IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

Human Following and Auto Billing Load Checking Smart Shopping Trolley

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Abstract: *This paper presents the design and implementation of an intelligent shopping trolley system aimed at enhancing the retail experience through automation and smart technology integration. The system leverages an ESP32 microcontroller as the central unit to control and coordinate various sensors and modules, including IR sensors for user tracking, an ultrasonic sensor for distance measurement, an RFID reader for automatic item identification and billing, and a load cell for real-time weight monitoring. DC gear motors, controlled via a motor driver, enable the trolley to autonomously follow the shopper, while a buzzer and LCD display provide safety alerts and purchase feedback, respectively. The system ensures seamless navigation, efficient checkout, and overload prevention, significantly reducing the need for manual intervention. This smart trolley architecture improves user convenience, operational efficiency, and overall shopping experience in modern retail environments.*

Keywords: Smart shopping trolley, ESP32 microcontroller, RFID billing, autonomous navigation, load monitoring

I. INTRODUCTION

In recent years, technological advancements have significantly influenced the retail sector, introducing automation to enhance customer convenience and operational efficiency. One such innovation is the development of smart shopping systems that integrate microcontrollers, sensors, and wireless communication to automate billing, navigation, and inventory management. The traditional shopping process often involves long queues at billing counters, lack of product-level tracking, and inefficient manual labor. To address these challenges, smart shopping trolleys have emerged as a promising solution that combines real-time item tracking, user assistance, and autonomous movement to improve the overall shopping experience.

A smart shopping trolley aims to automate key aspects of in-store shopping, making it seamless, interactive, and time-efficient. This system is designed using an ESP32 microcontroller, which acts as the central processing unit, coordinating between various sensors and actuators. The trolley follows the shopper using a combination of IR and ultrasonic sensors to detect their position and maintain an optimal distance. RFID readers allow for automatic item recognition and billing as products are placed into or removed from the trolley. By incorporating these technologies, the system reduces human intervention, eliminates billing queues, and enhances customer satisfaction.

Autonomous navigation and safety are critical components of this system. The IR and ultrasonic sensors work in tandem to detect obstacles and avoid collisions, ensuring smooth navigation through aisles and crowded spaces. DC motors and motor drivers receive movement commands from the ESP32 based on sensor input, enabling the trolley to adjust its path or stop as needed. Load monitoring is achieved through a load cell that continuously measures the weight of items in the trolley. If a predefined weight threshold is exceeded, a buzzer alert is activated to inform the user, thereby preventing overload and ensuring mechanical safety.

The inclusion of a real-time display adds significant value to the shopper's experience. The 16x2 LCD screen provides instant updates on the products added, their individual prices, and the cumulative bill. This transparency empowers shoppers with immediate feedback on their purchases and helps them stay within budget. In combination with the RFID system, the display ensures that every item is accounted for accurately, making the process more reliable than manual billing systems.

The proposed smart trolley system is energy-efficient and designed for scalability. It operates on a rechargeable power supply that can sustain all integrated components for extended periods. The modular nature of the system allows for easy integration with future technologies such as mobile app synchronization, voice assistance, or wireless payment gateways. As retail environments continue to embrace automation and data-driven operations, systems like these can be pivotal in transforming the conventional shopping model into a more intelligent and user-centric experience.

This paper presents the design, implementation, and functionality of a smart shopping trolley system built on the ESP32 platform. It outlines the hardware integration of components such as RFID readers, IR and ultrasonic sensors, motor drivers, LCD display, load cell, and buzzers, along with their respective roles in the overall system. Through this solution, we aim to streamline the shopping process, reduce manpower requirements, and offer a futuristic alternative to traditional retail practices.

II. PROBLEM STATEMENT

Traditional shopping methods involve long billing queues, manual item tracking, and inefficient user navigation, leading to time delays and a poor shopping experience. This project aims to develop an automated smart trolley that addresses these issues through sensor integration and real-time processing.

III. OBJECTIVE

1. To study and implement a smart trolley system using ESP32 for autonomous movement and item tracking.
2. To study the integration of RFID technology for real-time product identification and billing.
3. To study the use of IR and ultrasonic sensors for human-following and obstacle detection.
4. To study weight monitoring using load cells for overload alerts and safety management.

