

Safedrop: Qr Enabled Delivery Bot

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Abstract – As a new Application to our everyday life. We designed and implemented the SafeDrop: QR-enabled delivery bot, which is an innovative automation system designed to increase efficiency and quality of the services. It is a cost-effective, and scalable solution for automating indoor package delivery. The system utilizes the ESP32 for communication tasks, sensing and to control navigation. It integrates autonomous navigation using IR sensors, secure QR- based authentication and multi-compartment design. Manual delivery of parcels in environments such as restaurants, hospitals, and offices demands continuous human involvement. often resulting in delivery delays, inefficiency, human errors, and compromised security. IR sensors are employed for obstacle detection and line following and ensuring accurate movement, while DC motors and a motor driver enables efficient mobility. A QR-based authentication mechanism enhances security by allowing access only to the authorized users. The delivery box is opened by servo motors and the OLED screen shows the status of the bot. The proposed solution is a cost-effective and reliable way for contactless delivery, and demonstrates the practical implementation of IoT and embedded technologies in real-world applications.

Keywords- IoT, ESP32, Autonomous delivery robot, QR Code Authentication, IR sensors, Line following, Embedded Systems.

I. INTRODUCTION

With the exponential expansion of e-commerce and the escalating demand for contactless services, the development of efficient, secure, and automated delivery systems has become imperative. Manual delivery of parcels in offices, restaurant, hospitals and in libraries requires continuous human effort, make the process slow and inefficient, Also leads to lack of security while handling multiple parcels together and increases the risk of virus transmission. By analyzing all these problems the SafeDrop: QR Enabled Delivery Bot is developed.

The SafeDrop QR-Enabled Delivery Bot is a cost-effective autonomous delivery robot designed to ensure secure and contactless parcel delivery. By enabling contactless operation through automated navigation and QR-based authentication, the system significantly reduces the risk of transmission of contagious pathogens. [1] An autonomous delivery robot equipped with qr code authentication to ensure secure and dependable parcel delivery. The system utilizes the esp32 microcontroller which serves as the central controller for processing, communication, and control operations. Navigation follows a predetermined

path via infrared sensors for line tracking, complemented by obstacle detection capabilities to promote safe traversal.

The robot is propelled by dc motors interfaced through a motor driver. [2]

The system also integrates the ESP32-CAM Module which is equipped with a built-in camera and WiFi capability, allowing real-time image capture and QR code scanning for user verification.

The parcel compartment remains secured throughout transit and unlocks solely upon successful authentication by the designated recipient. This mechanism is actuated by servo motors, offering a straightforward yet robust locking solution. Additionally, the system provides real-time updates through an OLED display, improving user interaction and system transparency. Wifi connectivity facilitates interaction with remote systems for verification and oversight [3].

The software implementation plays a crucial role in the system. The ESP32 is programmed using embedded C in the Arduino IDE, where control algorithms for navigation, sensor processing, motor control, and QR authentication are implemented. The system also uses

WiFi-based communication to interact with external servers or APIs for verifying QR codes and managing delivery status. A web-based or mobile interface can be used to monitor and control the system in real time.

In summary, safedrop is an instance of how the collaboration between robotics, embedded systems, and IOT approaches effectively overcomes the limitations encountered during deliveries. The system offers a cost-effective, secure, and scalable solution for last mile deliveries, making it useful in intelligent campuses, health institutions, corporate offices, and other areas.

II. LITERATURE REVIEW

Recent developments in autonomous robots and IoT technologies have improved the efficiency of smart delivery systems in healthcare, logistics, and institutional applications. Researchers have focused on navigation accuracy, contactless operation, and secure delivery mechanisms.

Patel et al. [1] developed a medicine delivery robot to reduce direct interaction between healthcare staff and patients during the COVID-19 pandemic. The system used Bluetooth communication and ultrasonic sensing for remote operation. However, the robot mainly depended on manual control and lacked secure authentication features.

Shirmohammadi and Baghbani [2] proposed a line-following robot using IR sensors and an L298 motor driver for accurate path tracking. Their system showed reliable navigation on different paths but did not include secure parcel access or IoT-based monitoring.

