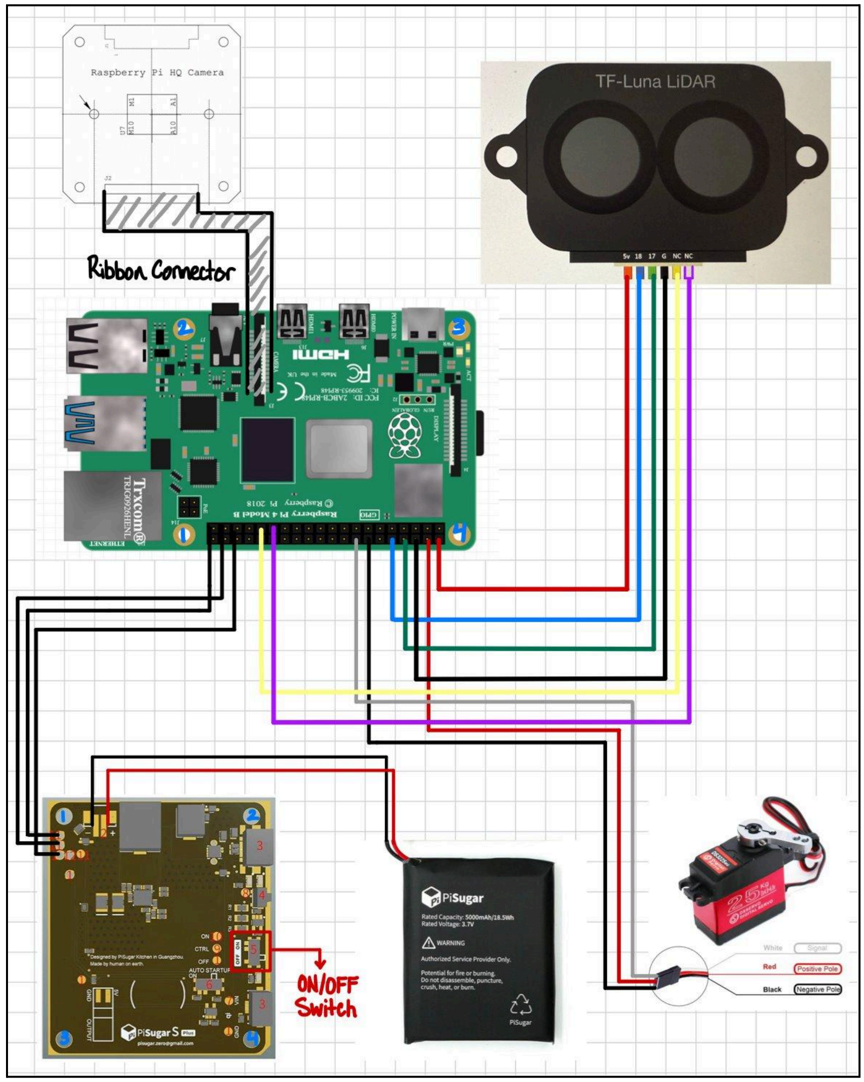


Figure 1

Wire Connections

PiSugar

- The battery pack is removable and makes contact at the back of pins 36, 38, and 40 raspberry pi to provide power to the system.
- The PiSugar board is attached by screws (labeled 1-4), and the battery pack is secured via a magnet on the board.

Raspberry Pi HQ Camera

- The camera is connected via a ribbon connector.

Servo Motor

- VCC (red) → Pin 4
- GND (black) → Pin 14
- Control (white) → GPIO23

Luna Lidar Sensor

- VCC (red) → Pin 2
- RXD (blue) → GPIO 15
- TXD (green) → GPIO 14
- GND (black) → Pin 14

Solution Design Description (see figure 2 & 3)

The developed system uses object detection to assist riders in braking when approaching objects at high speeds. A protective casing (1) houses the system, shielding it from the environment. This casing (1) houses the following internal components: processing unit (4), removable battery source (6), lidar sensor (3), object detection camera (2), and cinching cable (7). The processing unit (4) intakes data from the object detection camera (2) that identifies and classifies hazardous objects while the lidar sensor continuously monitors the systems path for objects position in relation to the non-motor vehicle. These internal components are inter connected via a bus system where the processing unit (4) utilizes a detection algorithm to calculate whether a identifiable object on path enters critical distance of the non-motor vehicle. Once the processing unit (4) sends the appropriate control signal to the motor (5), tension in the cinching cable (7) is created, thus activating the braking mechanism of the vehicle.

