Community Based Package Delivery Robot

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ABSTRACT

The rapid growth of e-commerce and smart logistics systems has increased the demand for efficient and contactless package delivery solutions. This paper presents the design and development of an Internet of Things (IoT) based community package delivery robot using the ESP8266 microcontroller. The proposed system is capable of wireless navigation, real-time monitoring, and secure package handling. The robot is controlled through Wi-Fi communication, enabling users to operate it remotely using a mobile device or web interface. A motor driver module (L298N / L293D) is used to control the movement of DC motors for directional navigation. An IP webcam is integrated into the system to provide live video streaming, assisting the user in monitoring the robot's surroundings during delivery operations. To ensure package safety, a solenoid lock mechanism is implemented for secure storage and controlled access. The system is designed to be low-cost, energy-efficient, and suitable for applications such as campus delivery, residential communities, and industrial environments. Experimental implementation demonstrates reliable movement control, effective wireless communication, and enhanced delivery security. The proposed robot contributes to the advancement of smart delivery technologies by offering a practical and scalable solution for last-mile delivery challenges.

Key words -IOT, Community, Delivery Robot, ESP8266, IP Webcam, Solenoid Lock, Motor Driver, Wireless Control, Last-mile Delivery.

INTRODUCTION

Robotic systems are increasingly being used in various fields such as industries, households, healthcare, military operations, and disaster management due to their ability to perform tasks efficiently and safely. Examples include cleaning robots, surveillance robots, and delivery robots designed to assist humans in routine and repetitive activities. These systems help reduce human effort, improve operational efficiency, and enhance safety in critical environments. [1] In recent years, the demand for fast, reliable, and cost-effective delivery services has grown significantly, especially with the rapid expansion of e-commerce platforms. This has led to the development of delivery robots that can transport packages within short distances, particularly in controlled environments such as campuses, residential areas, and industrial premises. [2] Unlike fully autonomous systems, many practical delivery robots operate using remote or manual control, where the user monitors and guides the robot through wireless communication. A remotely controlled delivery robot is an electrically powered mobile system that can carry packages from one location to another without direct physical involvement of a delivery person. The robot is typically controlled using a mobile device or web interface through Wi-Fi connectivity. A control system receives user commands and directs the movement of the robot accordingly, enabling functions such as forward, backward, and directional navigation. [3] The hardware components of such systems include microcontrollers, motor drivers, DC motors, sensors, and cameras. Sensors are used to detect obstacles and provide feedback about the surroundings, while actuators such as motors enable movement. The software component consists of embedded programming that processes user inputs and controls the robot's behaviour. [2] With increasing emphasis on contactless services and reduced human interaction, especially in densely populated areas, IoT-based delivery robots have gained importance. These systems offer real-time monitoring, improved delivery efficiency, and enhanced safety. In India, where most deliveries are still performed manually, the implementation of such robotic systems can significantly reduce workload and improve service speed. The proposed system focuses on the design and development of a community-based package delivery robot that operates through wireless remote control. It is capable of delivering small packages efficiently while providing live video monitoring and secure access through a locking mechanism. This approach provides a simple, low-cost, and practical solution for last-mile delivery challenges in localized environments.

LITERATURE REVIEW

Previous studies have primarily focused on the development of Wi-Fi controlled robotic systems using microcontrollers such as NodeMCU and ESP8266 for real-time communication and remote operation. These systems allow users to control robot movement through mobile applications or web interfaces, making them suitable for short-distance delivery tasks in controlled environments. Researchers have also integrated IP cameras into robotic platforms to provide live video streaming, enabling users to monitor navigation and surroundings remotely. This feature improves operational control and enhances safety during movement. In addition to monitoring, several studies have incorporated security mechanisms such as solenoid locks to ensure safe and authorized package handling. These locking systems are electronically controlled and help prevent unauthorized access during the delivery process. For robot mobility, motor driver modules such as L298N and L293D along with DC motors are widely used due to their simple design, low cost, and ease of implementation. Some existing systems have explored advanced navigation techniques using sensors like ultrasonic sensors for obstacle detection and basic path correction. These approaches improve the robot's ability to operate safely by avoiding collisions in dynamic environments. Line-following techniques and predefined path navigation methods have also been implemented in various projects to guide robot movement efficiently without requiring continuous user input. Other studies have focused on camera-based monitoring systems where visual feedback assists the user in manually guiding the robot. These systems rely on real-time video transmission rather than complex processing techniques, making them more practical and cost-effective for small-scale applications. Overall, existing research highlights that Wi-Fi based remote-controlled robots with integrated monitoring and basic sensing capabilities provide a reliable and economical solution for short-range delivery applications. However, limitations such as restricted communication range, dependency on user control, and lack of advanced navigation still exist. The proposed system builds upon these approaches by combining real-time monitoring, secure delivery mechanisms, and improved control strategies to enhance usability in community-based environments.

