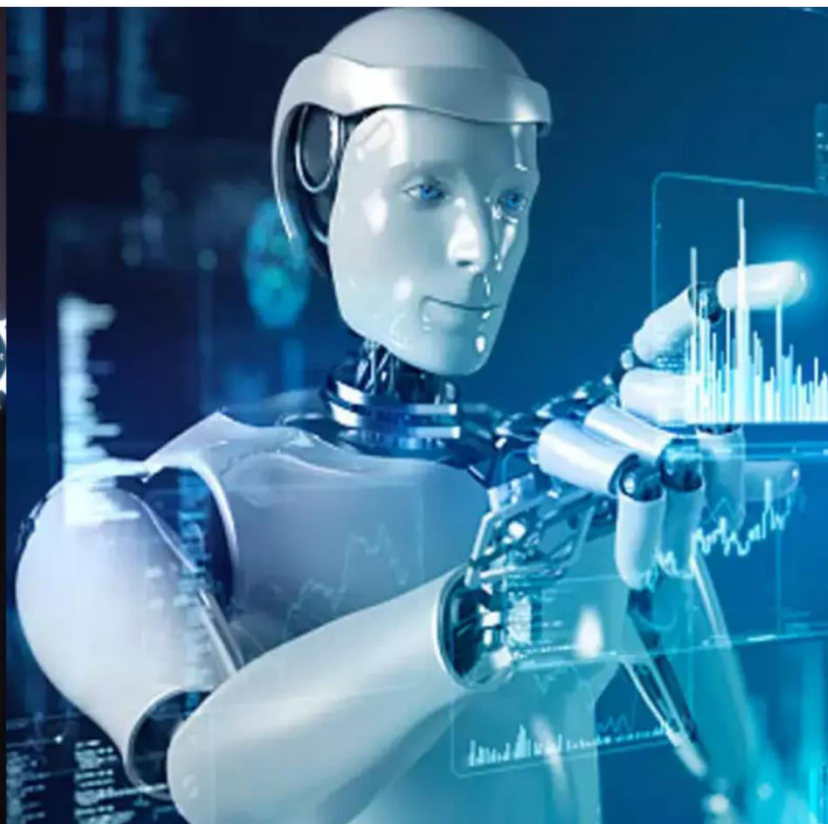




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NexaBot: Next-Gen Autonomous Delivery

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ABSTRACT: With the rapid growth of e-commerce and smart residential infrastructures, efficient and secure last-mile delivery has become a critical challenge. Traditional delivery systems suffer from high operational costs, dependency on human labor, delays, and security risks. This paper presents NexaBot: a Next-Generation Autonomous Delivery Robot designed for reliable last-mile delivery within gated communities, villas, and residential complexes. NexaBot integrates an ESP32-based control system with GPS, ultrasonic and ToF sensors, inertial measurement units, and RFID-based authentication to enable autonomous navigation, obstacle avoidance, and secure package handling. The proposed system operates continuously with minimal human intervention, offering improved delivery speed, safety, and energy efficiency. Experimental results from the developed prototype demonstrate smooth navigation, effective obstacle detection, and reliable access control in a controlled environment. The study concludes that NexaBot provides a practical and scalable solution for smart delivery applications and has strong potential for future enhancement using advanced artificial intelligence and machine learning techniques.

The proposed system is built around an ESP32 microcontroller and incorporates GPS for localization, ultrasonic and Time-of-Flight (ToF) sensors for obstacle detection, inertial sensors for motion tracking, and RFID-based authentication to ensure secure package access. Motor drivers and DC motors enable precise movement, while real-time wireless communication allows system monitoring and control. The robot is powered by rechargeable lithium-ion batteries with optimized power management to support extended operation.

Experimental evaluation of the developed prototype demonstrates reliable autonomous navigation, effective obstacle avoidance, and secure delivery in a controlled environment. The results indicate improved efficiency, reduced human dependency, and enhanced delivery reliability. NexaBot offers a scalable and sustainable solution for smart logistics and has significant potential for future enhancements through artificial intelligence, machine learning, and advanced navigation algorithms.

