

Research Article

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Smart Trolley System for Retail Stores: A Node MCU-Based Approach for IoT Integration

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Abstract— This project report presents the design, development, and implementation of an RFID and IoT-based Smart Trolley System. The project is a collaborative effort undertaken by a group of dedicated individuals. The primary objective is to enhance the traditional shopping experience by leveraging advanced technologies to improve efficiency, convenience, and data analytics in retail environments. The Smart Trolley System integrates Radio-Frequency Identification (RFID) technology and the Internet of Things (IoT) to create an intelligent and automated shopping cart. Each trolley is equipped with an RFID reader and sensors connected to the IoT platform. RFID tags are attached to the products in the store, allowing for seamless tracking and identification. The system facilitates an automated and frictionless checkout process, eliminating the need for manual scanning of each item. As customers add or remove items from their trolley, the RFID reader updates the cart's contents in real-time. The IoT platform ensures that this information is securely transmitted and processed. Furthermore, the system offers detailed data analytics to retailers, enabling better inventory management and personalized marketing strategies. By integrating these advanced technologies, the Smart Trolley System aims to revolutionize the shopping experience, making it more efficient and enjoyable for both consumers and retailers. The implementation of this Smart Trolley System also addresses common issues such as long waiting times at checkout counters and the inefficiency of manual inventory management. By automating these processes, the system not only enhances the shopping experience but also allows store employees to focus on more critical tasks, thereby improving overall service quality. Moreover, the data collected through the IoT platform can be analyzed to gain insights into customer behavior, helping retailers to optimize store layouts and product placements. This can lead to increased sales and customer satisfaction, further demonstrating the significant impact of integrating IoT and RFID technologies in retail environments.

Keywords- RFID, IoT, Smart Trolley, sensors, RFID Tags.

I. INTRODUCTION

The convergence of Radio Frequency (RFID) and Internet of Things (IoT) technologies has sparked a wave of innovation across industries, with profound implications for the retail sector. In response to the evolving demands of modern consumers and the increasing complexity of retail operations, there has been a growing interest in developing intelligent systems to enhance the shopping experience. This paper explores the design and implementation of an RFID and IoT-based

smart trolley system, which represents a significant advancement in retail technology [2].

At its core, the smart trolley system integrates a suite of cutting-edge components, including RFID Reader, RFID Tags, Node MCU (ESP 8266), Arduino Nano, ultrasonic sensor, battery, LCD display, and motor driver. These components work in tandem to create a seamlessly interconnected ecosystem, capable of automating various aspects of the shopping process. RFID technology plays a pivotal role in enabling automatic item detection and inventory management, facilitated by RFID tags affixed to merchandise. The RFID Reader captures tag data, allowing for real-time tracking and analysis of products within the retail environment. Complementing this capability, IoT functionalities provided by the Node MCU and Arduino Nano microcontrollers enable data communication, processing, and control, enhancing system flexibility and adaptability. Additionally, ultrasonic sensors ensure obstacle detection to facilitate smooth navigation of the trolley within the store premises [3]. Through the integration of these technologies, the smart trolley system promises to revolutionize retail operations, offering both retailers and consumers an unparalleled level of convenience, efficiency, and engagement. **Moreover**, the implementation of this system can lead to significant cost savings by reducing the need for manual labor and minimizing checkout times, thereby increasing overall store efficiency. The adoption of such smart technologies in retail is not only a response to consumer demand but also a strategic move to stay competitive in an increasingly digital market. Retailers who invest in these technologies are likely to see a higher return on investment through improved operational efficiency and customer loyalty. The smart trolley system also aligns with sustainable practices by reducing paper receipts through digital billing and minimizing the need for physical interventions in the shopping process[8].

