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Autonomous Vision Tracking Luggage Carrier for Indoor Application

Tan Jia Xin[1], Amirul Syafiq Sadun[1*]

[1] *Faculty of Electrical Engineering Technology*
Universiti Tun Hussein Onn Malaysia, 84600, Pagoh,Johor,Malaysia

*Corresponding Author: amirul@uthm.edu.my
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Abstract

This research explores the potential of self-driving luggage carriers to improve mobility and accessibility by addressing the challenges that travellers face when using traditional luggage carriers. Traditional luggage carts are non-ergonomic and lack intelligent features, making them particularly difficult for individuals with physical limitations or health conditions. To overcome these challenges, autonomous luggage carriers employ Automated Guided Vehicle (AGV) technology integrated with a vision system for hands-free operation. The AGV detects and follows predefined paths, ensuring precise movement and position tracking. A buzzer system is included to alert users in case of misplaced or lost tag detection. The project aims to develop a motorized luggage system with autonomous navigation, integrating a real-time vision tracking system that follows users through unique tag detection for seamless movement. The system also features a smart notification mechanism, including lost tag alerts and a battery monitoring function that triggers automatic recharging. This project was successfully implemented, demonstrating reliable autonomous navigation and accurate tracking using the HuskyLens camera for tag detection and position data. Despite minor limitations, such as sensitivity to lighting conditions, the system achieved its objectives, showcasing precise motion control and seamless hardware and software integration. This innovative approach addresses key issues in luggage transport, improving convenience, safety, and efficiency while highlighting its potential for real-world applications.

1 Introduction

In today's travel situations, the transportation of luggage remains an essential part of the travel experience in airport, yet traditional luggage carrier presents key challenges in terms of mobility, convenience, and accessibility. Travelers who navigate through busy airports and go through check-in, security screening, and boarding procedures are often unable to effectively handle their bags, leading to frustration, difficulty, and discomfort. Autonomous luggage carrier emerges as a promising solution to enhance mobility, convenience, and accessibility. Unlike traditional luggage carrier, smart luggage carrier integrates innovative technologies like tag tracking utilize vision system. The appearance of autonomous luggage carriers represents a significant advancement in technology. Autonomous luggage carriers employ innovative robotics, artificial intelligence, and motorized technologies to provide hands-free operation and self-navigation capabilities. Incorporating a camera vision system into a luggage carrier enhances its capabilities by enabling real-time object identification and tracking. This includes detecting tags or markers and reliably tracking a specific user. The system uses camera vision technology which are advanced image processing algorithms and machine learning techniques to achieve these functions seamlessly [9].

2 Methodology

2.1 Flowchart

The programming flowchart for camera vision module are shown in figure 1. It shows how camera vision works using Huskylens for tag tracking. In this project, the system learns the specific AprilTag before the user interacts. When the user interacts with the luggage carrier, the user places the AprilTag on the bag and aligns it with the camera for detection and tracking . The HuskyLens camera detects the tag and sends its coordinates data to the Arduino. The Arduino then processes the position data and adjusts the motor's speed, direction, and position accordingly. It continuously receives detection data from the HuskyLens and interprets it to control the motor's motion and speed to accurately track the tag. When the tag is lost, the motor will stop, its speed will be set to zero, and the buzzer will sound once to indicate that the tag has been lost.