Related Work

Recent developments in delivery robotics have contributed to the design of community-based package delivery systems that focus on simplicity, reliability, and cost-effectiveness. Researchers have explored mobile robotic platforms integrated with Internet of Things (IoT) technologies to enable real-time communication and remote operation. Many existing systems are based on Wi-Fi controlled robots, where users can monitor and control movement through mobile devices or web interfaces. These systems are particularly suitable for short-distance delivery applications in environments such as campuses, residential communities, and small industrial areas. Several studies have implemented obstacle detection techniques using sensors such as ultrasonic sensors to improve safety during robot movement. These sensors help in identifying nearby objects and assist the user in navigating the robot more effectively. In addition, live video streaming using IP cameras has been widely used to provide real-time visual feedback, allowing users to guide the robot accurately in dynamic environments. Security is also an important aspect in delivery systems, and many designs include features such as electronically controlled compartments, password-based access, or simple locking mechanisms to ensure safe package handling. Cloud-based or web-based interfaces are often used to improve user interaction, enabling better control, monitoring, and status updates during the delivery process. Despite these advancements, several challenges still exist, including limited communication range due to Wi-Fi dependency, battery constraints, and reduced performance in complex or crowded environments. Additionally, continuous user involvement is

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required for navigation in most systems. The proposed system builds upon these existing approaches by combining low-cost hardware, real-time monitoring, secure package handling, and user-friendly control mechanisms. This makes it a practical and efficient solution for community-level delivery applications while maintaining simplicity and affordability.

PROPOSED METHODOLOGY

Delivery robots have become an effective solution for improving last-mile delivery efficiency in controlled environments such as campuses, residential areas, and small industrial zones. In this work, the robot operates based on remote user control rather than full automation. The movement of the robot is directed through wireless communication using a mobile device or web interface, allowing the user to guide it in real time. This approach ensures better control, flexibility, and reliability during operation. The hardware components of the delivery robot include a chassis, DC motors, wheels, batteries, motor drivers, and a microcontroller. The chassis provides structural support for all components, while the motors and wheels enable smooth movement in different directions. The battery supplies power to the entire system, ensuring continuous operation during the delivery process. The microcontroller acts as the central control unit, receiving user commands through a Wi-Fi module and generating control signals for the motor driver.

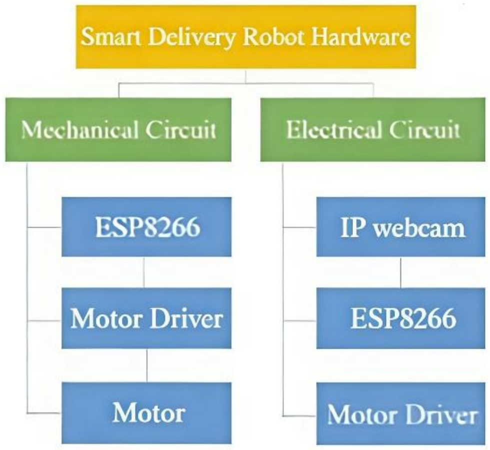

Fig 1. Robot Hardware Divisions

The diagram represents the hardware architecture of the smart delivery robot, which is divided into two main sections: the Mechanical Circuit and the Electrical Circuit. The mechanical circuit consists of components responsible for the physical movement of the robot, including the ESP8266 controller, motor driver, and DC motors. In this section, the ESP8266 sends control signals to the motor driver, which in turn drives the motors to enable forward, backward, left, and right movement of the robot. The electrical circuit section includes components used for monitoring and control functions such as the IP webcam, ESP8266 module, and motor driver. The IP webcam provides real-time video streaming for remote navigation and surveillance, while the ESP8266 handles wireless communication and command processing. Together, these circuits ensure proper coordination between robot mobility, remote monitoring, and overall system operation for efficient package delivery.