Yashaswini and Manitha [3] presented an IoT-based system using ESP32-CAM for real-time image processing and wireless communication. Their work demonstrated the effectiveness of embedded vision and IoT technologies in automation systems.

Chen et al. [10] designed an intelligent medicine delivery robot based on Raspberry Pi and infrared navigation. The system improved delivery efficiency using smart navigation and object detection

techniques, but the hardware complexity increased the overall cost.

Elsanhoury et al. [18] discussed advanced indoor positioning methods for smart logistics applications using ultra-wideband technology. Their study emphasized the importance of accurate localization in autonomous robotic delivery systems.

Kavirayani et al. [20] proposed an AI-based medicine delivery robot capable of autonomous movement in hospital environments. The system reduced human involvement and improved delivery efficiency using intelligent navigation methods.

Compared with existing systems, the proposed SafeDrop system combines line-following navigation, QR-based authentication, IoT communication, and multi-compartment delivery in a single compact platform. The system improves delivery security, automation, and real-time monitoring while maintaining a cost-effective design.

III. METHODOLOGY

The proposed SafeDrop system is developed to perform autonomous and secure parcel delivery using embedded control, sensor-based navigation, and QR-code authentication techniques. The system combines hardware modules and software algorithms to achieve reliable contactless delivery in indoor environments. The ESP32 microcontroller acts as the central processing unit responsible for navigation control, sensor interfacing, communication, and decision-making operations.

The system is designed to follow predefined routes using infrared sensing while continuously monitoring environmental conditions for obstacle detection and operational safety. QR-based authentication is integrated to ensure that parcel access is restricted only to authorized users. Wireless communication through WiFi enables real-time verification and monitoring, improving delivery security and system transparency.

A. System Architecture

The overall architecture of the system consists of sensing units, control unit, actuation system, and communication module.

1. This project uses IR sensors for line-following navigation and obstacle detection.
2. A motor driver (L298N) controls the movement of DC motors.
3. Four DC motors are used for locomotion of the robot.
4. This project uses Servo motors to control the locking and unlocking mechanism of the compartment.
5. An OLED display shows the real-time system status.
6. The ESP32-CAM module is used for QR code scanning and visual verification.

All hardware modules are interfaced with the ESP32 controller through GPIO and communication interfaces. The controller continuously acquires sensor data and executes navigation algorithms to maintain stable movement along the predefined path. PWM-based motor control is implemented to achieve smooth directional adjustment and controlled robot speed.

The ESP32 also manages WiFi communication for QR verification and system monitoring.

The authentication process validates scanned QR data before granting access to the delivery compartment. Synchronization between sensing, control, and actuation modules ensures reliable operation with minimal delay. This integrated architecture improves delivery accuracy, operational stability, and system security.

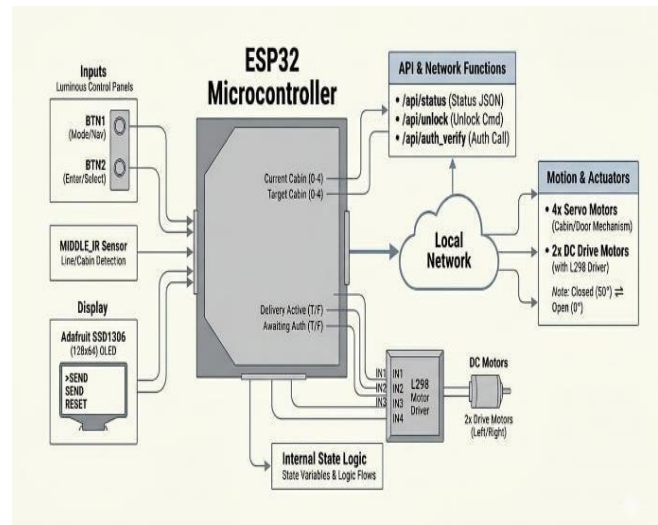


Fig. 1. System Architecture

B. Working Flow Of The System

Working of the system begins with initialization of the ESP32 and configuration of all connected components. Once powered, the robot starts following a predefined path using IR sensors:

Navigation Phase:

The IR sensors continuously detect the path, and the robot adjusts its movement accordingly to stay on track.