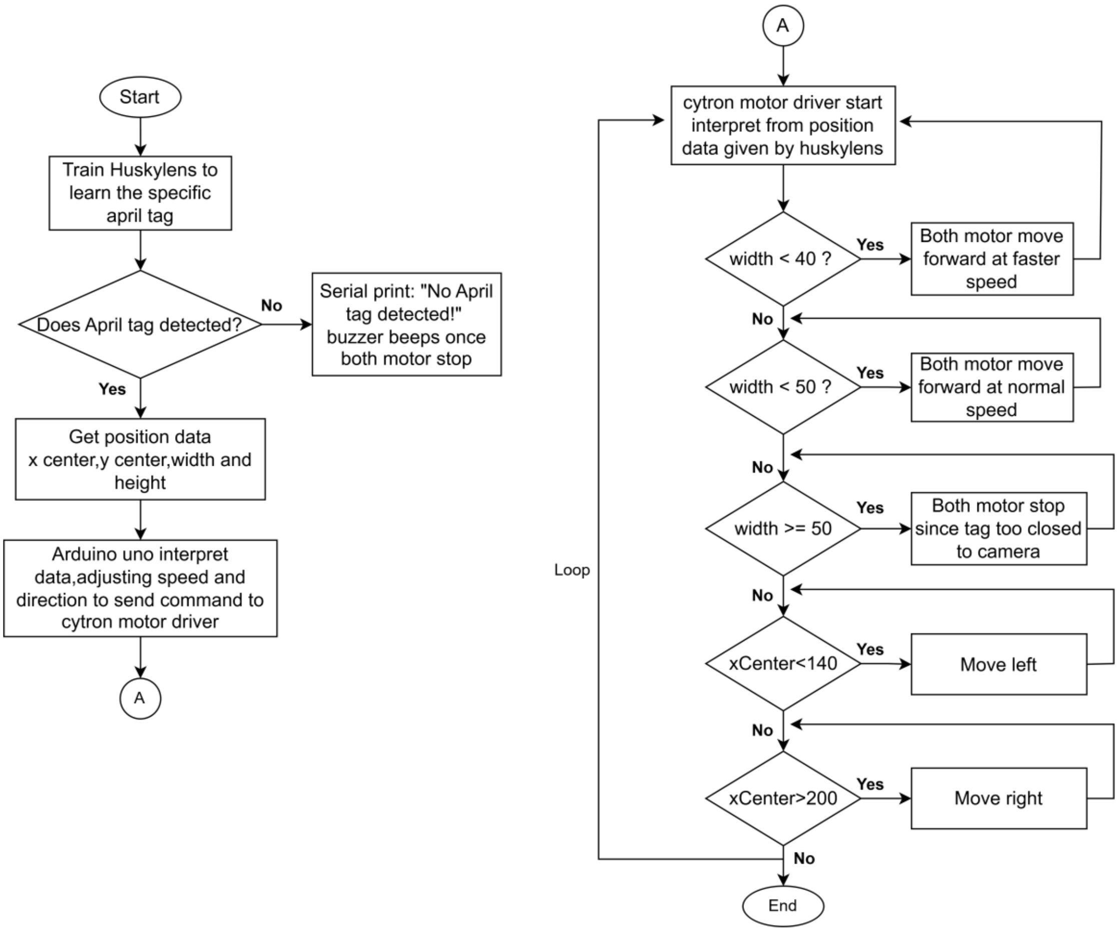


Fig. 1: Programming Flowchart for Camera Vision Module

The programming flowchart for battery monitoring system shown in figure 2 illustrates how voltage sensor works using ESP32 for display the real time data. It starts with the initialization of the ESP32, voltage sensor, LCD, and Bluetooth serial communication. The voltage sensor reads the power supply value in ADC format and converts it to the actual voltage in volt (V). This voltage data is then sent to the ESP32 for further processing. If the voltage detected is greater than 12V, this means that the battery has sufficient power to allow an autonomous carrier to be powered for navigation. The LCD and Bluetooth terminal application will display "Voltage: ". On the other hand, if the voltage that has been detected goes lower than 12V, it means the battery doesn't have the required power for running the luggage carrier. The "Low Battery!" will display in the LCD and Bluetooth terminal application to notify the user.

