IOT AND AI - BASED AUTONOMOUS ORDER PICKUP AND DELIVERY ROVER

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ABSTRACT

The rapid growth of e-commerce and on-demand delivery services has created a strong need for efficient, cost-effective, and contactless delivery solutions. The robotic rover is defined as a small vehicle that can move over rough ground and it is initially used by NASA for space exploration. Robotic rover fills the gap without endangering personnel involves in life-threatening condition or scenario that human sometimes needs to deal with. Order picking is one of the most expensive tasks in warehouses nowadays and at the same time one of the hardest to automate. Technical progress in automation technologies however allowed for first robotic products on fully automated picking in certain applications. This paper presents a mobile order picking robot for retail store or warehouse order fulfilment on typical packaged retail store items, equipped with obstacle detection capabilities, and capable of unlocking the storage unit. This paper presents the design and development of an IoT and AI-based autonomous robotic system capable of performing both warehouse order picking and last-mile delivery to users' homes through a mobile application-based ordering platform. This task is especially challenging due to the variety of items which need to be recognized and manipulated by the robot. Besides providing a comprehensive system overview the paper discusses the chosen techniques for textured object detection and manipulation in greater detail. The paper concludes with a general evaluation of the complete system and elaborates various potential avenues of further improvement.

Keywords: Autonomous Delivery Rover, Order Picking System, Object Localization, Robot Vision, Face Recognition, Object Detection, Last-Mile Delivery, Autonomous Vehicles, Internet of Things (IoT), Artificial Intelligence (AI), Mobile Application Interface, Secure Delivery System, Human-Robot Interaction.

INTRODUCTION

The rapid growth of e-commerce and on-demand delivery services has significantly increased the need for fast, efficient, and reliable last-mile delivery solutions. Traditional delivery methods often face challenges such as high operational costs, traffic congestion, delayed deliveries, and dependency on human resources. As customer expectations shift toward real-time tracking and same-day delivery, there is a growing demand for intelligent and automated delivery systems that can address these challenges effectively.

In recent years, advancements in Artificial Intelligence (AI), Internet of Things (IoT), and robotics have enabled the development of autonomous delivery systems, particularly mobile delivery rovers. This system is designed to operate with minimal human intervention while ensuring accurate, secure, and efficient package delivery.

By integrating smart technologies, delivery rovers can optimize routes, monitor environmental conditions, and interact with users in real time.

This proposed system introduces an integrated architecture consisting of a Mobile App Interface, Order Processing Database, Route Planning Dashboard, System Monitoring Dashboard, and AI Vision-based Face/Object Recognition module.

The mobile application serves as the primary customer interaction platform, allowing users to place orders, specify delivery locations, and track the rover's movement. All order-related data is securely stored and managed within a centralized database, ensuring seamless communication between system components. The core intelligence of the system lies in the route planning module, which utilizes AI and IoT data to determine the most efficient delivery path based on real-time rover location and environmental factors. Additionally, the system monitoring dashboard enables operators to supervise rover performance, including location tracking, battery levels, and system alerts, ensuring reliability and operational safety.

Security and accuracy in delivery are further enhanced through AI-based vision systems capable of face and object recognition. This feature enables secure pickup and delivery by verifying the identity of recipients or detecting specific objects, thereby reducing the risk of package loss or unauthorized access.

This study aims to design and develop a smart autonomous delivery rover system that addresses the limitations of traditional delivery methods while improving efficiency, reducing operational costs, and enhancing customer satisfaction. By leveraging modern technologies, the proposed system contributes to the advancement of intelligent logistics and sustainable delivery solutions for future smart cities.

LITERATURE SURVEY

Recent advancements in autonomous delivery systems have focused on improving efficiency, safety, and contactless delivery mechanisms using robotics, AI, and IoT technologies. Various researchers have proposed different models and architectures to address challenges in last-mile delivery.

Shankar et al. (2025) developed a low-cost autonomous mobile robot designed for safe package delivery. The system integrates GPS-based navigation for accurate positioning and a digital compass for maintaining trajectory. Additionally, a password-protected container ensures secure delivery, preventing unauthorized access. The study highlights significant improvements in delivery speed and promotes contactless delivery, reducing the risk of virus transmission. This approach demonstrates how combining navigation systems with security mechanisms enhances both efficiency and reliability.