Fig 2. ESP8266 Controller

ESP8266 Controller: The ESP8266 controller is a low-cost Wi-Fi enabled microcontroller widely used in Internet of Things (IoT) applications. In the delivery robot system, it acts as the main control unit that receives commands from a mobile device or web server through wireless communication. The controller processes these commands and generates appropriate signals to control the motor driver and other connected components. It also enables real-time data transmission and remote monitoring, improving the efficiency of robot operation. Due to its compact size, low power consumption, and built-in networking capability, the ESP8266 is suitable for smart automation and robotic control systems.

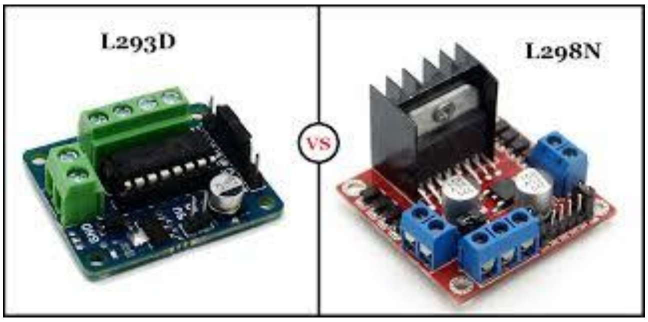

Fig 3. L298N/L293D Motor Driver

L298N/L293D Motor Driver: The L298N or L293D motor driver is an interface module used to control the speed and direction of DC motors in robotic applications. It receives low-power control signals from the microcontroller and amplifies them to drive motors that require higher current and voltage. This motor driver enables the robot to perform movements such as forward, backward, left, and right by controlling the rotation of the motors.

Fig 4. DC Motor

DC Motors: DC motors are electromechanical devices that convert electrical energy into mechanical rotational motion. In the delivery robot, they are used to drive the wheels and enable movement in different directions based on control signals from the motor driver. Their simple construction, easy speed control, and compatibility with battery power make them suitable for mobile robotic applications.

Fig 5. IP Web Camera

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IP Web Camera: An IP web camera is a network-based camera used to capture and transmit real-time video over a Wi-Fi connection. In the delivery robot, it provides live visual feedback to the user for remote monitoring and navigation control. This helps in observing obstacles, guiding robot movement, and improving delivery safety and efficiency.

Fig 6. Solenoid Lock

Solenoid Lock: A solenoid lock is an electromagnetic locking device used to secure the delivery box in the robot. It operates by converting electrical energy into linear motion to lock or unlock the mechanism when a control signal is applied. This ensures safe and authorized access to the package during the delivery process.

Fig 7. Lithium Batteries

Lithium Batteries: Lithium batteries are rechargeable energy storage devices widely used in portable electronics and robotic systems due to their high energy density and lightweight design. In the delivery robot, they provide a stable power supply to the microcontroller, motor drivers, motors, and other electronic components. Their long-life cycle, fast charging capability, and efficient performance make them suitable for mobile and IoT-based robotic applications.

The block diagram illustrates the working principle of the smart package delivery robot controlled through a mobile device. The phone location or user command acts as the input to the system, which is processed by the central controller. Along with this input, live visual feedback from the IP web camera is also provided to assist in navigation and monitoring of the robot's surroundings.