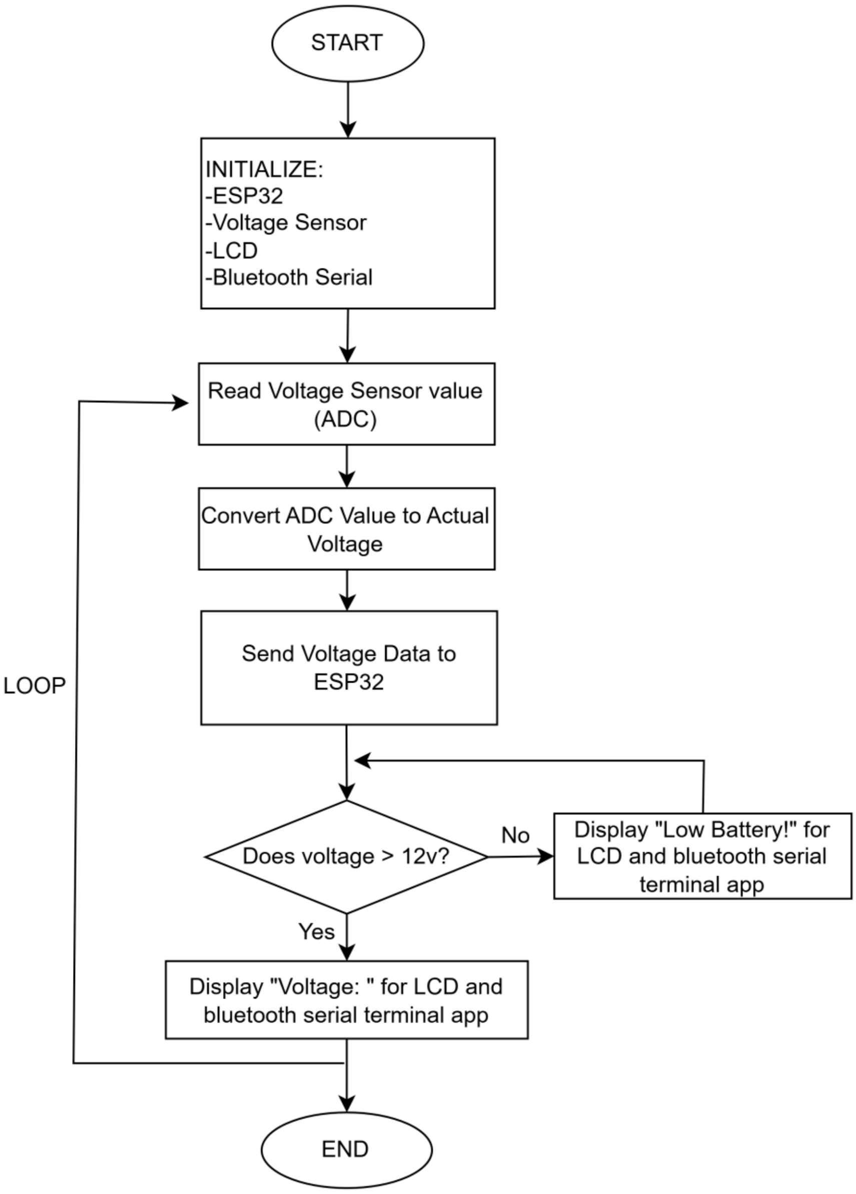


Fig. 2: Programming Flowchart for Battery monitoring system

2.2 Circuit design

The schematic circuit diagram for Huskylens and motor driver are shown in figure 3. The Arduino uno, the 5v pin is connected to the VCC terminal of husky lens and the GND pin is connected to the GND terminal of husky lens. SDA terminal from husky lens will connect to pin 10 and SCL terminal will connect to pin 11 of Arduino. For the MD20A Cytron motor driver, pins 3 and 4 of the Arduino will be used for the first motor's PWM and direction control, while pins 5 and 6 will control the second motor's PWM and direction. Two DC gear motors, each rated at a speed of 160 RPM, will be connected to individual motor drivers. The MA and MB pins on each driver will be used to connect their respective motors. The positive pin of the buzzer will be connected to pin 12, while the ground (GND) pin will be connected to the GND of the Arduino. The VB+ and VB- pin from each motor driver will be connected to positive terminal and negative terminal of 12v battery supply respectively.

