Autonomous Delivery Robot

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***Abstract*—In recent years, automation in logistics and material handling has gained significant momentum, particularly with the rise of smart infrastructure and Industry 4.0. This paper presents the design and implementation of an Autonomous Delivery Robot that leverages a compact and efficient control system based on the Raspberry Pi Zero. The robot is engineered to perform end-to-end delivery tasks without human intervention—picking up material from a designated source and transporting it to a specific destination where it autonomously dumps the payload.**

The robot incorporates a GPS module for real-time geolocation tracking, a camera module for visual feedback and object detection, and ultrasonic sensors for collision avoidance, enabling reliable navigation and obstacle avoidance. The Raspberry Pi Zero processes data from these modules and coordinates movement using dual motor driver circuits—one for robotic mobility and another for controlling the headlamp or dumping mechanism. Furthermore, the system incorporates IoT-based communication, allowing external devices or users to assign delivery tasks, monitor robot status, and receive real-time updates. The proposed robot system is scalable and cost-effective, suitable for indoor and outdoor applications such as warehouse automation, hospital supply delivery, or campus logistics. This project demonstrates the viability of autonomous material transport using low-power embedded systems and lays the foundation for future enhancements involving AI-based path planning and autonomous fleet coordination.

Keywords— Autonomous Delivery Robot, Raspberry Pi Zero, GPS Navigation, Object Detection, Obstacle Avoidance, IoT Communication, Motor Driver Control, Material Transport, Camera Module, Embedded Systems, Wireless Monitoring, Real-Time Tracking, Smart Logistics, Automated Dumping.

I. INTRODUCTION

The advancement of automation technologies has led to significant transformations in logistics, manufacturing, and material handling systems. Autonomous mobile robots (AMRs) are increasingly being adopted to reduce manual labor, improve efficiency, and ensure contactless delivery in dynamic environments such as hospitals, warehouses, and campuses. This paper presents the development of an Autonomous Delivery Robot designed to perform material pickup, navigation, and delivery with minimal human intervention.

The robot is built around the Raspberry Pi Zero, a compact and cost-effective microcontroller that manages various peripherals, including a GPS module for navigation, a camera module for visual feedback and object recognition, and ultrasonic sensors for obstacle detection. The robot receives delivery instructions through IoT-based communication, processes the data onboard, and navigates autonomously to the target destination. Upon arrival, it executes a dumping operation using an additional motor driver mechanism.

Mobility is achieved through a dual motor setup driven by an L298N motor driver, enabling precise directional control. A second motor driver operates the headlamp and the dumping unit. The use of real-time GPS data allows the robot to track its position and adjust its path dynamically. The system is designed to be modular and scalable, allowing for future upgrades such as AI-based vision, route optimization, and multi-robot coordination. This work aims to contribute to the growing field of smart logistics by demonstrating a robust and efficient autonomous delivery system.

II. PROPOSED WORK

The proposed system focuses on the design and implementation of an Autonomous Delivery Robot capable of executing a complete material transport cycle—from pickup to delivery and dumping—without human assistance. The robot is built using the Raspberry Pi Zero as the central processing unit, chosen for its low power consumption, affordability, and adequate performance for handling sensor data, motor control, and network communication.

The robot operates by receiving a delivery task via an IoT-based platform, such as a web or mobile application. The task includes the source and destination coordinates, which are processed using a GPS module to determine the optimal path. The robot then navigates autonomously toward the destination while continuously monitoring its surroundings using ultrasonic object sensors and a camera module. The ultrasonic sensors prevent collisions with obstacles by dynamically adjusting the robot's path, while the camera module supports object detection and future scope for visual processing tasks. Mobility is achieved through a motor driver circuit (L298N), which controls two DC motors connected to the robot's wheels. A second motor driver is dedicated to operating the headlamp direction and dumping mechanism. Upon reaching the delivery location, the robot activates the dumping motor to release the material payload.

The IoT module integrated into the Raspberry Pi handles communication with the control centre, allowing real-time updates on the robot's location, task status, and error reporting. The system is designed to be energy-efficient and robust enough for indoor and semi-outdoor applications. This proposed design not only automates the delivery process but also minimizes manual effort, reduces errors, and enables scalable deployment in environments such as hospitals, offices, industrial zones, and university campuses. Future improvements may include AI-based navigation, enhanced vision processing, and multi-robot task coordination.