Similarly, a study on GPS-guided delivery robots proposed an autonomous system consisting of a mobile robot, cloud server, and mobile application interface. The robot uses ultrasonic sensors for obstacle detection and GPS for navigation, enabling it to operate in outdoor environments. The inclusion of a password-based locking system ensures that only the intended recipient can access the package, improving delivery security. In broader research, autonomous delivery robots (ADRs) are identified as a promising solution to the last-mile delivery problem, which is often the most expensive and inefficient part of the supply chain. Studies show that ADRs can significantly reduce delivery costs, improve time efficiency, and lower environmental impact, especially in urban areas with high e-commerce demand. Further literature classifies delivery robots into sidewalk robots and road-based robots, depending on their operating environment. These systems are typically equipped with sensors, cameras, and AI-based algorithms to perform navigation, object detection, and decision-making tasks. The integration of AI and IoT technologies allows real-time communication, monitoring, and adaptive routing, making the system more intelligent and responsive.

METHODS AND MATERIAL

1. Cloud Server (The Brain & Control Centre)

The high-level management layer responsible for data processing, AI logic, and user interaction.

Mobile App Interface: The primary touchpoint where customers place orders, input delivery locations, and track the rover in real-time.

Order Processing Database: The central repository for all service data, including customer profiles, order history, and live delivery statuses.
Route Planning Engine: The core logic hub. It calculates optimal paths by synthesizing order details with real-time GPS data received from the Communication Layer.
AI Vision System: Handles high-level authentication (Face/Object Recognition) to ensure secure package pickup and delivery to the correct recipient.
System Monitoring Dashboard: An operator-facing interface used to track the health of the entire fleet, monitor battery levels, and respond to system alerts.

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2. Communication Layer
The bridge connecting the virtual cloud environment to the physical hardware.
IoT Gateway: Symbolizes the connectivity of physical devices to the internet.
Data Transmission (Wi-Fi/4G/5G): The medium through which commands (from the Cloud) and telemetry (from the Rover) are exchanged.

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3. Autonomous Rover (The Body)
The physical hardware powered by Raspberry Pi that executes the delivery mission.
A. Computing & Control
Raspberry Pi Zero W:

The primary on-board computer. It runs the operating system, processes sensor data, manages communication, and executes navigation algorithms locally.
ESP32 Microcontroller:

Acts as a secondary controller for real-time tasks. Handles fast sensor interfacing, Wi-Fi/Bluetooth communication, and offloads time-critical operations from the Raspberry Pi.
Real-time Motor Control:
Firmware/software running on Raspberry Pi + ESP32 that converts navigation decisions into precise electrical control signals for motors.
3.5-inch TFT Display:
Provides a local user interface for monitoring system status, navigation data, debugging information, and basic controls.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 04 | April - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

4. Delivery Endpoint
Delivery Location (Customer): The final destination where the rover interacts with the recipient to complete the Successful Delivery.
B. Navigation & Awareness
HMC5883L Magnetometer (I2C):
Digital compass sensor used to determine heading direction (North, South, East, West). Helps in accurate path navigation and orientation.

Ultrasonic Sensor (HC-SR04):
Measures distance to obstacles in real time, enabling collision avoidance and safe navigation.

C. Actuation & Mechanics
L298 Motor Driver:
Dual H-bridge motor driver that receives low-power control signals from Raspberry Pi/ESP32 and drives DC motors for forward, reverse, and turning movements.

Automated Lock Box:
Secure storage compartment for packages. Unlocks only when authentication is successful via system control.