Obstacle Detection:

If an obstacle is detected, the system temporarily stops movement until the path is clear.

Destination Arrival:

Upon reaching the delivery point, the robot halts and activates the authentication process.

Qr Authentication:

The ESP32-CAM is used to scan the QR code provided to the user. The scanned data is verified through WiFi communication.

Delivery Action:

If authentication is successful, the servo motors are triggered to unlock the delivery compartment.

Status Display:

The OLED display shows real-time updates such as delivery status and verification results.

The system continuously monitors sensor inputs to ensure smooth and accurate operation throughout the process. Error handling mechanisms are included to manage incorrect readings or failed authentication attempts. The control logic ensures proper coordination between navigation and authentication stages. Communication between modules is optimized to provide quick response and minimal delay. This improves the overall reliability and efficiency of the system. After completion, the system either stops or prepares for the next operation cycle.

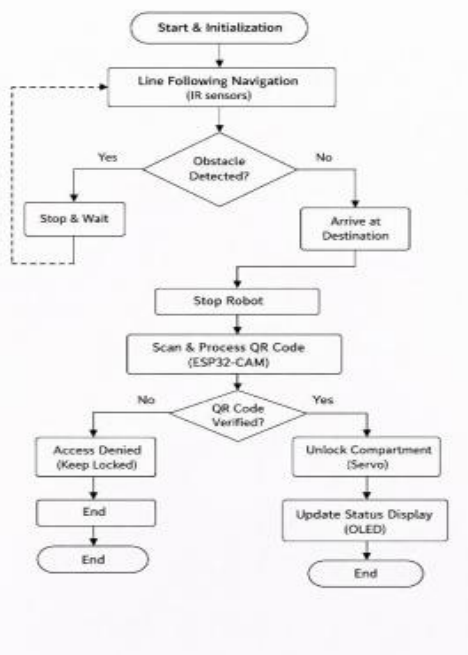


Fig. 2. Flowchart

C. Integrated Decision Logic

The system combines navigation, sensing, and authentication to ensure efficient operation. The ESP32 performs:

- Sensor data acquisition and processing
- Line-following decision control
- Obstacle detection and response
- QR-based authentication verification

Servo control for locking/unlocking mechanism The final output of the system includes:

- Successful navigation to the destination
- Secure parcel access through authentication
- Real-time system status displayed to the user

This integrated approach ensures reliable, secure, and contactless delivery, making the system suitable for applications in smart environments.

Hardware Specifications

• Esp32 Microcontroller And Wi-Fi Communication

The ESP32 acts as the main controller of the system, responsible for processing sensor inputs, controlling actuators, and managing communication. It executes the control logic for navigation, obstacle handling, and authentication. The module also enables wireless communication for QR verification and system monitoring through its built-in WiFi capability.

Key features of the ESP32 are:

- Dual-core 32-bit processor for efficient performance
- Built-in WiFi and Bluetooth support
- Multiple GPIO pins for interfacing
- Low energy usage with high processing capacity



Fig 3: ESP32 Microcontroller

IR Sensor

The IR sensor is used for line-following and obstacle detection by emitting infrared light and sensing its reflection from nearby surfaces. The sensor will assist the robot in determining the route and detecting objects ahead. It supplies digital input to the controller.

Key features of the IR sensor are:

- Fast response for real-time detection
- Suitable for short-range sensing
- Simple and reliable operation
- Low cost and easy integration

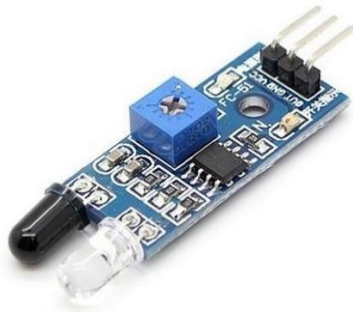


Fig 4: IR Sensor

MOTOR DRIVER (L298N)

The L298N motor driver is used to control the movement of DC motors by receiving signals from the controller. It enables forward, reverse, and turning actions by controlling motor direction and speed. It acts as an interface between low-power control signals and high-power motors.