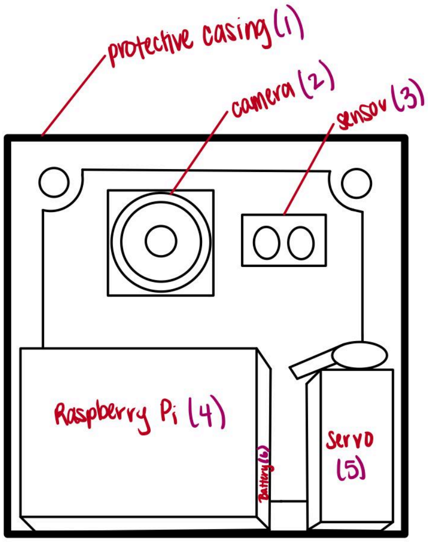


Figure 2

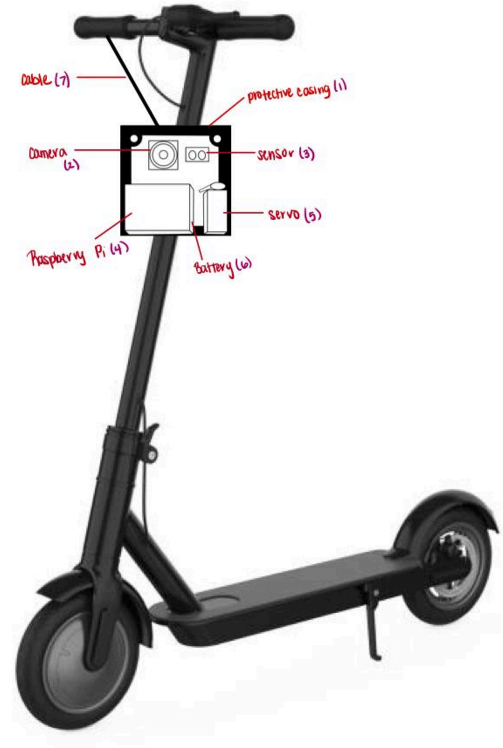


Figure 3

Agile Workflow

EECE404 Senior Design II			
404 Agile Weekly Project Implementation Plan			
Team Name		TEAM CTRL	
Final Solution Product		CTRL-B (Control Brakes): Assistive Braking System for Non-motor Vehicles	
Starting Date of Week (M)	**Sprint #**	**Increment (or intermediate working component)**	**Weekly development tasks**
1/27/25	2	Braking System with Object Detection Camera and Radar Sensor	Obtain scooter and examine braking mechanism to ensure usability
2/3/25			Obtain parts, wire and assemble the system
2/10/25			Set up source code for object detection algorithm using raspberry pi camera
2/17/25	1	Object Detection Algorithm	Coding of Raspberry Pi to take inputs from object detection camera
2/24/25			Coding of Raspberry Pi to take inputs from radar sensor, and combine with previous code
3/3/25			Coding of Raspberry Pi to activate servo motor
3/10/25			Combine code to ensure object detection algorithm recognizes and responds to objects on path
3/17/25	3	Portable Braking Mechanism for Non-Motor Vehicles	Testing of braking mechanism for efficiency and response time in a simulated environment
3/24/25			Testing of braking mechanism for response time in low light conditions, around sharp corners, and/or in inclement weather conditions
3/31/25			Further testing

Project Implementation Process

Sprint 1- Object Detection Camera Setup

The first sprint of this project focused on acquiring the hardware platform and establishing a virtual environment for initial development. Figure 4 shows the first week's progress, where the scooter's braking system was inspected and confirmed to be suitable for testing. In the second week, the focus shifted to creating a cloud-based virtual environment using Microsoft Azure. As shown in Figure 5, this virtual setup successfully simulated a Raspberry Pi configuration, allowing for early integration of key components—including the sensor, camera, and servo motor—to validate system functionality prior to physical deployment.

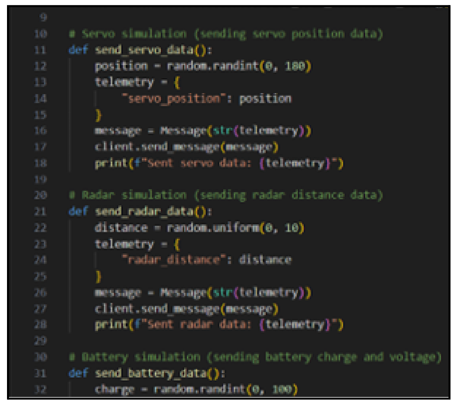


Figure 4 **Figure 5**

Sprint 2 - Lidar Sensor and Servo Test

The second sprint of this project focused on upgrading the processing platform and preparing the system for advanced computer vision tasks. Figure 6 shows the first week's progress, where a Raspberry Pi 1B+ was acquired and successfully initialized for baseline testing. In the second week, the system was upgraded to a Raspberry Pi 4B+, offering increased processing power and compatibility with modern peripherals. The upgraded board was then integrated with a camera module, enhancing the system's ability to process visual input in real time. As shown in Figure 7, OpenCV was introduced during this stage to begin testing object detection functions, setting the foundation for future implementation of dynamic vision-based responses.

