

SARIT PROJECT

OBJECT DETECTION SYSTEM

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EXECUTIVE SUMMARY

This report outlines the methodology adopted for the design and implementation of an Object Detection System tailored for SARIT. The system aims to enhance safety and operational efficiency under a variety of driving conditions by accurately detecting objects on the road. The methodology encompasses requirement analysis, hardware selection, software development and algorithm selection, algorithm training and validation, system integration and testing, and iterative improvement and maintenance.

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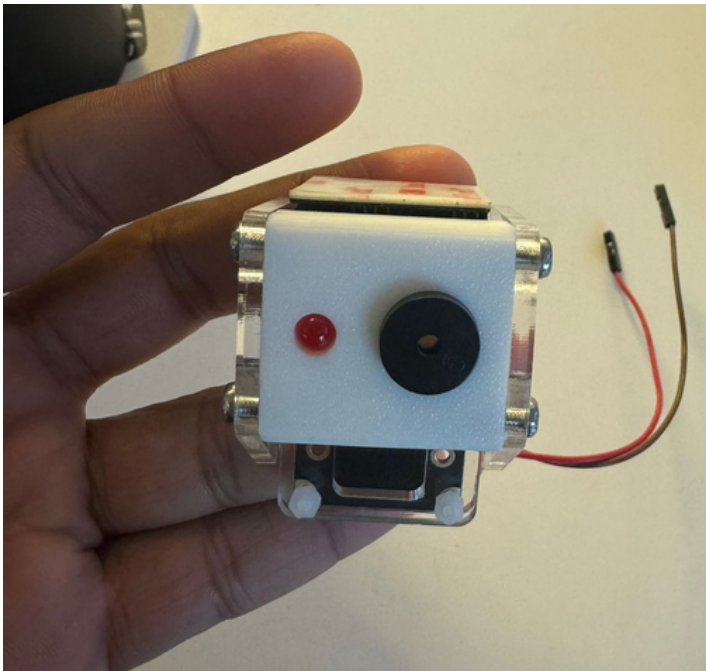


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INTRODUCTION

The advent of micromobility vehicles like SARIT introduces new challenges and opportunities in vehicular safety and navigation. Recognizing the critical need for advanced safety features, this project embarked on designing and implementing an Object Detection System (ODS) tailored to SARIT's unique operational environment. The project's scope encompassed a thorough requirement analysis to understand the specific needs of SARIT, the selection of suitable hardware to ensure real-time processing and energy efficiency, and the development of software capable of accurate and efficient object detection.

Furthermore, the project included rigorous testing under various conditions to validate the system's performance, followed by a structured plan for ongoing system improvement and maintenance. This report provides a comprehensive overview of the methodologies adopted, findings, and strategic plans for the future enhancement of SARIT's ODS.



REQUIREMENT ANALYSIS

The development of an Object Detection System (ODS) for SARIT requires a meticulous understanding of specific operational requirements. This analysis is crucial for ensuring the system's efficiency, safety, and compatibility with SARIT's unique design. It involves assessing driving conditions, determining detection ranges and accuracy, ensuring real-time data processing capabilities, and addressing integration challenges specific to SARIT.

DRIVING CONDITIONS ASSESSMENT

The prototype testing conducted at York University Keele Campus during winter offers valuable insights into SARIT's performance under challenging weather conditions. Given SARIT's micromobility nature, it is essential for the ODS to function effectively not only in varied weather scenarios such as snow, rain, and fog but also in diverse environments including urban pathways, bike lanes, and rural tracks. Ensuring reliable obstacle detection across these conditions is crucial.

REAL-TIME DATA PROCESSING

Given SARIT's operational dynamics, the ODS must process information and respond in real-time to ensure user safety. The system needs to be equipped with advanced computational capabilities to instantaneously analyze data from various sensors, thereby facilitating immediate obstacle detection and alerting the user promptly.