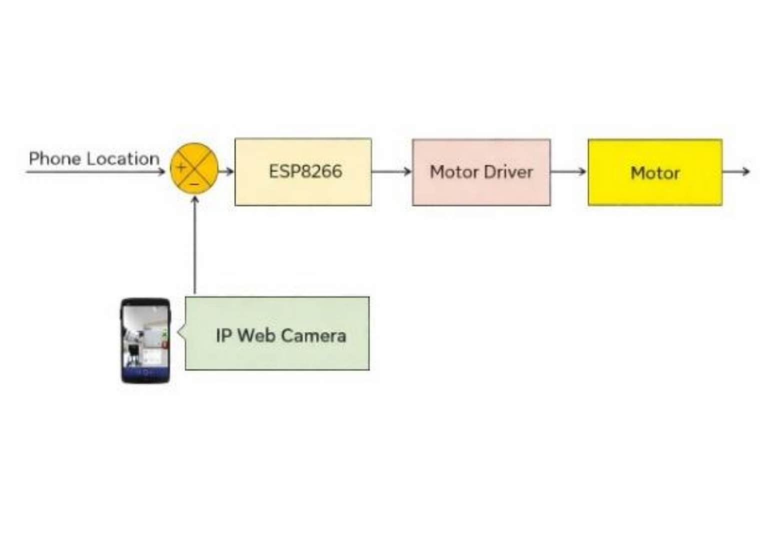

Fig 8. Block Diagram of Mechanical Circuit

The processed control signals are then sent to the ESP8266 controller, which acts as the brain of the system. Based on the received commands, the ESP8266 generates appropriate control signals and forwards them to the motor driver module. The motor driver amplifies these signals to drive the DC motors, enabling the robot to move in different directions such as forward, backward, left, and right. This integrated system allows real-time wireless control, visual monitoring, and efficient package delivery in controlled environments.