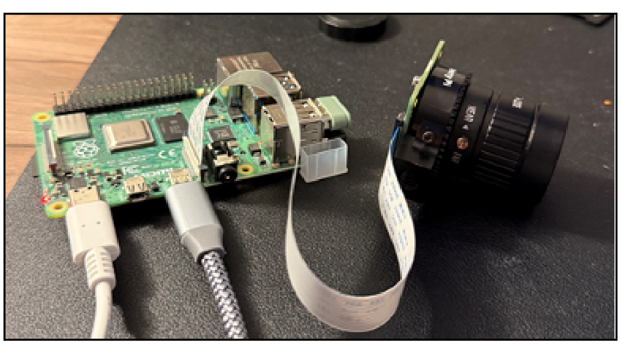


Figure 6 **Figure 7**

Sprint 3 - Mounting and System Level Testing

The third sprint of this project focused on mounting the systems' internal components so that they fit securely within the casing. Figure 8 shows the first week's achievement, where the system accurately identifies objects on path and within a critical distance. Once identified in a three-foot threshold, the servo motor motor is activates and performs a 90 degree sweep. Conversely, once an object is no longer detected within this set range, the servo motor sweeps back to its original position, releasing the tension within the cinch cable. Figure 9 shows a terminal view of the system accurately detecting a pedestrian on path actively changing position, which was the main objective in week 2. In the third week the PiSugar set up powers the system, making it portable. Figure 10 shows the systems fully mounted within its casing and when not attached to a non-motor vehicle.

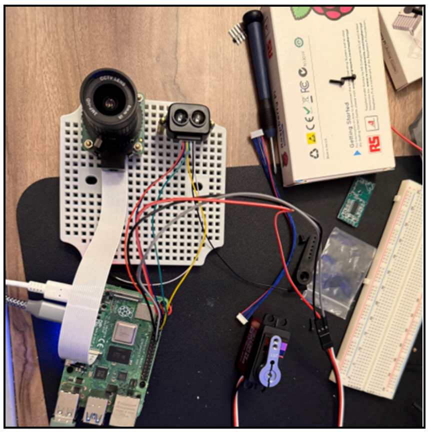


Figure 8

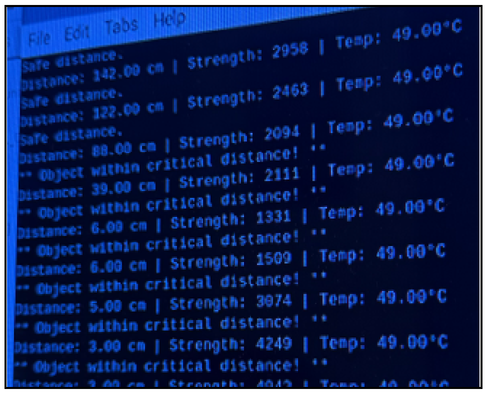


Figure 9

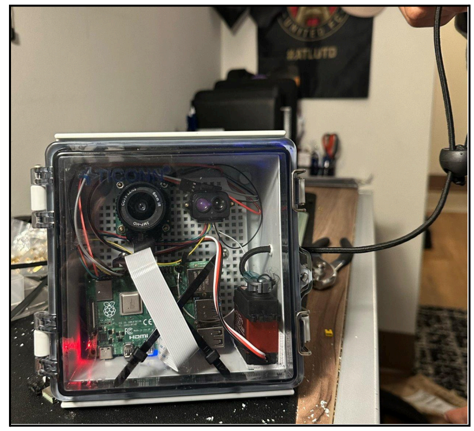
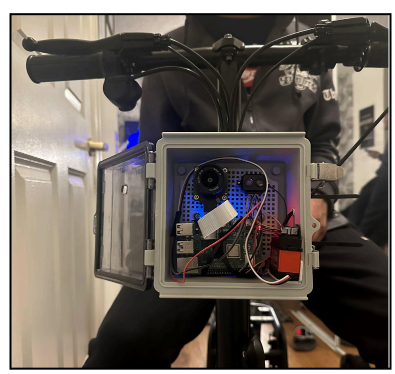


Figure 10

Conclusion

In conclusion, the developed system functions as desired. The generated solution adheres to the steps of the design process. It accurately detects and classifies objects known to cause non-motor vehicle accidents such as pedestrians, cars, street signs, light poles, and other scooters/bikes. Then, the system responds by pulling the cinching cable wrapped abround the brake handle and creating tension.

Ctrl-B is is designed to provide users with an added layer of protection when riding in high density areas at high speeds. This product aims to enhance rider safety by leveraging computer vision along with object detection and lidar technology. The detection algorithm uses a pre trained library to identify objects and lidar sensor inputs to manipulate physical hardware components. This innovative approach and implementation will allow for users to have a more controlled braking experience!



References

https://abc7.com/post/man-dies-after-being-knocked-down-woman-scooter-koreatown-police-investigating-hit-run/15337382/