DETECTION RANGE AND ACCURACY

The ODS's detection range and accuracy are critical for ensuring the safety of SARIT users. Stopping distance tests at a maximum speed of 30 km/h revealed a necessary stopping distance of 10-15 meters. This empirical data helps in defining the minimum effective detection range for the ODS to allow sufficient reaction time for the user to manually brake or for the vehicle to initiate an automated response. Incorporating a table with test results in the report will effectively communicate these critical requirements.

VIDEO RECORDING

In addition to real-time data processing and obstacle detection, the system must include a video recording feature. This capability is essential for documenting the circumstances surrounding any incidents or accidents involving SARIT, significantly improving liability assessments and facilitating a clearer understanding of events. The video recording system must be seamlessly integrated with the ODS, ensuring that it does not impede the vehicle's performance while providing valuable data for post-incident analysis.

HARDWARE SELECTION

Selecting the appropriate hardware for SARIT's ODS and video recording functionality is crucial for ensuring optimal performance, integration, and cost-effectiveness. This section outlines the hardware selection process, weighing the pros and cons of various options, and detailing the final choices made to meet SARIT's specific needs.

TESTED CAMERAS

Initially, LiDAR sensors were considered but deemed too expensive, and a camera was needed for video recording. The focus then shifted to evaluating various cameras: OAK-D Lite, OAK-D S2, OAK-D Pro, OAK-1 Lite, and STONKAM ADA 32, with prices ranging from \$99 to \$349.

PROS

- **Open-Source Programming:** Allows for customization to fit SARIT's unique requirements.
- **Online Resources:** Extensive community support and online resources for troubleshooting and implementation.
- **Luxonis Server:** Dedicated server for efficient data collection and analysis.

CONS

- **Power Consumption:** High power requirements could be challenging for SARIT, particularly for extended operations.
- **Visibility Obstruction:** Some models' dimensions could obstruct driver visibility, complicating integration.
- **Cost:** The financial investment for high-end models could strain the project budget.
- **Weatherproofing:** Lack of robust weatherproofing limits functionality in various environmental conditions.



OAK-D Pro | \$349
Night Vision
12 MP
90°



OAK-D S2 | \$249
12 MP
90°



OAK-D Lite | \$149
13 MP
81°



OAK-1 Lite | \$99
13 MP
81°

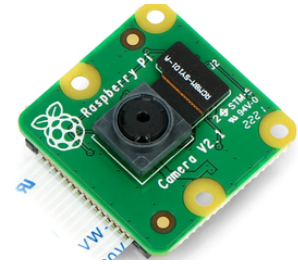


STONKAM ADA32 | \$99
12 MP
130°
Weather Proof
Additional Computing Unit

RASPBERRY PI CAMERA

Due to the limitations with the Oak Cameras, a Raspberry Pi Camera was selected. The chosen model was an 8-megapixel Raspberry Pi 2 camera, paired with a Raspberry Pi 4 board with 8 GB RAM.

This combination ensures compatibility, is cheaper than other solutions, smaller and reduces power consumption issues.



A case with a fan was implemented for the Raspberry Pi to manage the heat generated during the intensive tasks performed by the camera. This addition ensures stable operation of the system under various conditions.

NOTIFICATION SYSTEM



For the driver alert system, a 5V active buzzer and a 5mm LED light were chosen. These components were not part of the initial tests but were selected based on their compatibility and effectiveness in different solutions.

POWER COMPATIBILITY

The USB port available in the SARIT is 5V, which is enough for feeding the whole system, but for some reason with the current drop when the vehicle is running, the system lost power and resets. This is why a power inverter was use to connect the system directly to the battery. Once the SARITs have a proper plug to feed the system, this unit can be removed.



HARDWARE SELECTION PROCESS



OAK-D Pro: The mounting system, requiring alterations on the roof.



