

Automated Food Delivery System in Railway Compartments

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Abstract— IoT technologies and embedded systems have made automation feasible in various sectors, including transportation and service industries. The Indian Railways, as one of the world's biggest railway systems, faces a challenge in providing food delivery services that are efficient and accurate while maintaining cleanliness. The standard manual system is time-consuming, human-driven, and does not offer real-time tracking. Using QR codes and wireless communication, this paper describes an autonomous food robot that can deliver food intelligently within railway compartments. Passengers can order meals using a digital interface, thanks to the proposed system that assigns individualized QR codes to every seat. The order is relayed to a cloud database, which the robot accesses via retrieved Wi-Fi modules. By utilizing sensors and pre-set obstacles, the robot can navigate through different terrain types without any assistance. Tracking the delivery of food to ensure accuracy and punctuality.

This reduces the need for human intervention, improves hygiene, and reduce[update]. Compared to traditional methods, experimental results reveal greater efficiency and accuracy. Modern catering systems on the railway can be scalable using the proposed model.

Keywords: Internet of Things, Embedded Systems, Autonomous Robot, QR Code, Railway Automation, Smart Delivery System.

1. INTRODUCTION

Millions of passengers are served every day by Indian Railways, the national transportation system. One of the key services that improve passenger comfort is onboard food delivery. However, the current system is largely built on manual processes and often results in delays in service, incorrect delivery of orders or poor hygiene. The frequent problem for passengers is miscommunication and reliance on service staff.

With the growing need for automation and digital transformation, it becomes crucial to develop intelligent systems that can improve service quality and operational efficiency. By combining IoT and robotics, these issues can be resolved with great success. In industries such as healthcare, hospitality, and logistics, autonomous robots have become prevalent due to their ability to execute repetitive tasks with precision and efficiency. The suggested mechanism introduces a self-driving food delivery robot that is smart and designed for railway compartments. The system utilizes QR codes to place orders and also communicates with the cloud for real-time data delivery. Automated food delivery reduces human intervention and improves accuracy while reducing overall time for customers to access the service. Automation technologies have brought about significant changes in industries such as manufacturing, healthcare, transportation, and logistics. Railway transportation is also becoming significantly modern with the

introduction of smart technologies aimed at improving passenger comfort and increasing operational efficiency. ". By combining embedded systems with wireless communication and IoT, it is possible to create intelligent solutions that automate the repetitive tasks of human operators. This could enable services like these to be more accessible. The absence of staff, congested compartments, service delays, and trouble locating passengers are common problems that often occur in train food delivery services. These challenges vary. This can cause a decrease in passenger experience and an increase in operational complexity, among other issues. Accordingly, an automated delivery system can significantly enhance service quality while decreasing the need for manual labor. Moreover, the increasing demand for contactless public transportation has highlighted the importance of automation in this sector.

Automated food delivery robots can ensure that their food is delivered quickly and cleanly, while also ensuring that passengers are satisfied with the service.

1. SYSTEM HARDWARE DESIGN

The hardware design of the Automated Food Delivery System in Railway Compartments is focused on creating an efficient system that can deliver food on its own within a railway coach. This system is different from robots that move on the ground. It uses a track on the ceiling, which means we have to think about things like stability and vibration.

The system has parts that work together including a control unit, a motion control system, sensors and a power supply. All these parts are. Work as one to make sure the system can process information quickly and deliver food reliably. We want the system to work with help from people use less energy and be able to be used in many train compartments.

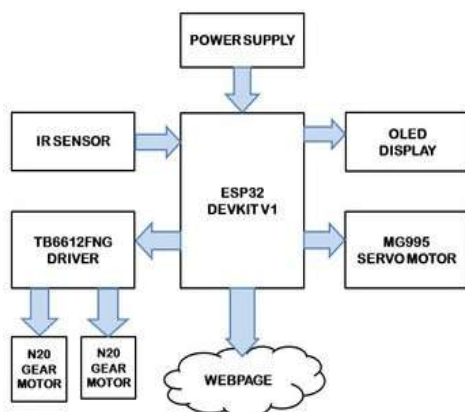


Fig. A: Block Diagram of system

2.1 ESP32 Microcontroller

The ESP32 Dev Kit V1 microcontroller is the main control unit of the system. It is a processor that can connect to the internet, which allows it to communicate with the user interface in real time. The microcontroller uses 3.3V of power. Has many pins that can be used to connect sensors, motors and displays. In this system the ESP32 microcontroller processes information from sensors controls motors manages communication and makes sure everything runs smoothly.