II. SYSTEM ARCHITECTURE DIAGRAM

Provide a high-level overview of the entire system. Illustrate the relationships and connections between RFID readers, IoT devices, the central server, and other relevant components. Use clear labels and annotations to explain the flow of information. The architecture diagram as shown in Figure 1. serves as a blueprint, guiding the implementation process and ensuring all components are correctly integrated.

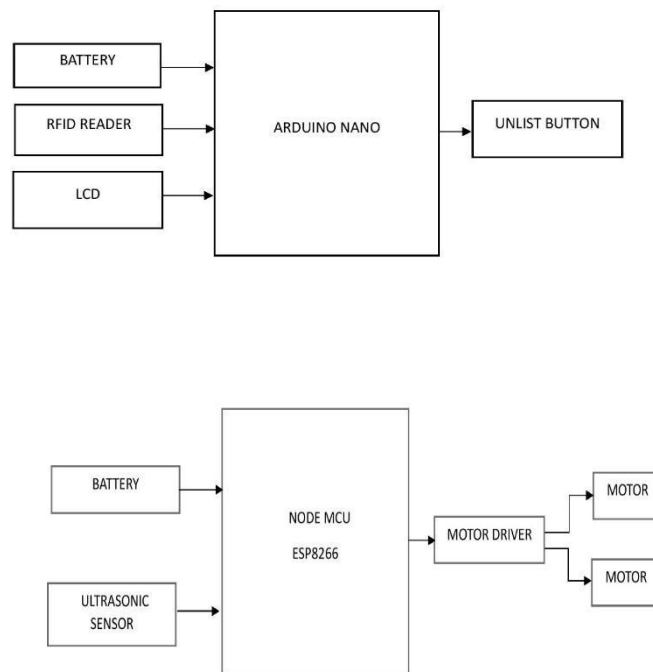


Figure 1 (a), (b) Interfacing Of Node Mcu With Ultraspnic Sensor And Motor Driver

III. IMPLEMENTATION

III.1 HARDWARE IMPLEMENTATION: . Hardware set up of the project is shown in Figure 2.

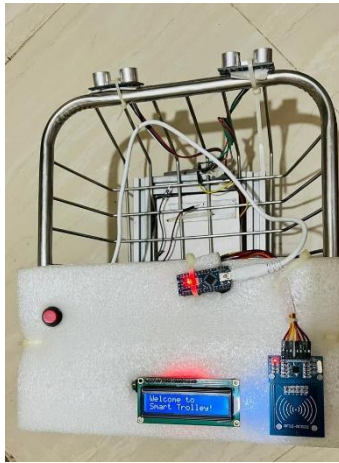


Figure 2. Hardware set up of the project

ESP32-WROOM Module

The ESP32-WROOM microcontroller serves as the central unit of the smart trolley, integrating Wi-Fi and Bluetooth capabilities for wireless communication with its powerful processing capabilities and extensive peripheral interfaces make it an ideal choice for this application. The module handles real-time data processing and ensures seamless connectivity with the IoT platform[1].

L298 Motor Driver Module

The L298 motor driver controls the DC motors that drive the trolley's wheels. It receives commands from both the ESP32 and Arduino Nano to move the trolley in the desired direction. The module is designed to handle high current loads, making it suitable for driving motors in various robotics applications[4-6].

Circuit Design :

ESP32-WROOM Connections

The ESP32 is connected to the Arduino Nano via serial communication (TX/RX pins) for data exchange.

The RC522 RFID reader is connected to the ESP32 via the SPI interface for efficient data transfer.

The ESP32 manages Wi-Fi connectivity to enable IoT functionalities, allowing for real-time data transmission to the cloud.

The design also incorporates a robust power management system to ensure the trolley can operate for extended periods without frequent recharging. This includes the use of energy-efficient components and optimized power consumption strategies, allowing for longer battery life and reliable performance throughout the shopping day[7].