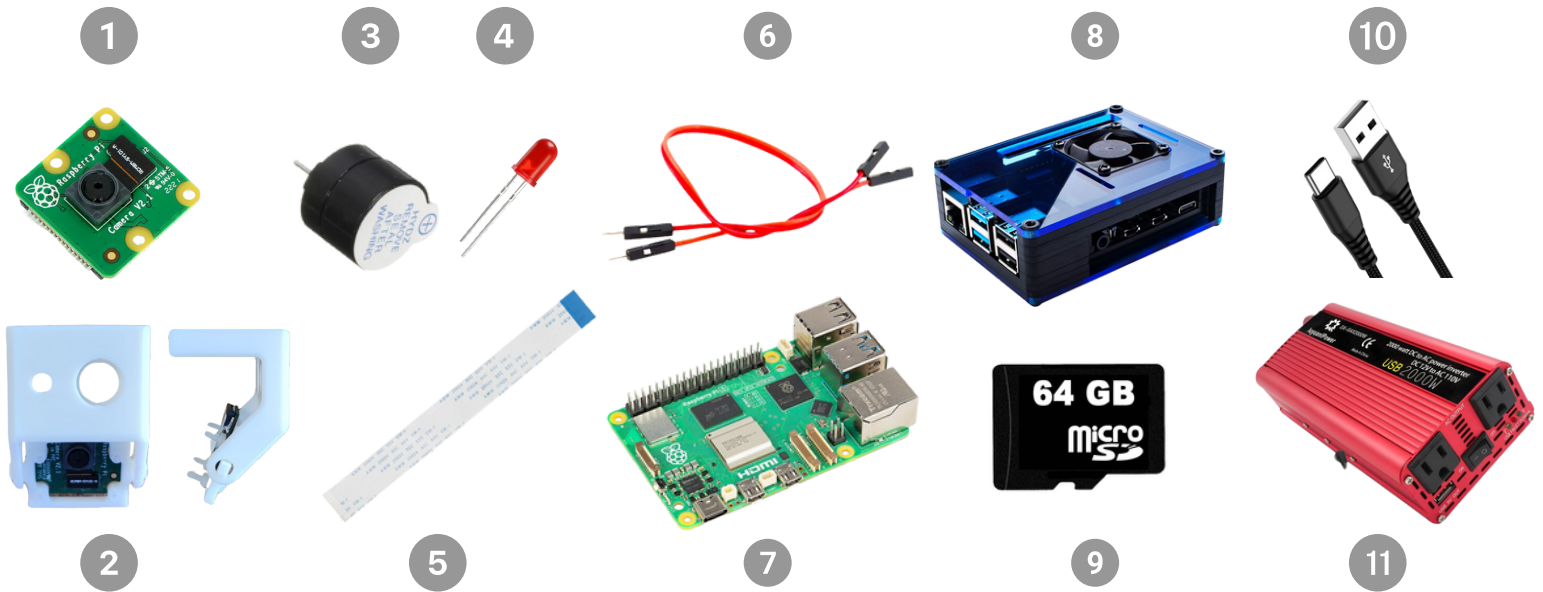
OAK1-Lite: Testing other mounting positions for the cameras (green tape on the right).



OAKD-S2: Pedestrian detection being tested.



TECHNICAL SPECIFICATIONS



No.	Description	Purpose	Dimensions (L x W x H) mm	Price* (CAD)
1	Raspberry Pi Camera Module V2-8 MP, 1080p	Object detection and video recording	25 x 24 x 9	\$53.99
2	3D Printed Adjustable Camera Holder.	Hold the camera and adjust the angle	33 x 35 x 44	\$11.25
3	5V Active Buzzer CLT1036	Audible notification	W12 x H17.2	\$0.84
4	5mm LED light	Visual notification	W5 x H31.7	\$0.17
5	FFC 15 Pin Ribbon Cable for Raspberry Pi Camera	Connection between Camera and Raspberry Pi Board	L300	**
6	Female to Male Jumper Cables Wires M/F	Buzzer and light connection with Raspberry Pi Board	L150	\$0.37
7	Raspberry Pi 4 Model B Quad Core 64 Bit WiFi (8GB)	Computer that controls the whole system. 5V input.	95 x 70 x 28	\$125.38
8	Raspberry Pi 4 Case with Fan	Protect the system from overheating	137 x 103 x 52	\$14.88
9	64GB microSDXC UHS-I Memory Card	Contains the algorithm and the recorded videos	1 x 15 x 11	\$13.99
10	USB Type-C to USB-A 2.0 Male Charger Cable	Connection between Raspberry Pi Board and Power Supply	3 m	\$6.00
11	Power Inverter 800W DC 12V to AC 110V Dual AC Outlets	Power the system using the battery of the car	200 x 95 x 55	\$69.99

* Prices listed are as of January 2024. GST/HST and shipping costs are excluded.