Key features of the L298N are:

- Dual H-bridge configuration
- Supports bidirectional motor control
- High current driving capability
- Built-in protection features



Fig 5: Motor Driver

Servo Motor

Servo motors are used to control the locking and unlocking of the delivery compartment. They operate

based on angular position control, allowing precise movement for opening and closing the box.

Key features of servo motors are:

- Accurate position control
- Fast response rate
- Low energy requirement
- Stable and precise operation



Fig 6: Servo Motor

Oled Display (I2c)

The OLED display is used to present system information such as status updates, authentication results, and delivery messages. It communicates with the controller using the I2C protocol, minimizing wiring complexity.

Key features of the OLED display are:

- High contrast and clear visibility
- Low energy usage
- Compact size
- I2C communication support



Fig 7: OLED Display

Esp32-Cam Module

The ESP32-CAM module is used for QR code scanning and visual verification in the system. It captures images of the QR code and processes them for authentication.

It also supports wireless communication for transmitting data.

Key features of the ESP32-CAM are:

- Integrated camera module
- WiFi-enabled communication
- Supports image processing
- Compact and efficient design

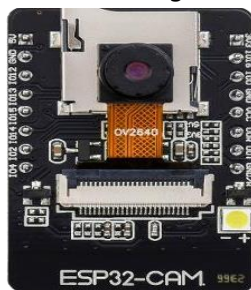


Fig 8: ESP32 CAM Module

III. CIRCUIT DIAGRAM

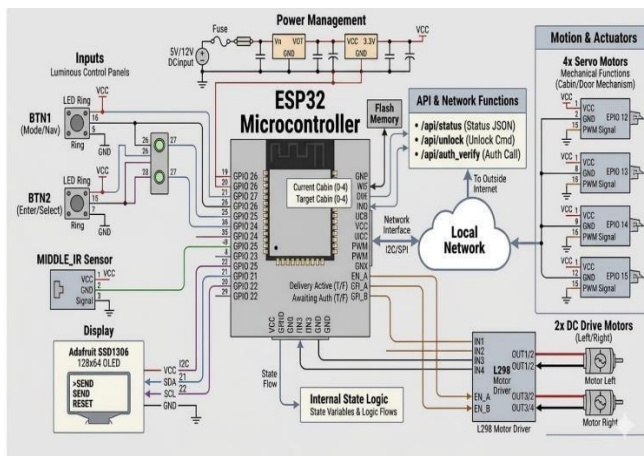


Fig 9: Circuit Diagram

Fig. 9 shows the circuit diagram of the proposed SafeDrop QR-enabled delivery system. The system is centered around the ESP32, which acts as the main control unit and coordinates all sensing, processing, and actuation tasks. The power management section provides a regulated supply from a 5V/12V input, ensuring stable 3V output required for the ESP32 and associated components. Input controls such as push

buttons are connected to the GPIO pins to allow manual interaction for mode selection and system operation. The IR sensor is interfaced with the controller to enable line-following and basic obstacle detection functionality.

An OLED display module is connected through the I2C interface (SDA and SCL pins) to present real-time system information such as status updates and delivery progress. For motion control, the ESP32 sends control signals to the L298 motor driver, which in turn drives the DC motors responsible for robot movement. The system also includes multiple servo motor connections used for operating the locking and unlocking mechanism of the delivery compartment. These servos are controlled through PWM signals generated by the ESP32. Additionally, the controller communicates with a local network to support API-based operations such as status monitoring and authentication.

Overall, the circuit integrates sensing, actuation, and communication modules in a structured manner, enabling coordinated operation of navigation, secure access, and real-time system feedback.

IV. RESULTS AND DISCUSSION

The developed SafeDrop QR-enabled delivery system was implemented and tested under real-time conditions. The system integrates sensors, the ESP32, motor control, and a QR-based authentication mechanism to perform secure and contactless delivery operations.

System Initialization & Cabin Selection

- The system starts when the robot is powered ON.
- All compartments are initialized in a locked condition.
- OLED display indicates system status and menu choices.
- Two push buttons are used: one for selection and one for scrolling (up/down).
- The user selects the required cabin using these buttons.
- This interface provides simple and effective manual control before operation starts.