III.2 SOFTWARE IMPLEMENTATION: It includes steps as follows:

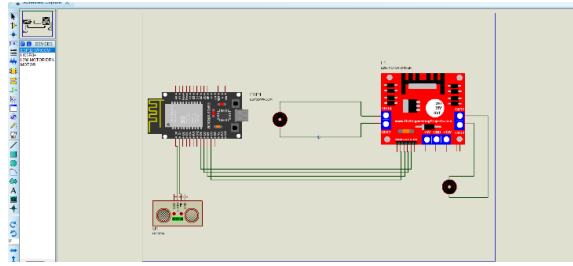


FIG 3. Simulation Results

Initialization

The ESP32 initializes the SPI interface for the RC522 RFID reader and sets up Wi-Fi connectivity.

The Arduino Nano initializes the GPIO pins for the HC-SR04 sensor and the L298 motor driver module. Simulation Results is shown in Figure 3.

Sensor Integration

The HC-SR04 ultrasonic sensor continuously measures distances to detect obstacles, with data processed by the Arduino Nano.

The RC522 RFID reader scans RFID tags and sends the tag information to the ESP32 for inventory logging.

Motor Control Logic

The Arduino Nano processes the ultrasonic sensor data to determine the trolley's movement and sends PWM signals to the L298 motor driver to control the DC motors.

The ESP32 communicates with the Arduino Nano to synchronize RFID data with the trolley's movement and location[3].

IoT Integration

The ESP32 sends real-time data, including RFID tag information and trolley location, to a cloud server, enabling remote monitoring and management of the trolley.

The cloud server processes the data and provides a user interface for tracking the trolley's status and inventory.

The motor control logic is designed to be adaptive, adjusting the trolley's speed and direction based on real-time sensor inputs. This ensures smooth navigation even in crowded store environments, preventing collisions and enhancing the overall user experience. The system is also capable of executing predefined routes for automated restocking or inventory checks, adding another layer of functionality to the smart trolley[2].

User Interface

A mobile application or web interface allows users to interact with the smart trolley, monitor its status, view inventory, and receive notifications. This interface is designed to be user-friendly, ensuring that even individuals with limited technical knowledge can easily navigate and utilize the system. Users can also provide feedback through the interface, helping to continuously improve the system based on real-world usage.

IV. RESULTS

1. Welcome Message

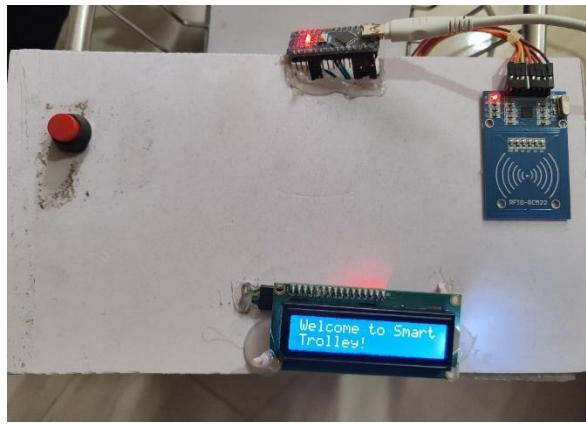


Figure 4. Welcome Message

This photo captures the initial state of the smart trolley system when powered on. The LCD display shows the welcome message: "Welcome to Smart Trolley." This greeting is designed to inform the user that the trolley is ready to begin scanning and adding products. The Welcome Message in window is shown in Figure 4.

2. Adding Milk



Figure 5. Product 1 Added

This Figure 5 shows the smart trolley after a carton of milk has been added. The LCD display indicates "Milk and Price". This confirms that the trolley has successfully scanned the milk and updated the total bill accordingly.