** The unit comes with the Raspberry Pi Camera.

Total \$296.86

SOFTWARE DEVELOPMENT



The development of the software component for SARIT's ODS and video recording functionality is pivotal in realizing the hardware capabilities of the Raspberry Pi Camera and board. This section outlines the structured approach to software development and algorithm selection, focusing on environment setup, dynamic storage management, object detection model loading, real-time video processing, zone detection, alert system, video recording, and cleanup procedures.

ENVIRONMENT SETUP AND VIDEO CAPTURE INITIALIZATION

The software development process begins with preparing the Raspberry Pi environment. This involves setting up a dedicated folder for storing video feeds, ensuring an organized structure for data management. Using OpenCV, a video capture object is created to facilitate live video capture from the Raspberry Pi Camera. This setup is crucial for subsequent real-time processing and video recording.

DYNAMIC STORAGE MANAGEMENT

To manage storage efficiently and ensure continuous operation without interruptions due to storage constraints, the script implements a check for available storage space before initiating recording. If necessary, it automatically deletes the oldest files, thus maintaining enough space for new recordings. This dynamic storage management approach prevents data loss and system crashes due to insufficient storage.

LOADING THE OBJECT DETECTION MODEL

A pre-trained SSD MobileNet model, optimized for real-time performance on lightweight devices like the Raspberry Pi, is loaded. This model, trained on the COCO dataset, can identify various object types, including 'person' and 'car', making it suitable for SARIT's pedestrian and vehicle detection needs.

REAL-TIME VIDEO PROCESSING

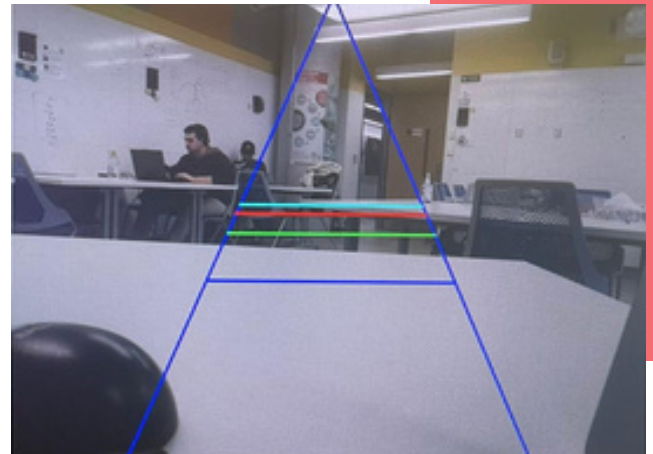
Each video frame captured by the camera is processed through the SSD MobileNet detection model. The model analyzes the frame, identifying objects and their attributes, including type, confidence levels, and bounding box coordinates. This real-time processing capability is fundamental for immediate obstacle detection.



ZONE DETECTION AND ALERT SYSTEM

The software visualizes a detection zone within the video feed, typically marking different proximity zones with a triangle overlay.

When an object, such as a person or vehicle, is detected within a predefined zone, the system triggers alerts. This includes visual cues within the video feed and auditory and visual alerts through the buzzer and LED connected to the Raspberry Pi's GPIO pins, enhancing situational awareness for SARIT operators.