Fig 10: System Initialization & Cabin Selection

Parcel Placement Mechanism

- After cabin selection, the respective compartment is activated.
- The servo motor opens the selected compartment automatically.
- The compartment remains open for a few seconds (around 5 seconds).
- The user places the parcel inside during this time.
- The compartment then closes automatically to secure the parcel.

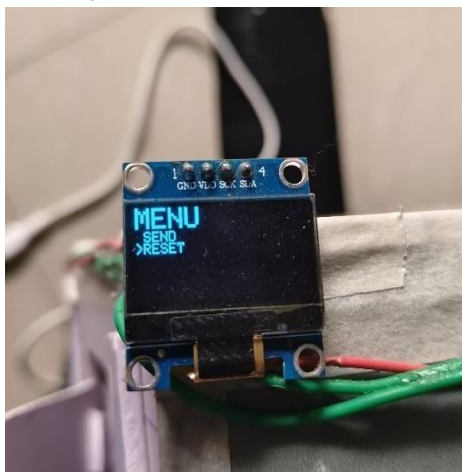


Fig 11: Parcel Placement Mechanism

Autonomous Navigation

- Once the parcel is secured, the robot starts moving.
- The system uses IR sensors for line-following navigation.
- Sensors continuously detect the path and guide movement.
- The control system adjusts motor direction in realtime.
- This ensures stable and accurate path tracking.

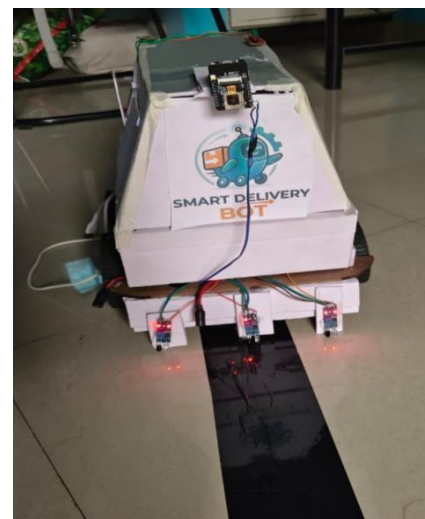


Fig 12: Autonomous Navigation

Authentication Process At Destination

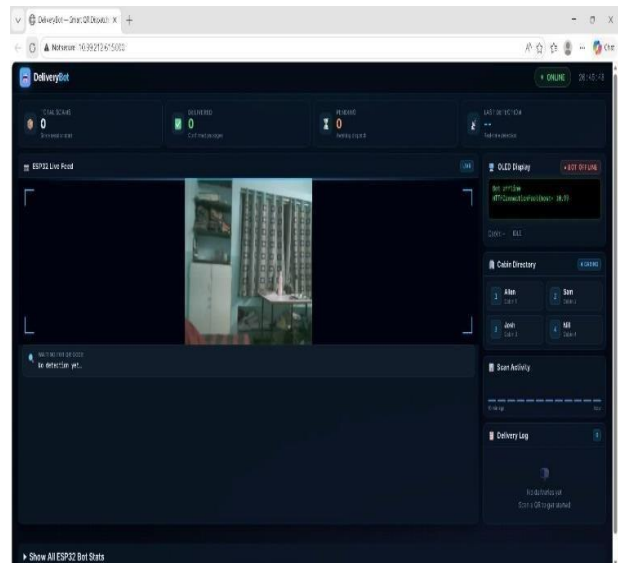


Fig 13: Authentication Process at Destination

- After reaching the destination, the robot stops automatically.
- The system activates the QR authentication process. • The ESP32-CAM scans the QR code provided by the user.
- The detected data is displayed on the web interface. • An access request is generated for verification.

Secure Parcel Delivery

- If the QR code is verified, access is granted.
- The corresponding compartment is unlocked using a servo motor.
- The user can collect the parcel securely.
- If verification fails, access is denied.
- This ensures safe and authorized delivery.