KEYWORDS: Autonomous delivery, NexaBot, ESP32, RFID authentication, Last-mile delivery, Robotics

I. INTRODUCTION

The rapid expansion of e-commerce and smart city initiatives has significantly increased the demand for efficient, reliable, and secure last-mile delivery solutions. Last-mile delivery, which represents the final stage of the logistics chain, is often the most complex and costly due to factors such as traffic congestion, labor dependency, fuel consumption, and security concerns. In residential areas such as gated communities, villas, and apartment complexes, traditional delivery methods frequently face challenges including delayed deliveries, limited accessibility, and the requirement for recipients to be physically present at the time of delivery.

Recent advancements in robotics, artificial intelligence, and embedded systems have opened new possibilities for automating last-mile delivery operations. Autonomous delivery robots have emerged as a promising solution by reducing human intervention, minimizing operational costs, and enabling round-the-clock delivery services. These systems are capable of navigating predefined environments, detecting obstacles, and interacting securely with users, making them well-suited for residential applications.

NexaBot is proposed as a next-generation autonomous delivery robot designed to address the limitations of conventional delivery systems. The robot integrates intelligent sensing, navigation, and communication technologies to operate safely and efficiently within residential environments. By utilizing an ESP32-based control unit, GPS

localization, ultrasonic and Time-of-Flight sensors, inertial measurement units, and RFID-based authentication, NexaBot ensures accurate navigation, effective obstacle avoidance, and secure package delivery.

The primary objective of this project is to develop a reliable, cost-effective, and environmentally friendly delivery solution that reduces dependency on human labor while improving delivery speed and safety. The proposed system aims to enhance operational efficiency and provide a scalable platform for future upgrades, including artificial intelligence and machine learning-based decision-making. This paper discusses the design, implementation, and evaluation of NexaBot, highlighting its performance, advantages, and potential applications in modern smart logistics systems.

II. LITERATURE SURVEY

Recent research in autonomous delivery systems has gained significant attention due to the rapid growth of e-commerce and smart city infrastructures. Several studies have explored the use of mobile robots for last-mile delivery to reduce operational costs, improve efficiency, and minimize human dependency. Autonomous delivery robots have been widely proposed for applications in residential areas, campuses, hospitals, and industrial environments.

Many researchers have focused on navigation and obstacle avoidance techniques using a combination of GPS, ultrasonic sensors, infrared sensors, and vision-based systems. GPS-based localization is commonly used for outdoor navigation; however, its accuracy is often affected by signal interference and environmental constraints. To overcome this limitation, inertial measurement units (IMUs) and distance sensors such as ultrasonic and Time-of-Flight (ToF) sensors have been integrated to enhance positional accuracy and enable safe navigation in complex environments.

Security and user interaction are critical aspects of autonomous delivery systems. Several studies have implemented authentication mechanisms such as QR codes, mobile applications, and RFID technology to ensure secure package access. RFID-based systems are particularly effective due to their low cost, ease of implementation, and reliable short-range authentication, making them suitable for residential delivery applications.

Power management and energy efficiency have also been addressed in existing literature. Researchers have utilized rechargeable lithium-ion batteries along with optimized charging and power control circuits to extend operational time. Additionally, wireless communication technologies such as Wi-Fi and Bluetooth have been employed for real-time monitoring and control of delivery robots.