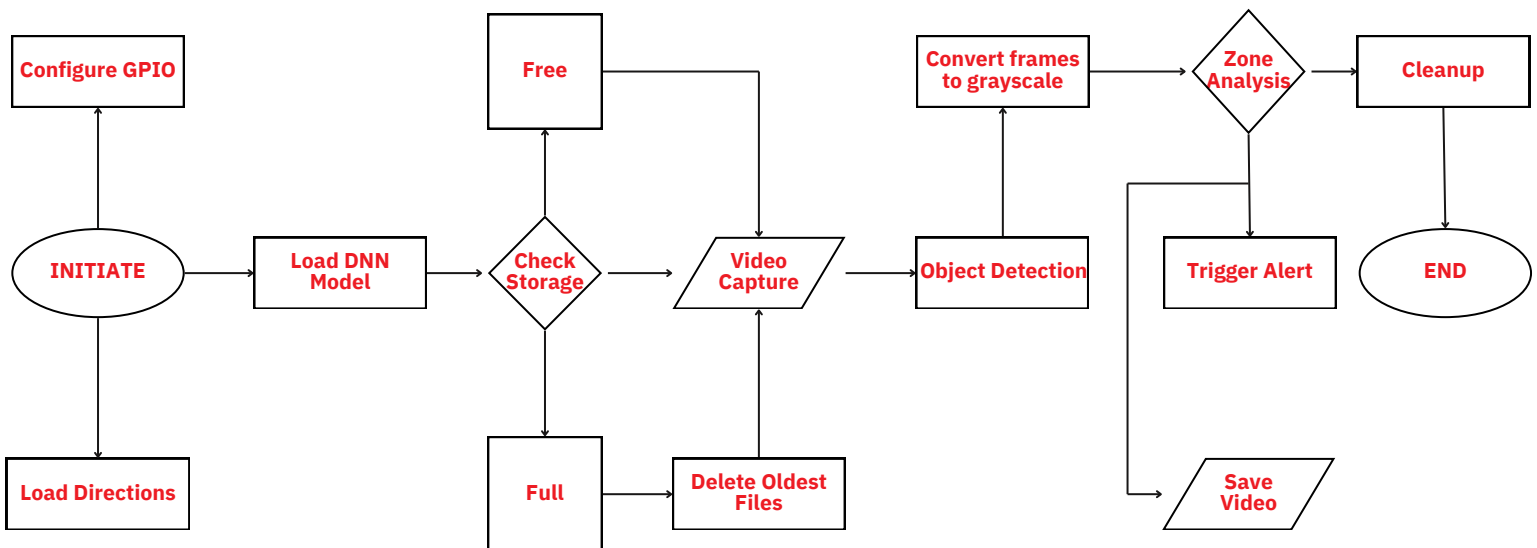
VIDEO RECORDING AND STORAGE

The live video feed, augmented with detection overlays (object bounding boxes and zone visualizations), is recorded and saved with a timestamp in the designated storage folder. This feature allows for historical review and is essential for liability and improvement analysis.

CLEANUP AND SESSION TERMINATION

At the end of a session or upon interruption, the system performs a cleanup, releasing all resources such as the video capture object and GPIO pins. It also closes any open display windows, ensuring a clean termination of the operation and readiness for the next session.

FLOWCHART



ALGORITHM VALIDATION



The implementation of the MobileNet SSD model in SARIT's ODS represents a critical step towards achieving real-time, efficient obstacle detection within the constraints of SARIT. This chapter outlines the process of algorithm training, system validation, and the adjustments made to optimize performance under various conditions.

ALGORITHM TRAINING

Model Selection

The MobileNet SSD model was chosen for its lightweight architecture, consisting of 267 layers and approximately 15 million parameters, making it ideal for real-time inference on devices with limited computational resources, such as the Raspberry Pi used in SARIT.

Training Approach

Utilizing a generic training system, the model was loaded onto the Raspberry Pi, leveraging the pre-trained weights on the COCO dataset. This dataset allows the model to recognize a wide range of objects, which is essential for ensuring the safety and operational efficiency of SARIT.