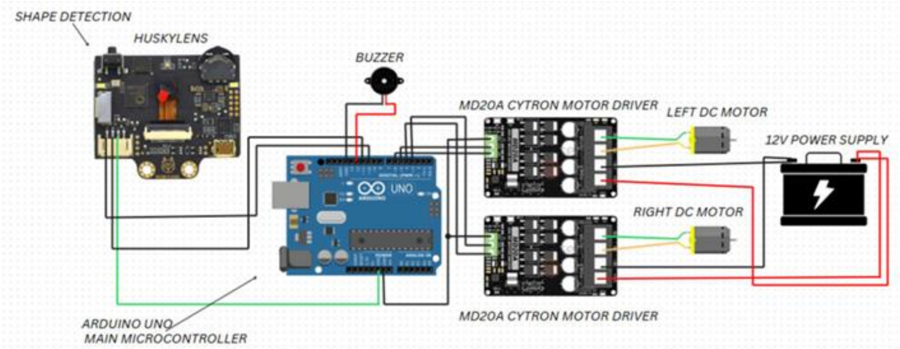


Fig. 3: Schematic Circuit Diagram for Huskylens and Motor Driver

The schematic diagram of the battery level monitor, which monitors the battery level in real time and prevents unexpected erratic movement of the carrier, is shown in Figure 4. On the ESP32, the VIN pin is connected to the positive pin (+) of voltage sensor and the VCC pin of LCD. The signal pin (S) of voltage sensor will be connected to the D26 pin of the ESP32, while the negative pin (-) will be connected to the GND pin of ESP32. The signal pin (S) of voltage sensor is responsible for reading voltage data and transmitting it to the ESP32 for real-time display on both the LCD and the Bluetooth serial terminal app. For the LCD, the SDA pin will be connected to the D21 pin of the ESP32, and the SCL pin will be connected to the D23 pin. These are the default pins for connecting the LCD to the ESP32. Additionally, the GND pin of the LCD will be connected to the GND pin of the ESP32. The ESP32 features built-in Bluetooth functionality, allowing users to connect and track real-time data conveniently.