III. PROPOSED SYSTEM

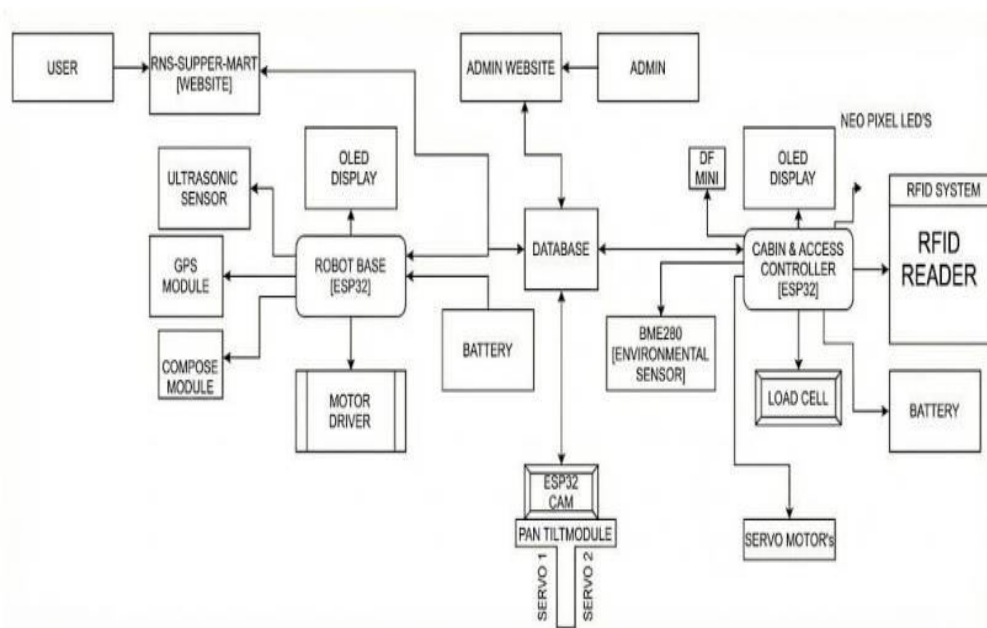
The proposed system, NexaBot, is a next-generation autonomous delivery robot designed to provide secure, efficient, and reliable last-mile delivery within gated communities, residential complexes, and villa environments. The system aims to overcome the limitations of traditional delivery methods by minimizing human intervention, reducing operational costs, and enabling continuous autonomous operation. NexaBot integrates multiple sensors, actuators, and communication modules to achieve intelligent navigation, obstacle avoidance, and secure package handling.

At the core of the system is an ESP32 microcontroller, which acts as the main control unit responsible for processing sensor data, executing navigation algorithms, and managing communication. GPS is used for outdoor localization, while inertial sensors such as the MPU6050 accelerometer and gyroscope provide motion and orientation information. To ensure safe navigation, ultrasonic and Time-of-Flight (ToF) sensors continuously monitor the surroundings and detect obstacles such as pedestrians, vehicles, and static barriers. Based on sensor inputs, the controller dynamically adjusts the robot's movement to avoid collisions.

Security and user interaction are achieved through an RFID-based authentication system. The delivery compartment remains locked during transit and opens only when an authorized user presents a valid RFID tag or authentication credential. Servo motors are used to control the locking mechanism, ensuring secure access to delivered items. An OLED display provides real-time status updates, while audio and visual indicators enhance user interaction.

The robot's movement is controlled using DC motors driven by an L298N motor driver, enabling precise speed and direction control. NexaBot is powered by rechargeable lithium-ion batteries, supported by efficient power management circuits to ensure extended operational time. Wireless communication via Wi-Fi allows monitoring, control, and future integration with smart delivery management systems. The proposed system offers a scalable platform that can be further enhanced with artificial intelligence and machine learning techniques for improved decision-making and autonomous performance.

IV. METHODOLOGY AND WORKING



The methodology of the proposed NexaBot system focuses on the integration of sensing, control, communication, and actuation units to achieve fully autonomous and secure last-mile delivery. The system operates through a sequence of well-defined stages, including navigation, obstacle detection, authentication, and delivery execution.

Initially, the delivery location is assigned to NexaBot through a predefined route or control interface. The ESP32 microcontroller serves as the central processing unit, continuously collecting data from various sensors and making real-time decisions. For navigation and localization, NexaBot utilizes a GPS module to determine its position, supported by an MPU6050 accelerometer and gyroscope to track movement and orientation. This sensor fusion approach improves navigation accuracy, especially in residential environments with narrow pathways and turns.

During movement, ultrasonic and Time-of-Flight (ToF) sensors continuously scan the surroundings to detect obstacles such as pedestrians, vehicles, pets, or unexpected barriers. When an obstacle is detected within a predefined safety distance, the controller either slows down, stops, or reroutes the robot to avoid collisions. This ensures safe operation within residential areas.

Upon reaching the destination, NexaBot initiates the delivery process through a secure authentication mechanism. An RFID reader verifies the identity of the authorized user. Once valid authentication is received, servo motors unlock and open the delivery compartment, allowing the recipient to collect the package. After successful delivery, the compartment automatically closes to maintain security.