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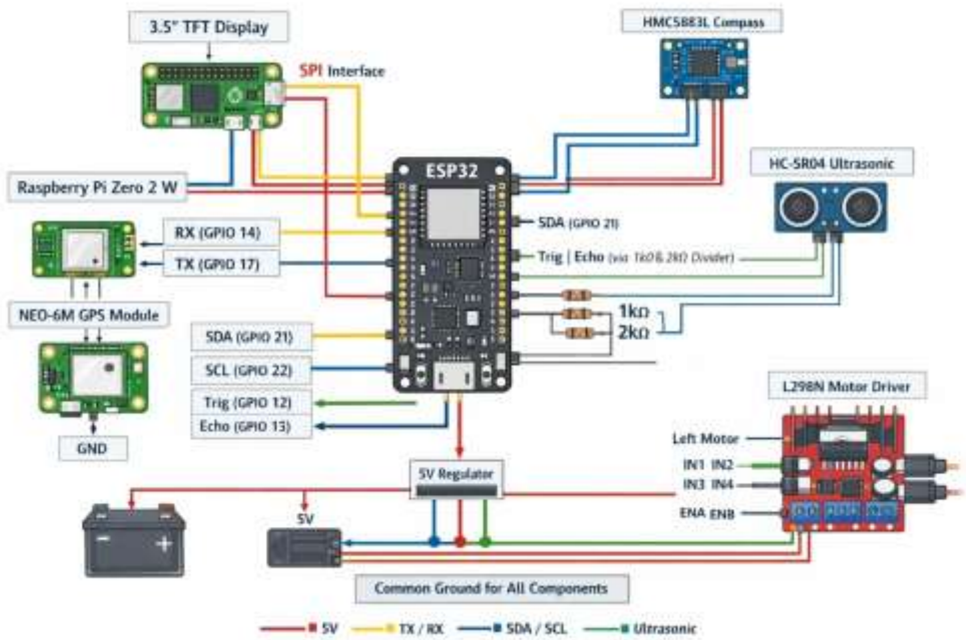

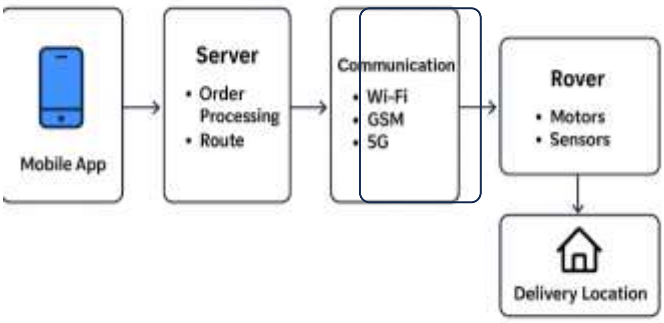

ASSEMBLY AND TESTING

The assembly stage involved building the autonomous delivery rover by connecting all hardware components such as the Raspberry Pi Zero W, ESP32, HMC5883L magnetometer (I2C), ultrasonic sensor (HC-SR04), L298 motor driver, DC motors, and 3.5-inch TFT display. All components were connected according to the designed circuit diagrams and system architecture. The Raspberry Pi was used as the main controller, while the ESP32 handled real-time sensor operations. Sensors like the ultrasonic sensor and magnetometer were properly interfaced to support navigation and obstacle detection. The motor driver controlled the movement of the rover, and the TFT display showed system status and information.

After a customer place an order through the mobile app, the system automatically generates the delivery location coordinates (latitude and longitude). These coordinates are sent to the rover through the communication system, and based on this data, the rover navigates and reaches the customer's location.

After assembly, testing was performed to check the proper working of each component. Individual components were tested first, such as sensor readings, motor movement, coordinate-based navigation, and display output. Then, complete system testing was carried out to ensure smooth communication between hardware and software.

The rover was tested for functions like movement control, obstacle detection, direction sensing using the magnetometer, and reaching the correct location using generated coordinates. The system was verified to ensure all components worked together properly, and necessary adjustments were made to improve performance and reliability.

CONCLUSION

This paper presented the design and development of a smart autonomous delivery rover using technologies like IoT, AI, and embedded systems. The system was developed to overcome the limitations of traditional delivery methods such as high cost, delays, and dependency on human effort.

The proposed system successfully integrates components like the Raspberry Pi Zero W, ESP32, sensors, motor driver, and communication modules to perform automated delivery tasks. After a customer place an order, the system generates location coordinates, and the rover navigates to the destination using sensor data and intelligent route planning.

The use of ultrasonic sensors and a magnetometer help in obstacle avoidance and direction control, while the TFT display and other feedback systems improve user interaction. Testing results show that the system can perform reliable navigation, real-time response, and accurate delivery.

Overall, the system provides a cost-effective, efficient, and secure solution for last-mile delivery. It also supports the development of smart cities by reducing human effort and improving delivery services. Future improvements can include better AI models, longer battery life, and enhanced communication systems for wider applications.

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