III. Problem statement

In today's fast-paced industrial and service sectors, the need for efficient, reliable, and contactless delivery systems is increasing rapidly. Manual delivery of materials in environments such as hospitals, warehouses, factories, and educational campuses presents several challenges, including human error, time inefficiency, high labor costs, and safety concerns, especially in health-sensitive environments. Additionally, traditional delivery mechanisms lack flexibility, real-time monitoring, and autonomous operation, which are essential for modern, smart logistics systems.

The core problem lies in the absence of a compact, low-cost, and intelligent system that can autonomously carry out the entire delivery process, from receiving the task, navigating through dynamic environments, avoiding obstacles, and reaching the destination to dumping the material safely. Existing solutions are either too expensive, limited to indoor environments, or require continuous human supervision.

This project addresses the problem by designing and developing a Raspberry Pi Zero–based Autonomous Delivery Robot that integrates GPS navigation, obstacle detection, motor control, and IoT communication. The robot is intended to autonomously execute pickup and drop operations in real-time with minimal human intervention. The system aims to reduce manual workload, ensure safe delivery of materials, and operate effectively in both indoor and semi-outdoor environments. By integrating essential features such as real-time tracking, wireless task assignment, and intelligent path planning, the proposed robot seeks to bridge the gap between manual handling and fully autonomous delivery systems in a cost-effective and scalable manner.

Significance of the Problem Statement:

1. **Reduces Human Dependency**
The system minimizes the need for manual labor in material transportation, which is crucial in high-risk or resource-constrained environments like hospitals or industrial plants.
2. **Enables Contactless Delivery**
Especially important during pandemics or in sterile environments, the robot ensures safe and hygienic delivery of materials without human contact.
3. **Improves Operational Efficiency**
Automation of repetitive delivery tasks leads to faster and more accurate operations, reducing delays and improving overall productivity.
4. **Supports Smart Infrastructure**
The robot aligns with the goals of smart cities and Industry 4.0 by integrating IoT and autonomous navigation into conventional logistics processes.
5. **Cost-Effective and Scalable Solution**
Using affordable components like the Raspberry Pi Zero makes the system viable for mass deployment, especially in small to medium-sized institutions or businesses.

Objective:

1. **To design and develop an autonomous robot** capable of navigating predefined routes using GPS and delivering materials without human assistance.
2. **To integrate real-time obstacle detection and avoidance** using ultrasonic sensors, ensuring safe navigation in dynamic environments.
3. **To implement IoT-based task management and monitoring**, enabling remote assignment of delivery tasks and real-time status tracking.
4. **To develop a controlled dumping mechanism** using a motor driver to automatically unload the material at the destination point.

Scope of the project:

The scope of this project is to design, develop, and implement an Autonomous Delivery Robot that can autonomously transport materials from one location to another without human intervention. This robot will be suitable for use in various environments such as hospitals, warehouses, factories, and educational campuses, where it can carry out tasks such as material pickup, transport, and delivery.

The system will incorporate a GPS module for navigation, enabling the robot to follow predefined paths with a high level of accuracy. It will also use ultrasonic sensors to detect and avoid obstacles, ensuring safe navigation even in crowded or cluttered environments. A camera module will provide visual feedback for advanced object recognition and task verification.

Additionally, the robot will be capable of real-time IoT communication, allowing users to remotely monitor and manage the robot's tasks, location, and status. The system will feature a motorized dumping mechanism, enabling the robot to unload materials at the designated destination automatically.

This project aims to create a scalable, cost-effective, and efficient solution for automating delivery processes. Future enhancements may include AI-based navigation and the ability for multiple robots to coordinate tasks within a shared environment. The proposed system has the potential to be deployed in various industries, leading to significant improvements in operational efficiency, safety, and cost reduction.

Literature Review

Autonomous Indoor Delivery Robot using ROS (Journal of Robotics, 2020): This study presents the design and implementation of an autonomous indoor delivery robot that utilizes the Robot Operating System (ROS) in combination with LIDAR sensors for indoor navigation and obstacle detection. The system uses Simultaneous Localization and Mapping (SLAM) for generating maps of the environment and relies on QR code-based docking stations for precise drop-off points. The robot demonstrates efficient path planning and reliable obstacle avoidance within structured indoor environments like hospitals and libraries. However, its reliance on LIDAR and ROS frameworks makes the system cost-intensive and complex, limiting its scalability for outdoor or semi-structured environments. Our project aims to address these limitations by utilizing more affordable components such as a Raspberry Pi Zero and ultrasonic sensors, while extending navigation capabilities to outdoor environments using GPS.