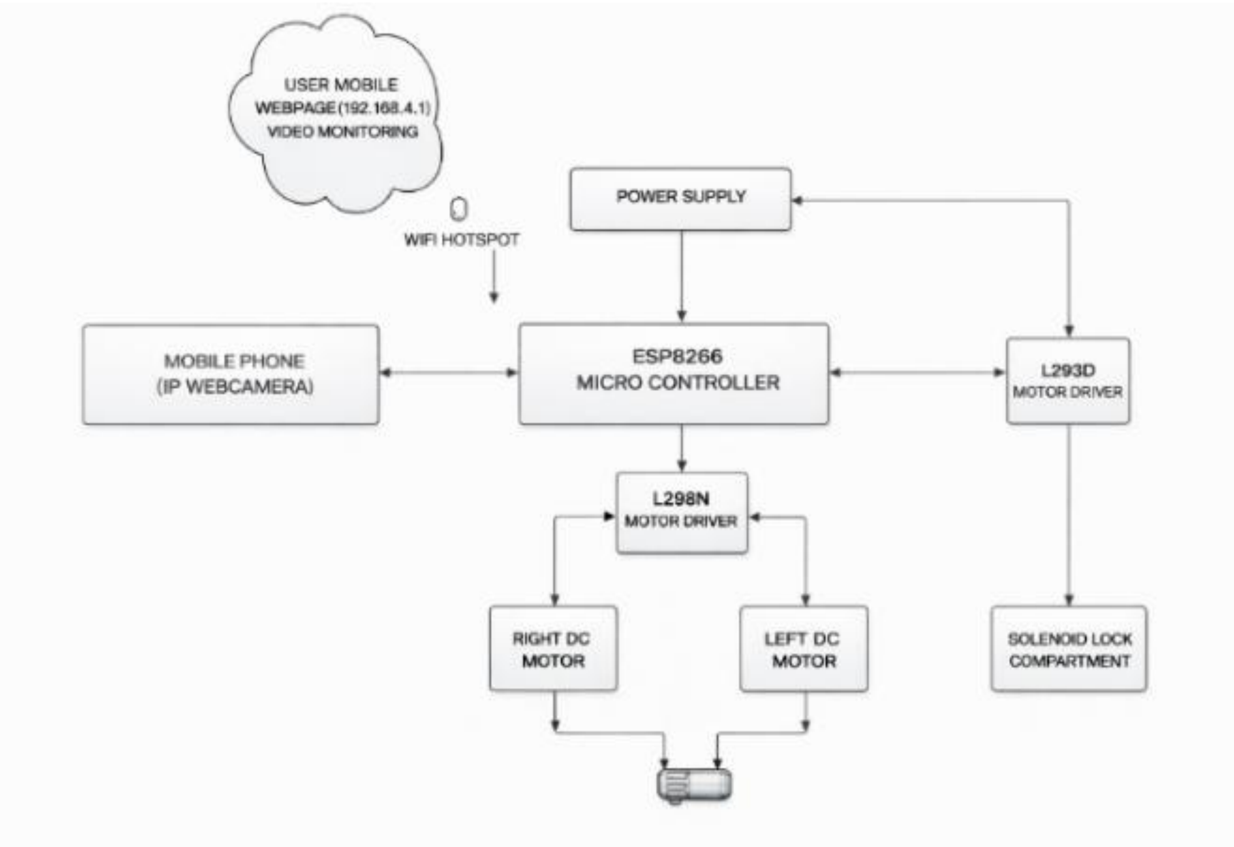

Fig 9. Implementation of Block Diagram

The implantation block diagram explains the overall system architecture of an IoT-based package delivery robot controlled through wireless communication. The user mobile webpage is connected to the robot using a Wi-Fi hotspot network, allowing the user to monitor live video and send movement commands. A mobile phone functioning as an IP web camera streams real-time video to help the user observe the robot's surroundings and guide its navigation safely. A regulated power supply provides the necessary electrical energy to the controller and motor driver modules for proper operation. Based on the received instructions, the ESP8266 sends control signals to the L298N motor driver, which controls the left and right DC motors to enable directional movement of the robot such as forward, backward, and turning. Additionally, the system includes an L293D motor driver connected to a solenoid lock compartment for secure package handling. This locking mechanism ensures that the delivery box can be electronically opened or closed only when authorized commands are given. The coordinated operation of wireless communication, motor control, real-time monitoring, and secure locking enables the robot to perform efficient and contactless package delivery in controlled environments.

RESULTS AND DISCUSSION

The developed community-based package delivery robot was successfully implemented and tested in a controlled environment. The system demonstrated stable and reliable operation using the ESP8266 controller integrated with motor driver modules, enabling smooth movement in different directions based on user commands. The robot was controlled through a Wi-Fi interface, allowing the user to guide its navigation in real time. The IP web camera provided continuous live video streaming, which helped the user monitor the robot's surroundings and control it effectively during the delivery process. The delivery mechanism, including the solenoid lock system, operated efficiently and ensured secure handling of small packages. The overall performance of the system indicated that the robot could complete delivery tasks within a short duration while reducing human effort. The response time between user commands and robot movement was minimal, resulting in smooth and accurate control. The system was found to be cost-effective and suitable for short-range delivery applications in environments such as campuses and residential areas. However, certain limitations were observed during testing. The battery backup was limited for long-duration operations, and the communication range depended on Wi-Fi availability. The robot also required careful manual control in crowded or complex environments, as navigation accuracy depends on user input. Additionally, uneven surfaces and obstacles could affect movement stability. Despite these challenges, the system provides a reliable and practical foundation for further enhancements. Future improvements may include better power management, improved mechanical design for rough terrain, and enhanced communication methods for extended range. Overall, the proposed system demonstrates an efficient and user-controlled approach for community-based package delivery.