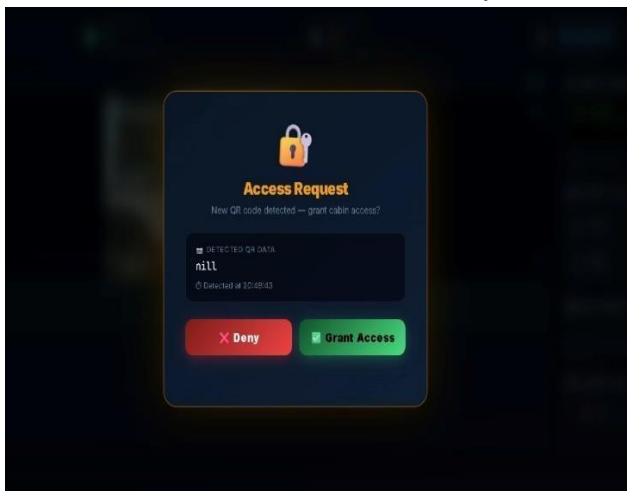


Fig 14: Secure Parcel Delivery

Monitoring And System Feedback

- The system includes a web-based monitoring dashboard.
- It provides live video streaming from the ESP32-CAM.
- Delivery status and scan activity are displayed in real time.
- System logs help in tracking operations.
- This improves visibility and control of the delivery process.

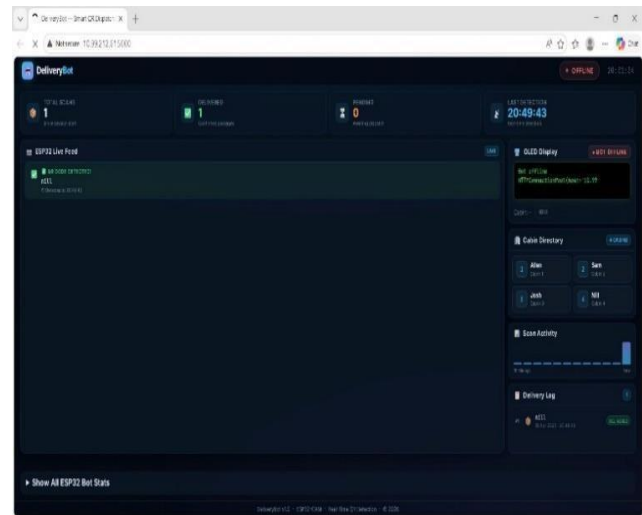


Fig 15: Monitoring and System Feedback

Performance Analysis

The performance of the proposed SafeDrop system was tested under real-time operating conditions to evaluate navigation, authentication, response time, and overall system reliability.

- The IR sensor-based line-following mechanism achieved approximately 93–95% tracking accuracy on predefined indoor paths. The robot maintained stable movement with automatic path correction.
- The obstacle detection system responded in less than 1 second, allowing the robot to stop safely whenever an obstruction was detected.
- The ESP32-CAM module completed QR-code scanning and verification within an average time of 2–3 seconds under normal lighting conditions.
- The servo motor mechanism operated reliably during repeated locking and unlocking operations of the delivery compartment.
- Continuous testing confirmed smooth coordination between navigation, sensing, and authentication modules with minimal operational delay.
- The system provided nearly 1.5–2 hours of continuous operation depending on motor activity and load conditions.

The experimental results demonstrate that the SafeDrop system performs efficiently for secure and contactless indoor parcel delivery applications.

VII. CONCLUSION

The SafeDrop system presents a reliable and practical solution for secure, contactless delivery by integrating embedded control, sensing, and wireless communication. Using the ESP32 as the core unit, the robot successfully combines line-following navigation, obstacle handling, and QR-based authentication into a single coordinated system. The use of multiple compartments, servo-based locking, and simple user interface allows efficient parcel handling with minimal human intervention.

Experimental observations show that the robot maintains stable movement along predefined paths and responds effectively to obstacles by pausing and resuming operation. The QR authentication mechanism ensures that only authorized users can access the parcel, improving overall system security. Additionally, the OLED display and web dashboard provide real-time feedback, making the system transparent and easy to monitor.

This project highlights the potential of combining IoT and robotics for smart delivery applications, especially in environments where safety and limited human contact are important. While the current system performs well in controlled conditions, its performance can be further enhanced by improving sensor accuracy, extending navigation capabilities, and integrating advanced features such as dynamic routing or AI-based decision making. Overall, the SafeDrop system demonstrates a scalable and efficient approach toward automated delivery solutions.

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