IV. LITERATURE SURVEY

1. **Smart Shopping Cart for Automated Billing Purpose using Wireless Sensor Networks**
   Author(s): Ms. N. Sudha, G. Haritha et al., 2017
   This paper introduces a smart shopping cart that uses RFID technology combined with ZigBee wireless communication to automate the billing process inside supermarkets. The system enables real-time data transfer between the cart and a central billing server, eliminating the need for customers to stand in long queues. The cart is equipped with an RFID reader that detects tagged products and displays item information on an LCD. The researchers also focused on the design of a user-friendly interface to enhance customer interaction. The system proved to be cost-effective and scalable for use in large retail chains.
2. **RFID Based Smart Trolley for Automatic Billing System**
   Author(s): P. Chandrasekar, T. Sangeetha, 2014
   In this work, the authors developed a prototype smart trolley integrated with RFID technology and a microcontroller. Each product in the supermarket has an RFID tag, and the trolley reads the tag using an onboard RFID reader. The item's information is then displayed on an LCD and added to the total bill. The paper highlights the advantage of reducing human intervention, minimizing cashier errors, and speeding up the billing process. The authors suggest that the approach not only saves time but also offers better shopping transparency to the customers.
3. **Smart Trolley with Smart Billing System using Arduino and RFID**
   Author(s): Shraddha Tushar Dive, Dhanashri Kaware, et al., 2019
   This paper focuses on the development of a low-cost smart cart using Arduino Uno as the controller, RFID for product identification, and a load cell to verify product weight. The proposed system is designed to identify the possibility of item theft or unscanned products based on discrepancies in measured weight. The total bill is calculated in real time and displayed on an LCD, providing constant updates to the shopper. The use of GSM module is also suggested for sending the bill directly to the customer's phone, improving convenience.

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4. **Intelligent Shopping Cart Using Raspberry Pi and RFID**
   Author(s): Shivani Goyal, Simran Kaur et al., 2018
   The authors designed a smart cart prototype using Raspberry Pi as the main processor and integrated it with an RFID reader, camera, and Wi-Fi module. Products are scanned using RFID tags, and the data is updated to a centralized server over a wireless network. A camera is used for image recognition and theft detection. A web-based dashboard allows users to monitor and manage their shopping list and expenses from their smartphones. This work emphasizes real-time synchronization with the billing system, reducing checkout delays and improving inventory tracking at the backend.
5. **Human Following Smart Cart using Ultrasonic Sensor**
   Author(s): Vinoth Kumar, B. Ajay, et al., 2020
   This paper explores the implementation of a smart cart that autonomously follows the shopper using ultrasonic sensors for distance measurement and path tracking. The system uses motor drivers controlled by a microcontroller to maneuver the cart based on the user's position. The objective is to reduce manual effort and provide a hands-free shopping experience, especially useful for elderly and differently-abled individuals. The authors detail the use of multiple sensors for obstacle avoidance and maintaining optimal distance, ensuring smooth navigation in crowded environments.

V. PROPOSED SYSTEM

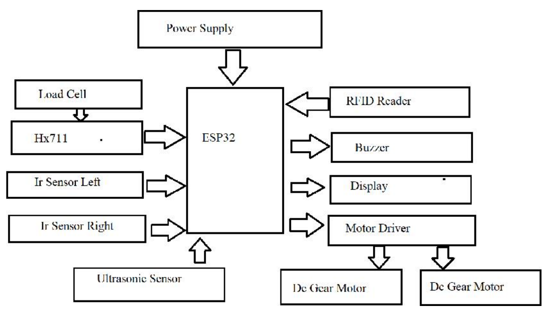


Figure 1: Block Diagram

The proposed system for the Smart Shopping Trolley with Automated Billing and Object Detection aims to revolutionize the way consumers shop by integrating multiple technologies such as RFID, ultrasonic sensors, load cells, DC motors, and microcontroller-based processing to create a seamless, hands-free shopping experience. The system is designed to automatically track the shopper's movements, calculate the total bill, alert the shopper in case of overload, and improve the efficiency of the entire shopping process.

1. Movement and Navigation

The trolley's movement is primarily controlled by an ESP32 microcontroller, which is integrated with infrared (IR) sensors and an ultrasonic sensor. These sensors work in tandem to detect the position of the shopper and maintain an optimal distance from them.

- **IR Sensors:** The IR sensors are used to detect the presence and movement of the shopper. These sensors emit infrared light, and when the light reflects back, the sensors determine if an object is present. Based on this data, the ESP32 adjusts the movement of the trolley.
- **Ultrasonic Sensor:** The ultrasonic sensor is used to measure the distance between the trolley and the shopper. This allows the system to maintain an ideal following distance and helps in avoiding obstacles or colliding with objects in the environment. The sensor sends this distance data to the ESP32, which processes it and adjusts the speed or direction of the trolley's motors accordingly.