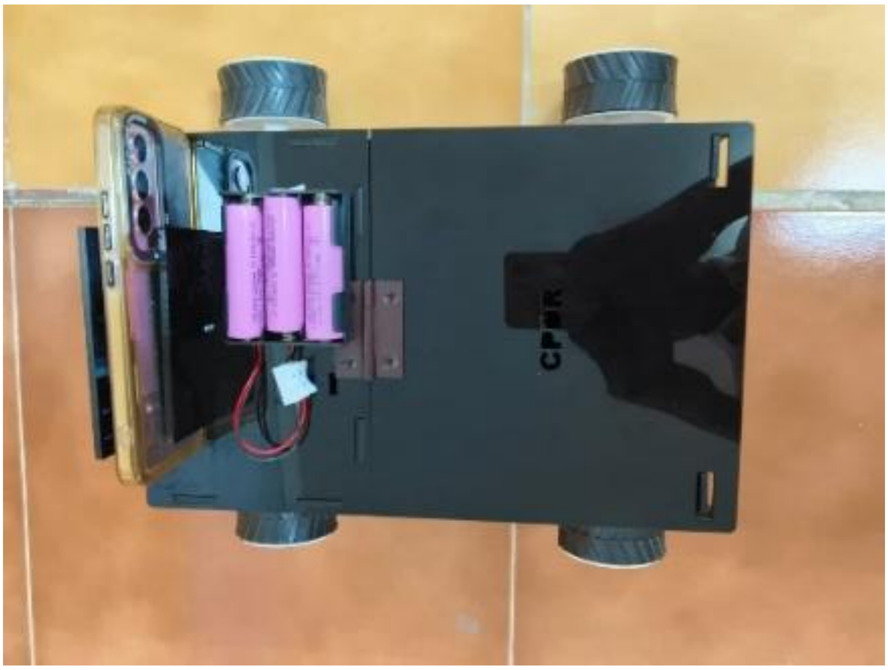

Fig 10. The IP web camera is mounted on the robot to provide continuous live video monitoring of its surroundings during operation. This enables users to remotely observe the robot's movement and delivery process in real time, improving control and transparency. The camera also supports obstacle detection by capturing visual data, which helps the system identify and respond to objects in its path. By integrating visual feedback with the control system, the robot can navigate more safely in dynamic environments. Overall, the inclusion of the IP web camera enhances both monitoring capabilities and operational safety of the delivery robot.

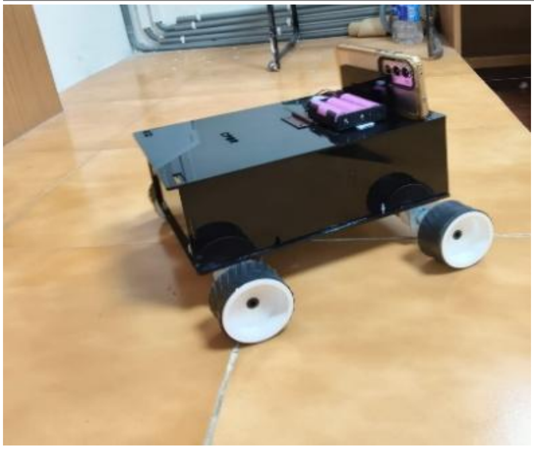

Fig 11. The robot is capable of moving in forward, backward, left, and right directions to navigate efficiently within its environment. It continuously monitors for obstacles using sensors and adjusts its movement accordingly to avoid collisions. When an obstacle is detected, the robot intelligently changes its direction and selects an alternative clear path. This adaptive movement ensures smooth and uninterrupted navigation during the delivery process. As a result, the system enhances safety, reliability, and efficiency while operating in dynamic and unpredictable surroundings.

Fig 12. The developed robot enhances efficiency by enabling fast and reliable package delivery within community environments while minimizing human intervention. It ensures a completely contactless delivery process, which improves safety and hygiene for both users and service providers. The integration of an IP web camera allows real-time monitoring and verification of the recipient, ensuring that packages are handed over only to authorized individuals. The system is capable of reaching the exact delivery location using predefined navigation paths, reducing errors and delays. Overall, the combination of automation, location accuracy, and user verification makes the robot a secure and practical solution for modern community-based delivery systems.

Fig 13. The solenoid compartment is unlocked only after successful verification of the user's face and associated details, ensuring secure access to the delivered package. The system uses camera-based recognition to match the

person with stored data before granting permission. Once authentication is confirmed, the solenoid lock is activated to open the compartment automatically. This approach prevents unauthorized access and enhances the safety of the delivery process. Additionally, the verification mechanism improves user trust and ensures that packages are received only by the intended recipient.

Once Delivery attempted then locked the compartment go to next delivery.