IoT-Based Autonomous Delivery Vehicle using Arduino and ESP32 (International Journal of Embedded Systems, 2021): This paper outlines the development of a lightweight IoT-based delivery vehicle that employs Arduino UNO and ESP32 microcontroller modules for communication and control. The system was equipped with basic obstacle detection, RF-based control, and Wi-Fi communication to provide live location tracking. The vehicle could be controlled via a mobile application and could deliver small items autonomously within a confined area. The strength of the system lies in its low cost and simplicity. However, it lacked GPS-based global navigation, autonomous pathfinding, and task automation. Unlike this model, the current project utilizes a Raspberry Pi Zero, which offers more processing power, supports Python-based scripting, and allows for real-time GPS integration and smarter task execution with camera support and cloud connectivity.

Pathfinding Algorithms for Mobile Robots – A and Dijkstra (IEEE Access, 2019): This study focuses on comparing different pathfinding algorithms, notably A* and Dijkstra, for autonomous robots operating in dynamically changing environments. The research shows that the A* algorithm provides a good balance between computation time and optimality of the path, making it suitable for real-time navigation systems. This technique is widely adopted in warehouse robots and robotic vacuum cleaners. While the study primarily emphasized indoor robots, its insights can be translated into outdoor systems as well. The current project has the potential to integrate similar path planning algorithms on the Raspberry Pi to enhance navigation accuracy. The inclusion of such algorithms could help in dynamically adjusting routes when obstacles are detected or when GPS drift occurs, enhancing the system's robustness.

Development of GPS-Based Smart Delivery Robot (International Journal of Computer Applications, 2022): In this research, a GPS-based autonomous delivery robot was developed for use on educational campuses. The system used an Arduino Mega board and a GPS module to track positions and follow pre-programmed routes between defined waypoints. Though it demonstrated functional outdoor navigation, the system lacked precision due to inherent GPS limitations (±2.5m error) and did not include object detection or real-time rerouting capabilities. Moreover, it did not support two-way communication with users, limiting its adaptability. The proposed project improves upon this by incorporating ultrasonic sensors for obstacle avoidance and an IoT module to allow users to send tasks remotely and receive updates. Additionally, a camera module can be used to enhance the robot's awareness, particularly near destination points where GPS accuracy may degrade.

Smart Material Handling Robot for Industry 4.0 (Procedia CIRP, 2018): This study investigates the role of autonomous material handling robots in the context of Industry 4.0, emphasizing the need for smart automation in logistics. The system presented uses conveyor belts and AGVs (Automated Guided Vehicles) equipped with RF tags and track-following mechanisms. While the approach ensures accurate delivery and timing, it is limited by the requirement of a fixed infrastructure (i.e., tracks and magnetic strips). This makes the system unsuitable for applications where flexibility and adaptability are essential. In contrast, the proposed delivery robot offers an infrastructure-independent model, relying instead on GPS and camera-based guidance systems. This makes it better suited for applications in semi-structured or dynamically changing environments such as hospital corridors, campuses, or small factories.

Autonomous Agricultural Robot using Raspberry Pi and GPS (IEEE Transactions on Automation Science, 2020): This paper presents an autonomous agricultural robot capable of navigating farms using GPS and image processing for plant detection. It used the Raspberry Pi 3 module for processing and decision-making. The study effectively demonstrated how low-cost computing platforms like Raspberry Pi can be utilized for real-time decision-making in outdoor environments. This directly supports the choice of Raspberry Pi Zero in the current project as a cost-effective yet powerful platform for navigation, task execution, and communication.

Methodology

The proposed autonomous delivery robot is designed to perform tasks such as picking up a material box, navigating to a destination using GPS, avoiding obstacles, and automatically dumping the material at the target location. The methodology is based on a modular, sensor-integrated, and IoT-connected system, orchestrated by a central Raspberry Pi Zero controller.