The ESP32 microcontroller can do things at the same time which means it can handle communication and control operations simultaneously. This makes the system work efficiently. We chose the ESP32 microcontroller because it is powerful can connect to the internet and uses power.



2.2 Infrared Sensor

The infrared sensor is used to detect the position of the robot along the track. It works by reflecting light and detecting special markers placed at specific seat locations. As the robot moves the infrared sensor keeps checking the track. Sends signals when it detects a marker. The ESP32 microcontroller then uses these signals to figure out where the robot is and make sure it stops at the place. The infrared sensor is very important for navigation. It gives the system feedback about the robots position, which helps it stop precisely at the target location. The sensor is simple responds quickly. Is well-suited for robots.



2.3 Ultrasonic Sensor

The ultrasonic sensor is used to detect obstacles and keep the system safe. It measures the distance to objects by sending out waves and timing how long it takes for them to bounce back. If an obstacle is detected the system stops the robot to prevent accidents. The ultrasonic sensor is reliable. Can detect obstacles within a short range making it perfect for small spaces like railway compartments. It helps keep the system safe by checking the surroundings. This is especially important in trains where people and luggage can create obstacles.

2.4 N20 DC Gear Motor

The N20 DC gear motor is used to move the robot along the track. It is a motor with a built-in gearbox that provides a lot of power and controlled speed. The motor makes sure the robot moves smoothly and steadily which is necessary for maintaining balance and avoiding jerks. The speed of the motor is controlled by the ESP32 microcontroller, which sends signals to the motor. The N20 gear motor provides a balance between speed and power. Its small size makes it easy to fit into the robot. It has enough power to carry food items.

2.5 Motor Driver (TB6612FNG)

The TB6612FNG motor driver is used to control the DC motors. It acts as a bridge between the ESP32 microcontroller and the motors because the microcontroller cannot supply power on its own. The driver allows the motors to move forwards and smoothly and efficiently.

It helps the robot move in both directions. Makes sure the motors work efficiently with minimal power loss.

2.6 Servo Motor

The servo motor is used to open and close the food delivery compartment. It allows for control of movement using special signals. When the robot reaches its destination the servo motor turns to open the compartment and after delivery it closes the compartment securely. The servo motor makes sure the delivery compartment works reliably and consistently. It reduces the chance of failure during repeated operations.

2.7 OLED Display

The OLED display is used to show information like order ID, seat number and delivery status. It communicates with the ESP32 microcontroller using a protocol and requires minimal wiring. The display is clear uses power and is perfect for battery-powered systems. When the system starts all the parts are configured. Then it enters a loop where it checks inputs processes data and controls outputs in real time. The system is designed to respond and make sure critical operations, like obstacle detection and motor control happen without delay.

3. SOFTWARE DEVELOPMENT

The software for the automated food delivery system is designed to work with the user interface, the control unit and the hardware. This system software handles user requests manages communication, controls movement and carries out delivery tasks in time. It is made up of parts each doing a specific job while working together with the rest of the system. The software is divided into three parts: the control software that runs on the microcontroller the communication part that handles data exchange and the user interface part that lets passengers interact with the system. This layered approach makes sure the system works efficiently reduces delays and performs well. The software is designed to be modular and scalable. Each software part works on its own while sharing information with parts. This makes it easier to find and fix problems test the system and upgrade it in the future. The system can handle tasks in time thanks to efficient task management on the ESP32 platform. Important functions like sensor monitoring and obstacle detection are given priority to ensure responsive operation. The modular design also makes it easy to add improvements like artificial intelligence and cloud-based monitoring.

3.1 Embedded System Software

The embedded software is written for the ESP32 microcontroller using the Arduino IDE. Programmed in Embedded C/C++. It handles sensor inputs, motor control, servo operation, display management and wireless communication. The program has two phases: initialization and continuous execution.

3.2 Motor Control Software

The motor control system regulates the robots movement along the track using signals from the ESP32. These signals control the speed of the motors. The direction is controlled through signals allowing the robot to move forward backward and stop. The software ensures movement by adjusting the signals, which helps maintain stability. The control logic checks input from sensors. Stops the robot when it reaches the target position ensuring accurate delivery.

3.3 Sensor Data Processing

The software continuously processes data from sensors to enable navigation and safety. The sensors provide signals used to detect position markers helping the system determine the robots location. The sensor measures the distance to obstacles. Compares it with a predefined threshold to detect obstacles. The processed data is used for real-time decision-making during robot operation.