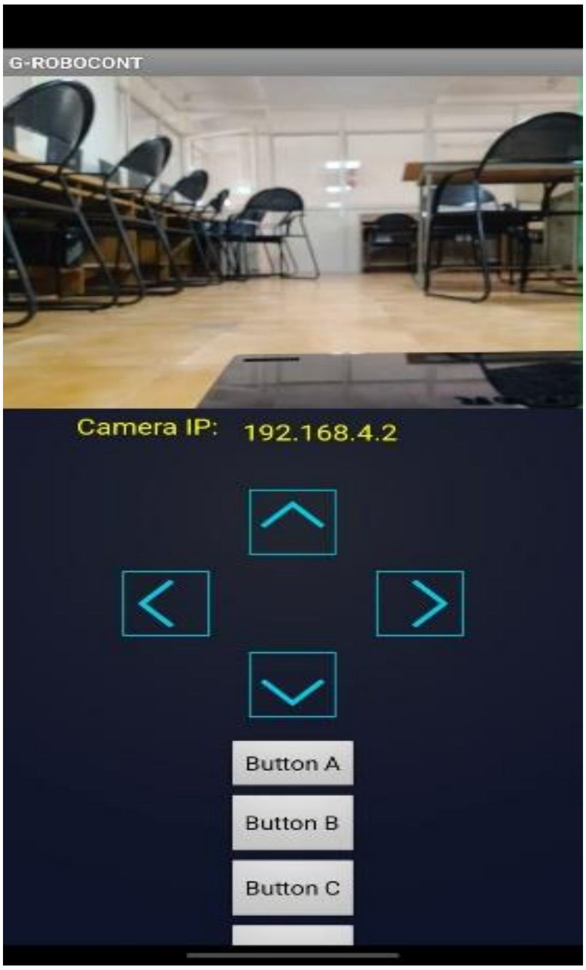

Fig 14. Once the delivery is attempted, the robot automatically locks the compartment to ensure the safety and security of the package. This locking mechanism prevents unauthorized access after the package has been placed or delivered. After securing the compartment, the system updates the delivery status and prepares for the next task in the queue. The robot then navigates to the next delivery location using its predefined path or routing algorithm. This sequential delivery process improves efficiency and allows the robot to handle multiple deliveries in a single operation without human intervention.

CONCLUSION

The community-based package delivery robot provides an efficient and practical solution for addressing last-mile delivery challenges in controlled environments. The system is designed to operate through remote user control, integrating wireless communication, real-time monitoring, and a secure delivery mechanism. This approach reduces the need for direct human involvement while maintaining accurate control over the delivery process. The use of cost-effective components such as the ESP8266 controller, motor drivers, and camera module makes the system suitable for applications in residential communities, campuses, and small-scale logistics environments. The robot successfully demonstrates reliable movement, effective communication, and secure package handling within a limited range. The inclusion of live video monitoring enhances user control and ensures safe navigation during operation. In addition, the compact and simple design allows easy implementation and maintenance, making it a feasible solution for localized delivery needs. However, certain limitations such as battery capacity, restricted communication range, and dependency on user control in complex environments were observed. These factors may affect performance in larger or highly dynamic areas. Future improvements can focus on enhancing battery efficiency, improving mechanical stability for different terrains, and extending communication capabilities for wider coverage. Strengthening the security system with additional authentication methods can further improve reliability. Overall, the proposed system offers a low-cost, user-controlled, and reliable framework for community-based package delivery, meeting the growing demand for efficient and contactless delivery solutions.

Future Scope

In future developments, the delivery robot can be enhanced by integrating advanced obstacle detection and avoidance sensors such as ultrasonic sensors, infrared sensors, or LiDAR modules. This will enable the robot to perform semi-autonomous or fully autonomous navigation without continuous human control. The implementation of intelligent path planning algorithms and machine learning techniques can further improve navigation accuracy, efficiency, and adaptability in dynamic environments. Another important improvement area is the communication and monitoring system. The robot can be upgraded with GPS or GSM modules to support long-distance tracking and operation beyond Wi-Fi range

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