Central Control System (Raspberry Pi Controller)
At the core of the system lies the Raspberry Pi Zero, which processes input data from sensors and modules and controls output devices such as motor drivers. It acts as the brain of the robot, making real-time decisions based on sensory input and GPS data.

Sensory Input System

- **Object Sensor**: Continuously monitors the environment for nearby obstacles. If an obstacle is detected, the robot stops or reroutes its path.
- **Camera Module**: Can be used for additional tasks like QR code recognition, visual confirmation of the delivery point, or obstacle classification.
- **GPS Module**: Provides real-time latitude and longitude data to guide the robot toward the delivery destination. The coordinates are compared with the target to plan the path.

Motion and Actuation

- **Motor Drivers**: Receive commands from the Raspberry Pi to drive the motors connected to the robot's wheels, enabling forward/backward movement and turning.
- **Motor Driver for Arm**: Controls a robotic arm or actuator that picks up and dumps the material box at the desired location.

IoT Communication

The system includes an IoT device for remote communication. It allows for:

- Real-time monitoring and tracking of robot location.
- Status updates (e.g., "Material picked", "In transit", "Delivered").
- Remote commands or alerts.

Power Supply
A battery power source supplies energy to all components. Efficient power distribution ensures the robot operates autonomously for long durations.

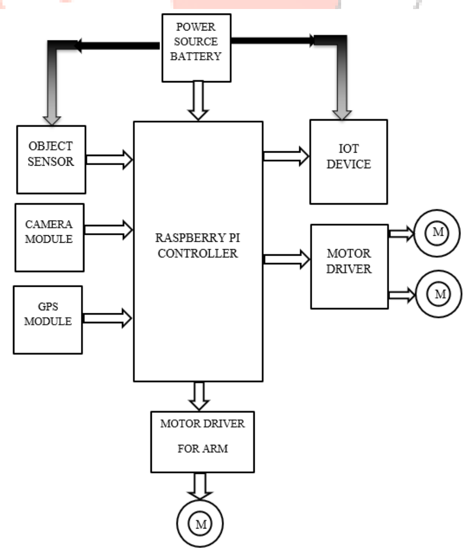

Fig 1. Block Diagram of the system

Block diagram explanation

Raspberry Pi Controller (Central Processing Unit)

At the core of the system lies the Raspberry Pi Zero, a compact yet powerful microcontroller that orchestrates all the operations of the robot. It acts as the main control unit and is responsible for processing inputs from all peripheral devices, executing decision-making algorithms, and issuing appropriate control signals to output devices.

The Raspberry Pi performs the following key functions:

- Interface with the camera module for image/video processing.
- Receive distance or obstacle detection data from object sensors.
- Fetch and decode geographic data from the GPS module.
- Control the direction and speed of the motors via motor drivers.
- Communicate real-time data to the cloud or mobile interface through the IoT module.

Object Sensor

The robot uses **object detection sensors**, typically ultrasonic or infrared (IR), to monitor the proximity of obstacles in its path. These sensors play a vital role in the robot's navigation and collision avoidance mechanism.

The object sensor provides:

- Real-time distance measurement.
- Detection of static and dynamic obstacles.
- Signal input to the Raspberry Pi to halt or redirect movement.

Ultrasonic sensors function by emitting sound waves and measuring the echo time to determine the distance of nearby objects. The Raspberry Pi processes this data to decide if an obstacle is too close, in which case the robot either stops or finds an alternative path.

Camera Module

The **camera module** is essential for the robot's visual input. This module can be used for various intelligent tasks such as:

- Barcode/QR code scanning for location identification.
- Lane tracking using image recognition.
- Live streaming or image capturing for remote monitoring.

The camera is connected to the Raspberry Pi via the CSI (Camera Serial Interface). Using OpenCV or similar libraries, the images are processed in real time to help the robot make informed decisions. For instance, the robot can recognize a marked pickup spot or a delivery destination by scanning a code or identifying visual markers.

GPS Module

For autonomous navigation, the robot is equipped with a **GPS module**, which provides real-time location data in the form of latitude and longitude coordinates. This information is vital for:

- Navigating the robot from the source location to the destination.
- Real-time location tracking and path planning.
- Identifying arrival at the pickup and drop-off points.