VALIDATION PROCESS

Indoor and Outdoor Testing

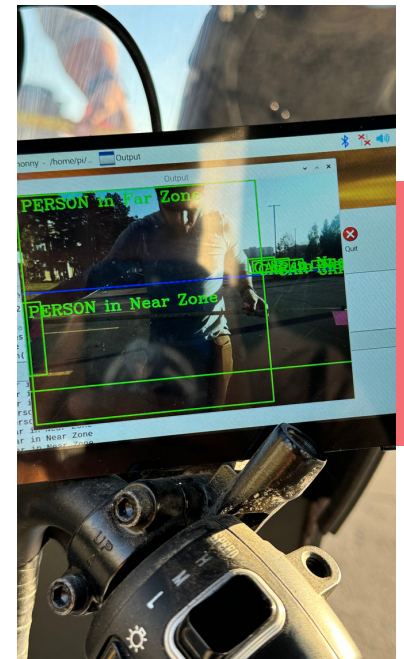
The ODS was validated in both indoor and outdoor environments under varying light conditions. This comprehensive approach ensured the system's robustness across different scenarios SARIT may encounter.

Light Level Challenges

It was observed that at low light levels, the detection capabilities were diminished, especially for objects located on the sides or far from the camera. This limitation necessitates future enhancements to improve low-light performance.

Movement and Delay Adjustments

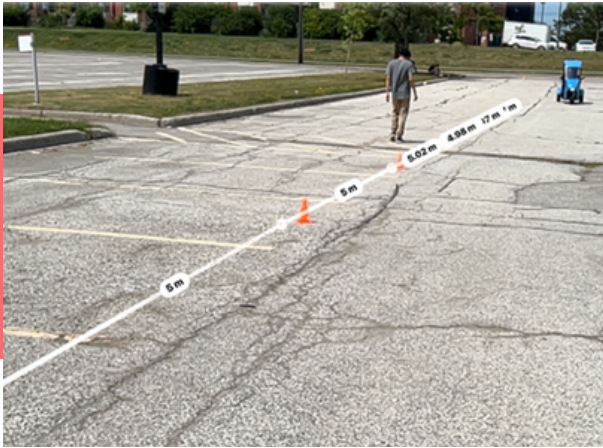
Validation while SARIT was in motion revealed a small delay in object detection. To mitigate this, the video quality was reduced, which, while decreasing the system's demand for computational resources, did not compromise the essential functionality of recording and saving video for liability purposes. Since SARIT does not require live video feedback to be displayed to the driver, this adjustment was deemed acceptable.



PERFORMANCE ASSESSMENT AND ZONE DEFINITION

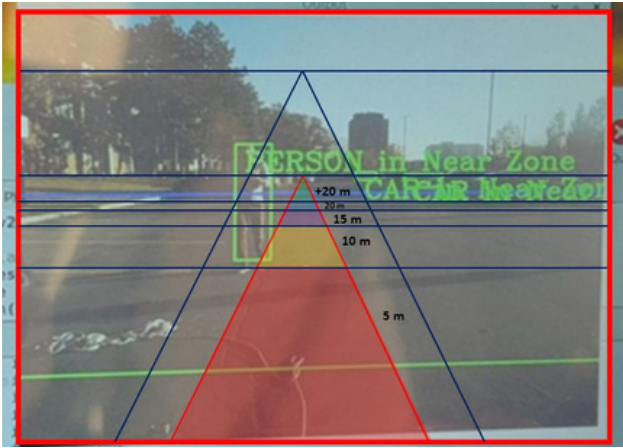
Braking Distance Evaluation

The system's efficacy was further assessed by measuring braking distances at speeds ranging from 10 km/h to 30 km/h, following AASHTO guidelines. The worst-case stopping distance recorded was 25.91 meters, attributed mainly to human perception and reaction times. This insight underscores the potential for ODS to significantly reduce stopping distances by automating the detection and reaction process.



Detection Zones

Based on the validation tests, detection zones were defined to maximize the system's effectiveness. While the camera is capable of detecting objects up to 20 meters or more, it was determined that distinguishing between zones beyond 20 meters did not enhance the system's practical utility. Therefore, any detection beyond 20 meters is categorized within the +20 meters zone, with notifications sent to alert the driver accordingly.