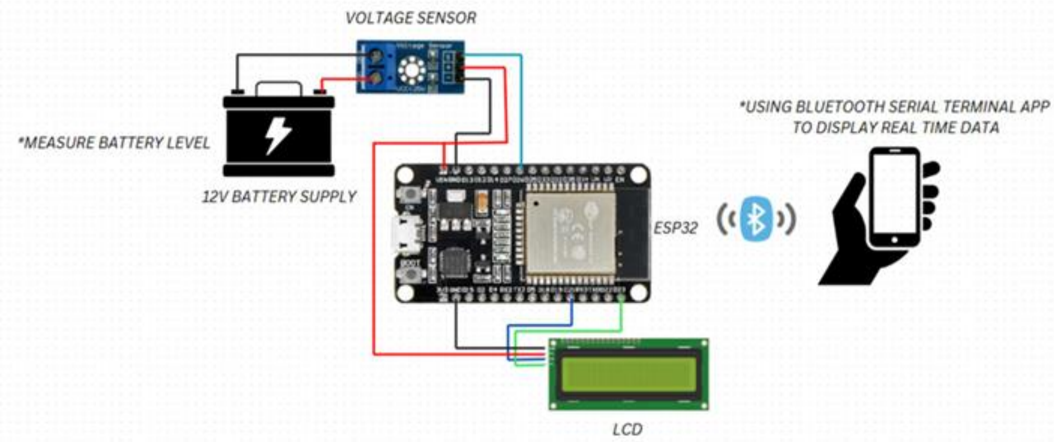


Fig. 4: Schematic Circuit Diagram for battery monitoring system

Block diagram of Operation of Autonomous Luggage with Features shown in figure 5 illustrates how was the overall operation in autonomous luggage carrier. The integration of the HuskyLens with an Arduino microcontroller activates the functionality for April tag recognition and tracking. The Huskylens serves as a camera vision capable of identifying specific April tag. In this project, April tag ID1 will be chosen as the unique identity for tag tracking. Once the Huskylens detects the April tag ID1 from user, it communicates this information to the Arduino microcontroller. The Arduino then processes this data and generates commands to control the MD20A Cytron motor driver. The motor driver, in turn, adjusts the speed and direction of the left and right motors, allowing the system to move and adjust position according to the position data of the April tag ID1. When the luggage encounters an obstacle or not detect the April tag ID1, luggage carrier will stop. Otherwise, the system continues to move the luggage carrier for April tag detection, ensuring responsiveness to position changes in the April tag tracking system. When HuskyLens loses detection of the AprilTag, the buzzer will emit beeps to inform the user of the lost detection. In the context of the battery monitoring system, the voltage sensor will monitor the battery level in volts and transmit the data to the ESP32 for real-time display via a Bluetooth serial terminal application. Simultaneously, the LCD will present this real-time data.

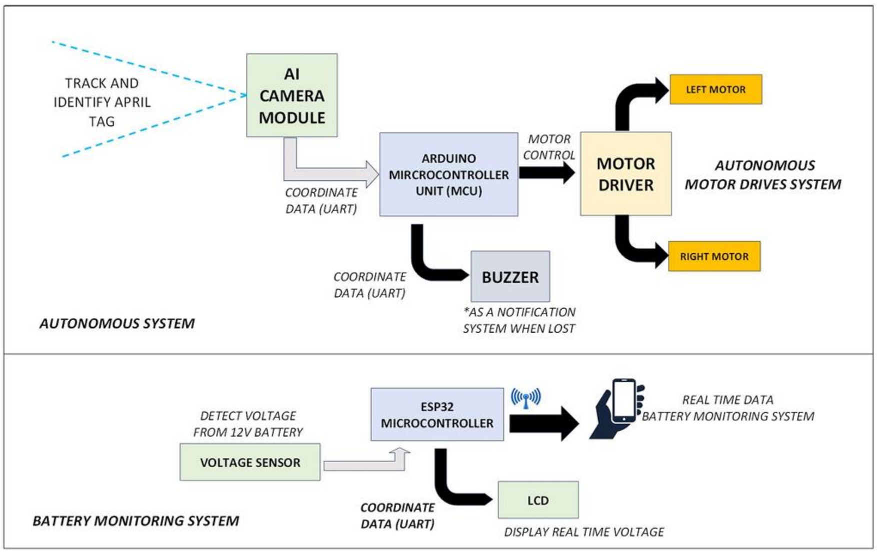


Fig. 5: Block diagram of Operation of Autonomous Luggage with Features

2.3 Implementation of hardware

Figure 6 shows the actual hardware setup, which includes the mechanical frame constructed from lightweight of 3030 aluminum profiles for durability, a wooden as a basement of the luggage carrier, wheels for mobility, and the HuskyLens camera mounted on top for tag detection and tracking. This setup demonstrates the integration of all components, forming the foundation of the Autonomous Luggage Carrier.