3. Removing Last Item

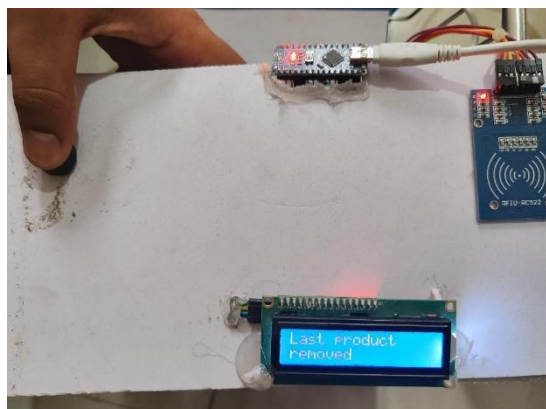


Figure 6. Removed Last Product

This photo in Figure 6. captures the action of removing the last item added to the smart trolley. After pressing the designated key, the display shows a message indicating that the last item has been removed and the bill has been updated accordingly. For example, if sugar was the last added item, the display might read "Sugar removed. Total updated."

4. Updated Bill After Removal

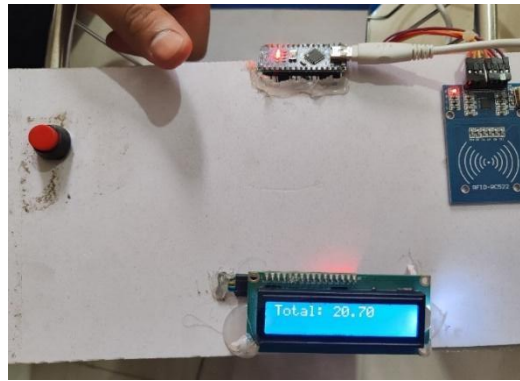


Figure 7. Bill Generate

This Figure 7. shows the updated bill on the LCD display after removing the last added item (e.g., sugar). The display reflects the new total amount, demonstrating the system's ability to accurately adjust the bill when an item is removed.

V. APPLICATIONS

The RFID and IoT-based trolley system offers versatile applications across industries. In retail, it expedites checkout processes by automatically tracking items in the trolley, enhancing customer satisfaction. In logistics and warehousing, it optimizes inventory management and order fulfilment by accurately monitoring goods movement. Healthcare facilities benefit from improved asset tracking and inventory control, ensuring timely availability of medical supplies. Hospitality venues utilize the system for efficient guest services, such as room service and amenities delivery. Smart city initiatives leverage RFID-enabled trolleys for waste management, public transportation, and maintenance tasks, contributing to urban efficiency. Educational institutions enhance campus logistics and student services through automated book transport and supply management. Overall, the system's ability to automate tasks, track assets, and streamline operations makes it a valuable solution across diverse industries, improving efficiency and user experiences[9]. Additionally, by providing detailed analytics and insights, the system helps organizations make informed decisions, thereby optimizing operational processes and enhancing overall productivity. In addition to these applications, the system can be tailored for use in library management, where it can automate the process of book sorting and inventory tracking. By attaching RFID tags to books and utilizing the smart trolley for handling and shelving, libraries can significantly reduce the time and effort required for these tasks. This adaptability makes the RFID and IoT-based smart trolley a versatile tool across various sectors, beyond traditional retail and logistics[7].

CONCLUSION

In conclusion, the RFID and IoT-based Smart Trolley System represents a transformative leap in the realm of smart retail technology, successfully addressing challenges in conventional checkout processes and inventory management. The project's meticulous design and implementation have resulted in a functional and efficient system, validated through rigorous experimentation. The system's capabilities, from seamless RFID tag reading to real-time data transmission and enhanced user experience, underscore its potential to revolutionize the retail industry. User feedback indicates a positive impact on the shopping experience, demonstrating the practical implications of the implemented solution. While the project has achieved its primary objectives, there exists a promising trajectory for future enhancements and adaptations to further elevate the system's utility and relevance in the dynamically evolving landscape of smart retail. The successful integration of RFID and IoT technologies not only augments operational efficiency but also sets the stage for a more intelligent and responsive shopping environment, positioning the Smart Trolley System as a noteworthy advancement in the intersection of technology and retail innovation.

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