STOPPING DISTANCE USING AASHTO* GUIDELINES

Speed km/h	Reaction Time (s)			
	Alert Driver 1.0 s	Average Driver 1.5 s	Fatigue Driver 2.0 s	Worst Case 2.5 s
	Stopping Distance (m)			
10	3.3	4.7	6.1	7.5
20	7.8	10.6	13.4	16.2
30	13.4	17.5	21.7	25.9

* American Association of State Highway and Transportation Officials

The process for evaluating braking distance was developed by Bhavitesh Garg and Rupayon Haldar, and presented under the title “Enhancing Urban Mobility and Road Safety: Integration of AI Vision Technology in SARIT Vehicles” at the LURA Conference in 2023.



SYSTEM INTEGRATION

The integration and testing phase is a pivotal component in the development of SARIT's ODS. This chapter outlines the comprehensive approach taken to install, integrate, and rigorously test the system within a SARIT vehicle on the York University campus. These steps ensure the system's functionality, reliability, and safety under a variety of real-world conditions.

ALGORITHM TRAINING

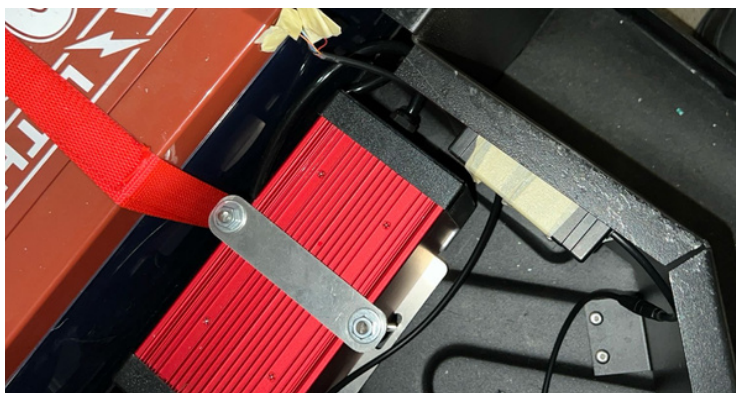
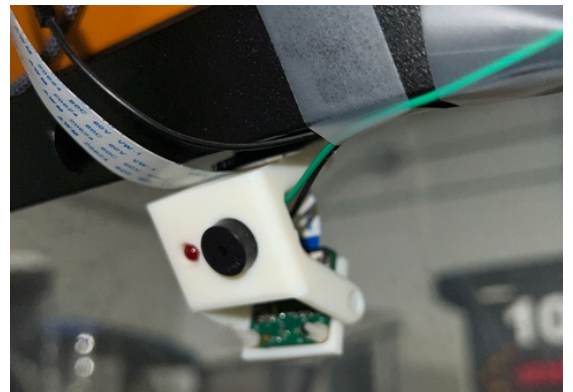
Installation

The ODS was installed in one of the SARIT vehicles to consolidate the components and facilitate system coherence. This initial setup aimed to evaluate the system's performance in an operational environment while identifying any immediate integration challenges.

Safety and Aesthetics

Given the operational vibration and movements experienced by SARIT, it was noted that a more secure method of integrating the system components was necessary to avoid safety issues. To this end, plans for designing and 3D printing a custom case were initiated. This case will not only ensure that all components are securely housed together but will also enhance the system's aesthetic appeal.

The design and production of this case are scheduled to proceed once the system has been approved and fully tested.



TESTING PROTOCOL

The testing phase was designed to assess the system's performance across a wide range of scenarios, reflecting the diverse conditions SARIT is expected to navigate.

Diverse Road Conditions

Tests were conducted on campus roads featuring varying scenarios, including:

- Roads frequented by cars.
- Pedestrian-heavy pathways.
- Areas where both vehicles and pedestrians are present.
- Roads with steep inclines, challenging the system's adaptability to changes in elevation.