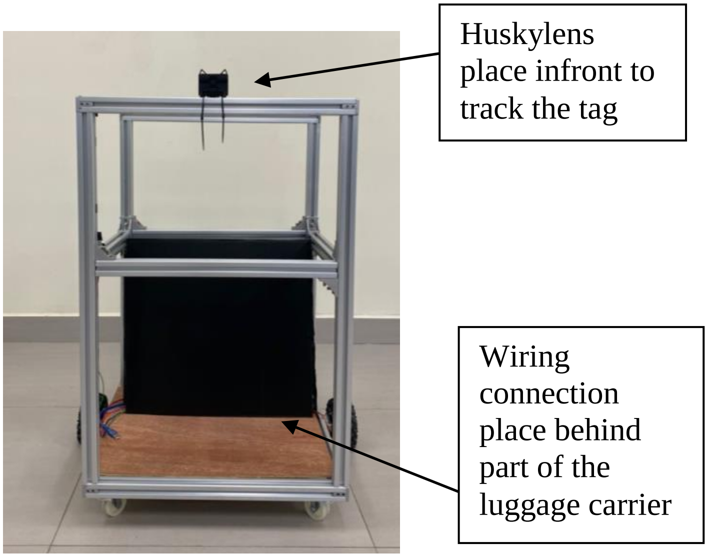


Fig. 6: Hardware setup

Figure 7 shows a close-up of the aluminium frame used in the hardware setup, highlighting the connection joints secured with L-brackets and bolts for stability and durability. The red circle focuses on the mid-frame joint, while the inset zooms in to provide a clearer view of the fastening mechanism using bolts and nuts according to size of aluminium profile. This robust design ensures the structural integrity of the Autonomous Luggage Carrier during operation.

Fig. 7**:** Hardware setup

This figure 8 shows the highlights of a 3-way corner joint of the aluminium frame, constructed using 3030 aluminium profiles and secured with a corner bracket. The fastening is done using hexagon socket screws, tightened with an Allen key for a secure and robust connection.

Fig. 8**:** 3 Way Corner Joint

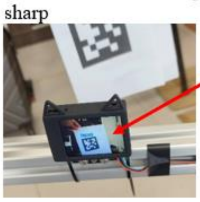
3 Result

3.1 Light Condition Test

The test evaluates the autonomous system’s ability to navigate and plan paths accurately under varying indoor lighting conditions. The test examines the system’s performance in scenarios such as intense indoor lightning and replicating evening. This test aims to identify how lighting variations impact the system’s navigation and path planning. Insights gained will help optimize the system for consistent and reliable performance in diverse indoor environments. Following table 1 are the test method on different light conditions.

Based on table 4.1, it can be concluded that the performance of the tag detection system is significantly influenced by the lighting conditions. The table indicates that under intense indoor lighting, the detection accuracy is high, and the camera screen is bright and sharp. However, in replicating evening conditions, the detection accuracy decreases, leading to erratic issues during navigation and frequent loss of tag detection. Additionally, the appearance of blue lines on the camera screen in the evening indicates a potential loss of detection accuracy and overall system performance. Therefore, the conclusion drawn is that the lighting conditions play a crucial role in the effectiveness of the tag detection system, with better performance observed in bright indoor lighting compared to evening conditions.

Table 1**:** Light Condition Test

Light condition	**Detection Accuracy (Observation)**	**Camera detection**
Intense indoor lighting	Yes, perform well Tag detection keep on track	Camera screen was bright and sharp 
Replicating evening	No, some erratic issue happen during navigation Often losing tag detection	Camera screen start showing blue lines 

3.2 Speed Performance Test

During the test, the trolley's ability to maintain a consistent distance, respond to changes in movement speed, and navigate along the path without delays or errors was evaluated. The results demonstrated the system's effectiveness in real-time detection and tracking, highlighting its capability to adjust its speed dynamically to match the target's movement. This test verified the accuracy and responsiveness of the trolley in fulfilling its autonomous tracking functionality. Table 2 shows how the distance between the autonomous luggage carrier and the April Tag influences its speed in following a person.

Table 2 illustrates that the speed of the autonomous luggage carrier increases as the distance from the April Tag increases. Testing will begin with the minimum detection distance for initiating movement set at 0.6 m and the maximum detection distance set at 1.8 m. The speed of the trolley is limited by the specifications of the DC motor, which has a maximum speed of 160rpm, resulting in slow to moderate movement. The motor speed affects the trolley's ability to track the tag, with lower speeds increasing the time required for tracking. In addition, the effort required by the system to centralize the tag as it moves also affects the time taken to reach or approach the person carrying the tag.