The robot's motion is controlled using DC motors driven by an L298N motor driver, enabling precise speed and directional control. Power is supplied by rechargeable lithium-ion batteries, supported by efficient power management circuits to optimize energy consumption and extend operating time. Throughout the operation, system status and alerts

are displayed on an OLED display, and wireless communication via Wi-Fi enables monitoring and future system upgrades.

Overall, the proposed methodology ensures reliable navigation, effective obstacle avoidance, secure package handling, and energy-efficient operation, making NexaBot a practical solution for autonomous delivery in residential environments.

V. RESULT

The developed NexaBot prototype was tested in a controlled residential-like environment to evaluate its autonomous navigation, obstacle detection, and secure delivery performance. The experimental results demonstrate that the system successfully performed end-to-end delivery operations with minimal human intervention.

During navigation tests, NexaBot accurately followed predefined routes using GPS-assisted localization combined with inertial sensor feedback. The integration of ultrasonic and Time-of-Flight (ToF) sensors enabled effective real-time obstacle detection. The robot was able to detect pedestrians, static objects, and unexpected barriers and responded appropriately by slowing down, stopping, or changing direction, ensuring safe operation throughout the test environment.

The RFID-based authentication mechanism functioned reliably during all test cases. The delivery compartment remained securely locked during transit and opened only when a valid RFID tag was presented at the destination. This ensured protection against unauthorized access and improved delivery security.

Battery performance tests showed stable power supply and sufficient operational time for multiple delivery cycles under normal load conditions. The motor control system provided smooth movement and accurate turning, contributing to overall navigation stability. Minor limitations such as occasional GPS signal inaccuracy and reduced battery life under continuous operation were observed; however, these did not significantly affect the delivery success rate.

Overall, the results confirm that NexaBot effectively achieves autonomous, secure, and reliable last-mile delivery within residential environments, validating the feasibility of the proposed system.

VI. CONCLUSION

This paper presented NexaBot, a next-generation autonomous delivery robot designed to address the challenges of last-mile delivery in residential environments such as gated communities, villas, and apartment complexes. By integrating an ESP32-based control system with GPS, inertial sensors, ultrasonic and Time-of-Flight sensors, and RFID-based authentication, the proposed system achieves autonomous navigation, effective obstacle avoidance, and secure package handling.

Experimental results demonstrate that NexaBot operates reliably in a controlled environment, successfully completing delivery tasks with minimal human intervention. The system reduces dependency on manual labor, improves delivery efficiency, and enhances security while maintaining energy-efficient operation. Although minor limitations such as GPS inaccuracies and limited battery runtime were observed, these challenges can be addressed through future enhancements.

Overall, NexaBot proves to be a practical, cost-effective, and scalable solution for smart last-mile delivery applications. The proposed system has strong potential for future development through the integration of advanced artificial intelligence, machine learning-based navigation, and improved power management techniques, making it well suited for emerging smart city and autonomous logistics systems.

REFERENCES

- [1] S. Thrun, W. Burgard, and D. Fox, *Probabilistic Robotics*. Cambridge, MA, USA: MIT Press, 2005.
- [2] A. Elfes, "Using occupancy grids for mobile robot perception and navigation," *Computer*, vol. 22, no. 6, pp. 46–57, 1989.
- [3] STMicroelectronics, "VL53L0X Time-of-Flight Ranging Sensor: Datasheet and Application Notes," 2023.
- [4] Adafruit Industries, "DHT22 Temperature and Humidity Sensor – Product Documentation," 2023.
- [5] Espressif Systems, "ESP32 Series Datasheet," 2023.
- [6] NXP Semiconductors, "MFRC522 RFID Reader IC Datasheet," 2022.
- [7] L. Chen, Y. Zhang, and M. Li, "Autonomous delivery robots: Challenges and opportunities in residential environments," *IEEE Access*, vol. 12, pp. 34521–34534, 2024.
- [8] M. Quigley et al., "ROS: An open-source Robot Operating System," in *Proc. ICRA Workshop on Open Source Software*, 2009.



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