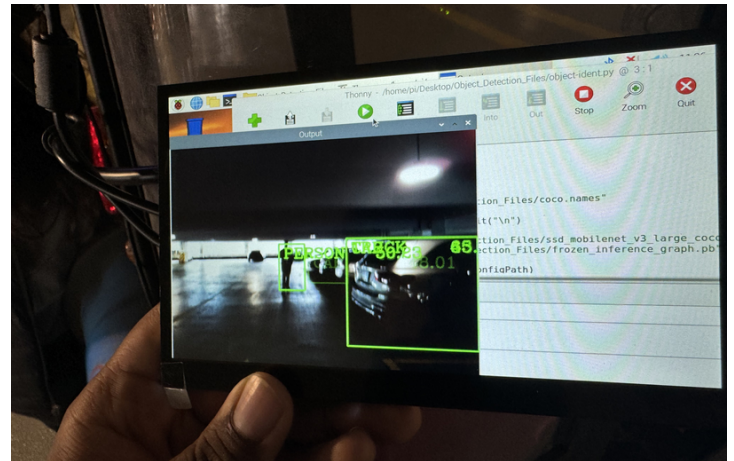


Adverse Weather Conditions

To ensure the system's robustness, testing included operations under cold and rainy conditions. These tests are critical for assessing the system's reliability in adverse weather, which is crucial for ensuring year-round operational capability.

Different Times of Day

The system was tested during both day and night to evaluate its performance across different light levels. This is particularly important for ensuring that the system can reliably detect obstacles and hazards regardless of the time of day, which is vital for user safety.



Performance Across Conditions

The system demonstrated promising functionality across most tested scenarios. However, adjustments are anticipated as the system undergoes further refinement, especially in enhancing low-light detection capabilities and ensuring consistent performance under adverse weather conditions.

OBSERVATIONS AND ADJUSTMENTS

Custom Case Design

The testing phase underscored the importance of developing a custom case for the system. This case will address safety concerns related to system stability and integrate all components into a single, cohesive unit that is both functional and visually appealing.

ITERATIVE IMPROVEMENT AND MAINTENANCE

The journey towards refining SARIT's Object Detection System (ODS) is ongoing, emphasizing the importance of iterative improvement and maintenance to ensure its long-term reliability and efficiency. Although this process is in its initial stages, it is a critical component of the project's lifecycle, aiming to continuously enhance system performance based on real-world usage and feedback. This chapter outlines the planned steps for iterative improvement and maintenance, serving as both a conclusion and a roadmap for future enhancements.

ESTABLISHING A FEEDBACK AND DATA COLLECTION SYSTEM

Performance Data Collection

A system to collect and analyze performance data in real time will be developed. This system will monitor various metrics, including detection accuracy, system responsiveness, and environmental adaptability, to identify potential areas for improvement.

User Feedback Integration

User feedback is invaluable in understanding the system's practical challenges and areas for enhancement. A mechanism for collecting and analyzing feedback from SARIT drivers will be implemented, allowing for user experiences to directly inform system refinements.

MAINTENANCE SCHEDULE DEVELOPMENT

Maintenance Team Briefing

Once a comprehensive understanding of the system's components and functionalities is achieved, the maintenance team will be briefed in detail. This will enable them to develop a thorough maintenance schedule that addresses both routine checks and more complex system updates.

Scheduled and Predictive Maintenance

The maintenance schedule will include both scheduled maintenance to prevent system degradation and predictive maintenance informed by performance data to preempt potential failures.



CONCLUSION



The development and integration of the Object Detection System into SARIT mark significant strides towards enhancing micromobility safety. The project successfully navigated the complexities of system design, from hardware selection and software development to extensive real-world testing. The iterative improvement and maintenance phase, although in its starting stages, sets the path for continuous enhancement of the system based on user feedback and performance data.

The insights gained from the implementation and validation processes underscore the system's potential to significantly improve safety outcomes for SARIT users. As the project transitions into its next phases, the focus will shift towards refining the system's capabilities, ensuring its adaptability to evolving user needs and technological advancements. This report not only chronicles the journey of SARIT's ODS development but also lays the groundwork for future innovations in micromobility safety, paving the way for safer, more reliable urban transportation solutions.