The GPS module communicates with the Raspberry Pi via UART or USB and uses libraries such as GPSD to decode NMEA strings. Once the robot is given coordinates for the pickup and delivery locations, it uses GPS data to determine its current position and calculate movement instructions accordingly.

IoT Device

An **IoT communication module** enables the robot to share its status and receive commands over the internet. This may be implemented using a Wi-Fi-based ESP8266/ESP32 module or the built-in Wi-Fi of the Raspberry Pi.

Functions of the IoT module include:

- Transmitting GPS data and robot status to a cloud dashboard.
- Sending task completion alerts to a user interface.
- Receiving updates or remote-control commands.

Motor Driver (for Robot Movement)

The **motor driver** acts as an intermediary between the Raspberry Pi and the motors responsible for robot mobility. Since the Raspberry Pi cannot directly power the motors, the motor driver interprets control signals and supplies the necessary voltage and current to the motors.

Functions of the motor driver:

- Controls the forward, reverse, left, and right motion of the robot.
- Modulates speed using PWM (Pulse Width Modulation).
- Supports dual-motor configurations for differential drive systems.

Common motor drivers like L298N or L293D are used to drive DC motors. The Raspberry Pi sends GPIO signals based on GPS and sensor data, which the driver translates into motion instructions.

Motor Driver for Arm (Pickup/Delivery Mechanism)

In addition to wheel movement, the robot is also equipped with a **motorized arm or actuator**, used to pick up and release the material box. This arm is controlled via a separate motor driver dedicated to the actuator.

Responsibilities of this driver:

- Receives control signals from the Raspberry Pi to lift or drop the box.
- Coordinates with GPS and sensor data to determine when to activate the pickup or dump routine.

The movement of the arm can be pre-programmed using servos or linear actuators, which are precisely controlled to perform the mechanical tasks.

Power Source Battery

The robot is powered by a **rechargeable battery**, which supplies the necessary voltage and current to all components. It may include a Li-ion battery pack with voltage regulators to deliver stable power.

Key features:

- Provides uninterrupted power to the Raspberry Pi, motors, sensors, and modules.
- May include a power management circuit to prevent overcharging or deep discharge.
- Ensures mobility and independence from external power supplies.

Battery selection depends on the current rating of all components and the expected duration of operation. A well-regulated power system is crucial to maintain consistent functionality across all modules.

System Integration and Workflow

All these blocks work in coordination to execute the delivery task:

1. **Initialization:** On power-up, the Raspberry Pi initializes all sensors, GPS, and communication modules.
2. **Input Reception:** The user sends a delivery task via the IoT interface, specifying pickup and drop coordinates.
3. **Navigation:** The GPS and object sensors guide the robot to the pickup point while avoiding obstacles.
4. **Pickup Action:** Once the robot reaches the pickup point, the arm motor driver activates the pickup mechanism.
5. **Transit:** The robot continues navigation using updated GPS data and sensors.
6. **Delivery:** On reaching the destination, the arm mechanism is triggered again to dump the material.
7. **Status Update:** The robot sends a completion message via the IoT device.

SIMULATION OF THE CIRCUIT:

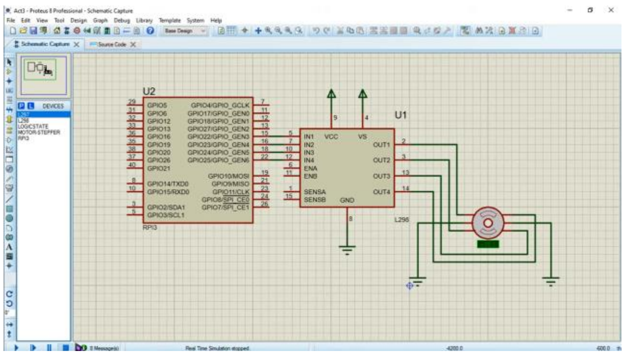

Fig 2. Machine control i.e., motors driving simulation

VI. CONCLUSION

The autonomous delivery robot successfully demonstrates smart navigation, object detection, and material transport using Raspberry Pi, GPS, sensors, and IoT. It performs automated delivery tasks with minimal human intervention, offering a cost-effective and efficient solution for last-mile logistics. The integration of real-time tracking and intelligent control ensures accurate, safe, and timely delivery. This system shows great potential for applications in healthcare, smart cities, and e-commerce, paving the way for scalable and sustainable automation in delivery services

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