3.4 Servo Control Software

The servo motor is controlled using signals to operate the delivery compartment. When the robot reaches the destination the software generates a signal to rotate the servo and open the compartment. After a delay the servo returns to its original position closing the compartment. The control logic ensures movement preventing mechanical stress and ensuring reliable operation.

3.5 Communication and IoT Integration

The ESP32 uses its built-in Wi-Fi module to communicate with the user interface. The software implements communication protocols to exchange data. When an order is placed the data is. Processed by the ESP32. The system sends updates back to the user interface. Basic error-handling mechanisms are included to manage network issues.

3.6 User Interface Software

The user interface is developed using web technologies like HTML, CSS and JavaScript. It allows passengers to place orders by scanning a QR code linked to their seat. The interface displays the menu accepts user input and shows order status updates. It communicates with the backend system, which interacts with the ESP32 to execute delivery operations.

3.7 Display Control Software

The display is controlled using a protocol. The software initializes the display. Updates it with information like order ID and system status. Efficient data handling ensures that display updates do not interfere with system operations.

3.8 Software Integration and Execution Flow

The software system operates as an unit where all parts function together. After initialization the system continuously monitors inputs and processes data. When an order is received the robot begins navigation while checking sensor inputs. Once the destination is reached the delivery mechanism is. The system updates the user interface.

Reading Digital Compass Keypad Interfacing

The delivery product is kept safe in a container. When the robot reaches its destination it. Waits for the customer to enter a four-digit password sent to their cell phone. The customers input password is matched with the password. If the passwords match the servo motor opens the lid of the container. If not the buzzer. The customer needs to retype the password.

4. WORKING PRINCIPLE

The automated food delivery system works based on the interaction between the user interface, control system, sensors and motors. The system is designed to deliver food inside railway compartments with human intervention. The operation begins when a passenger accesses the food ordering interface by scanning a QR code. The QR code redirects the user to a web-based application where the menu is displayed. The passenger selects food items. Confirms the order. Once the order is placed the data is transmitted to the ESP32 microcontroller. The communication is established using Wi-Fi protocols ensuring reliable data transfer.

The system processes parameters like seat number and order identification. The system then maps the seat number to a predefined position along the track. This mapping ensures that each seat corresponds to a position marker simplifying navigation and improving delivery accuracy. After processing the order the ESP32 initiates the movement of the robot by sending control signals to the motor driver. The robot moves along the track and the infrared sensors monitor the track for position markers. The ultrasonic sensor scans the surroundings to detect obstacles. If an obstacle is detected the sensor sends a signal to the ESP32, which immediately halts the robot.

When the robot reaches the designated seat position the ESP32 stops the motors. Initiates the delivery process. The display shows the order ID or seat number for verification. The microcontroller generates a signal to control the servo motor, which opens the food compartment. The passenger collects the food. After a predefined time interval the servo motor returns to its original position closing the compartment securely.

Once the delivery is completed the system updates the user interface with the delivery status and commands the robot to return to its base position or proceed to the delivery task.

The working principle demonstrates the feasibility of implementing automated delivery systems in confined transportation environments. The modular nature of the system allows expansion and integration with advanced technologies in the future. The continuous feedback mechanism established between sensors and the control unit allows the system to dynamically adjust its operation according to conditions. Real-time monitoring ensures navigation and prevents errors that could affect delivery performance. The automation process reduces intervention and improves consistency in service delivery. By combining communication, sensor-based navigation and embedded control the system achieves efficient and reliable operation, within railway compartments.

5. RESULTS

The automated food delivery system that was proposed was tested to see how well it worked. This was done by making a model that was like a train car and trying it out. The people doing the test looked at things like how accurate the deliveries were, how long it took to get the food and how well the system worked. They also looked at how the system could navigate and how reliable it was. The system was really good, at getting the food to the seats. It used sensors to figure out where it was and it always stopped in the right place. The system did not make mistakes when it was being tested. This shows that the way the system used sensors to navigate was an idea. The system was tested times and it always worked the same way. The time it took to deliver the food was also looked at. It was found that the robot could deliver the food quickly depending on how it had to go. The robot moved smoothly. Did not take a long time to get to the seat because it used a special kind of motor control. This made the system work better than if a person was delivering the food. The automated food delivery system was faster. People did not have to wait as long for their food. The automated food delivery system got the food to people quickly. It did not take a long time.