Table 2**:** Speed Performance Test

Diagram	Tag size	Distance (m)	Time taken(s)	Speed (m/s)
	10x10cm	0.6m	2.46	0.244
	10x10cm	0.7m	2.51	0.272

	10x10cm	1.8m	6.15	0.292

3.3 Detection Range Test

The test involved positioning the trolley at varying distances from the April Tag, starting from the minimum distance where the tag was closest to the camera and gradually increasing the separation to the maximum distance at which detection remained reliable. The HuskyLens was assessed for its accuracy in identifying the tag within its field of view, as well as its ability to maintain consistent tracking as the tag moved further away. The results indicated the maximum effective detection range, as well as any potential limitations in environments with obstacles or low lighting. Table 3 shows the detection range test carry out. The minimum distance between the luggage carrier and the April Tag required to initiate movement is 0.6 m, while the maximum distance to initiate movement is 1.8 m. The minimum distance required for the luggage carrier to stop is 0.5 m, whereas the maximum distance to stop is 1.9 m.

Table 3: Detection Range Test

Trial	Tag size	Distance	Tag detect?
1	10x10cm	0.5m	No(min,stop)
2			No(min,stop)
1		0.6m	Yes (min)
2			Yes (min)
1		1.8m	Yes (max)
2			Yes (max)
1		1.9m	No (max)
2			No(max)

3.4 Lost Tag Detection test in Indoor Environments

The system was tested in an indoor environment by having a person hold the tag and simulate real-world movements. The testing involved the person moving in far distance and near distance to trigger the lost tag detection feature. The following table 4 illustrates the results of the lost tag detection feature test based on different distance of tag.

The buzzer responds differently depending on the distance of the tag from the camera. When the tag is far away, the system continuously adjusts to track the tag, and the buzzer triggers frequent alerts due to intermittent loss of detection. When the tag is at a medium distance, the system still adjusts its movement, but the buzzer triggers less frequent alerts. When the tag is close to the camera, the system halts, and the buzzer only triggers once when the tag is lost. Based on the testing presented in the table, it can be concluded that the performance of lost tag detection varies depending on the tag distance. The farther the tag distance, the more frequent the alerts triggered, and the trolley continuously moves. As the tag distance decreases, the alerts triggered become less frequent, and the trolley behavior changes from continuously moving to eventually stopping. Therefore, the conclusion is that tag distance plays a significant role in the detection performance and subsequent behavior of the trolley.

Table 4: Lost Tag Detection Performance Test According to Tag Distance

Trials	Tag detection conditions	Tag distance (m)	Buzzer alerts triggered	Trolley behaviour
1	Far	1.5m	Frequent	Continuously

2	Distance		alerts	moving
1	Medium Distance	1.0m	Less frequent alerts	Continuously moving
2				
1	Near Distance	0.5m	Once	Stop moving
2				

4 Conclusion

In conclusion, an Autonomous Luggage Carrier project has been successfully implemented, demonstrating efficient and reliable navigation capabilities. The integration of HuskyLens camera for tag detection and tracking has been proven effective, with the system providing precision tag detection, tracking and motion control. This project effectively utilized vision-based technologies to enable autonomous operation, highlighting the potential for practical applications in various fields such as healthcare, logistics, security, and environmental monitoring. Despite these achievements, certain limitations have been identified. A key challenge is the sensitivity of the Huskylens camera to environmental lighting conditions, which can influence the accuracy of tag detection and tracking. Lighting conditions may impact the overall performance of the system, particularly in replicating evening or dim light at indoor environment. Nonetheless, the project has successfully achieved the objectives, scope, implementation on hardware and software and the method of testing.

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