Obstacle detection using sensor proved to be reliable in different test conditions. The sensor detected objects within a range and stopped the robot immediately. This ensured operation and prevented potential collisions. The system resumed operation once the obstacle was removed. This showed adaptability in environments like crowded compartments. The communication between the user interface and ESP32 microcontroller was tested under conditions. The system. Processed order data in real-time with minimal delay. This confirmed the reliability of Wi-Fi-based communication for IoT applications. The system maintained connectivity during continuous operation. Power

consumption was a parameter considered during testing. The system operated continuously for a duration using a fully charged battery. The use of energy- components like ESP32 and OLED display helped optimize power utilization. Efficient power management ensures operational cycles without frequent recharging. Despite performance certain limitations were observed. External factors like vibrations and unstable network connectivity could affect system performance. However, these issues can be addressed through improved hardware design and better communication protocols. The results indicate that the proposed system delivers food accurately and efficiently in a railway compartment. The prototype validation confirms the feasibility of implementing systems in real-world applications. The developed prototype demonstrated performance during repeated testing cycles. The navigation system consistently identified seat positions. Executed delivery operations accurately. The coordinated operation of sensors, motors and communication modules contributed to system functionality. The system showed adaptability under varying operating conditions. Real-time obstacle detection and automatic recovery mechanisms enhanced safety. The overall user experience was improved through delivery response and contactless service. The modular architecture allows scalability. The same design approach can be extended to railway coaches. It can be integrated with monitoring systems for enhanced operational management.

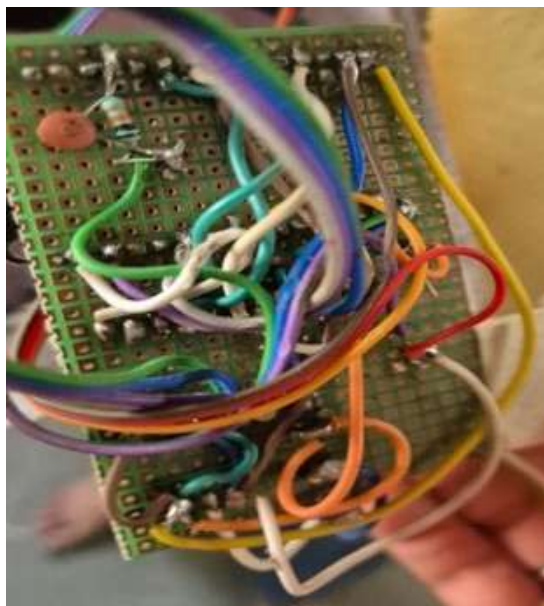
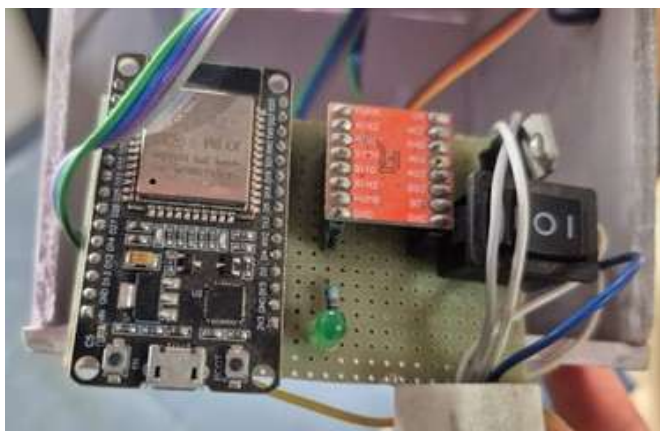


Fig. (B): Connections

6. CONCLUSION

This research presents the design and implementation of an automated food delivery system for railway compartments using IoT and embedded systems. The proposed system addresses limitations of manual food delivery methods by introducing automation, accuracy and improved hygiene. The integration of ESP32 microcontroller with sensors, motors and communication modules enables navigation and controlled delivery operations. The use of a track mechanism enhances efficiency by eliminating interference with passenger movement. It ensures operation in confined spaces. Experimental results demonstrate that the system achieves delivery accuracy and reliable performance under simulated conditions. The implementation of sensor-based navigation and obstacle detection ensures precise operation. The IoT-based communication system provides real-time interaction between the user and the robot. The proposed system has potential for real-world application in railway catering services. It can improve passenger satisfaction by providing contactless and reliable food delivery. It reduces dependency on labor and enhances operational efficiency. Future enhancements like integration with intelligence and improved battery systems can further increase effectiveness. The modular design of the proposed system enables enhancements without major hardware modifications. The integration of embedded control, IoT communication and robotic automation demonstrates applicability of modern engineering technologies. The successful implementation of the prototype validates the feasibility of using automated delivery systems in railway environments. It highlights their potential for large-scale deployment. The proposed system is a scalable solution, for modernizing food delivery services in railway environments.

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