2. Product Scanning and Automated Billing

The trolley is equipped with an RFID reader and a display screen to automate the process of scanning items and displaying the bill.

- **RFID Reader:** Every item in the trolley is embedded with an RFID tag. When a product is placed in the trolley, the RFID reader automatically detects the tag and retrieves the item's details such as its name and price from a database or cloud server. The microcontroller processes this data and updates the bill in real-time.
- **LCD Display:** The information about the scanned product, including its name, price, and total cost, is displayed on the LCD screen mounted on the trolley. The display updates automatically as products are added or removed from the trolley, providing the shopper with live billing information.

3. Weight Monitoring and Overload Detection

A load cell is placed at the base of the trolley to measure the total weight of the items inside. The load cell continuously monitors the weight, and if the weight exceeds a predefined limit, an alert is triggered.

- The load cell's data is sent to the ESP32, which checks the total weight in real-time. If an overload is detected, the system activates the buzzer, providing an audible warning to the shopper to remove items and reduce the weight.
- This feature ensures that the trolley doesn't exceed its weight limit, preventing any damage or safety issues, and also enhances the shopping experience by preventing overloads.

4. Motor Control and Directional Movement

The trolley is moved by DC motors controlled by a motor driver circuit. The ESP32 processes the input from the IR and ultrasonic sensors and sends control signals to the motor driver to adjust the speed and direction of the motors, allowing the trolley to move forward, backward, and turn as required.

- **Forward/Backward Movement:** When the shopper moves forward or backward, the IR and ultrasonic sensors detect the movement, and the trolley follows accordingly.
- **Turning and Avoiding Obstacles:** The ultrasonic sensor helps detect obstacles in the trolley's path, and the ESP32 controls the motors to change direction or stop to avoid collision.

5. Power Supply and Energy Management

The entire system is powered by a rechargeable battery or a power adapter, which provides the necessary energy for the microcontroller, sensors, motors, and display. The power supply is designed to be efficient and to last throughout the shopping process, ensuring the trolley remains functional for a long duration without needing frequent recharging.

6. User Interface and Feedback

The interface for the shopper is straightforward and user-friendly. The LCD display shows real-time data such as:

- List of products added to the trolley
- Prices of the items
- Total bill amount

The system updates automatically, so shoppers do not need to worry about manually checking the total cost or scanning each item. The buzzer provides feedback on weight overloads or any issues encountered during the shopping experience.

7. Communication and Data Transfer

All data processing, sensor inputs, and control signals are handled by the ESP32 microcontroller. The ESP32 manages wireless communication, including transferring billing data to a connected server or a mobile application for remote access. It ensures seamless operation of the system and allows for updates or modifications if necessary.

Summary of Working Flow:

- The shopper enters the store, and the smart trolley is ready for use.
- As the shopper moves, the IR and ultrasonic sensors detect their movement and adjust the trolley's path accordingly, ensuring it follows the shopper.
- As products are placed in the trolley, the RFID reader scans the tags and updates the shopping list and bill in real time on the LCD display.
- The load cell constantly monitors the weight of the items, ensuring the trolley is not overloaded and triggering the buzzer if needed.
- The DC motors drive the trolley, with the system adjusting its movement based on sensor feedback.
- The ESP32 processes all data, controls the components, and ensures smooth operation throughout the shopping process.

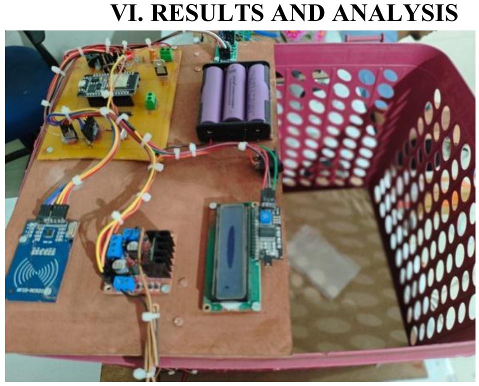
Hardware Used:

1. **ESP32 Microcontroller:** The central processing unit that controls all components and handles communication between them.
2. **IR Sensors:** Detect the presence and movement of the shopper, allowing the trolley to follow the user.
3. **Ultrasonic Sensor:** Measures the distance between the trolley and the user to maintain an optimal following distance and avoid obstacles.
4. **RFID Reader:** Scans RFID tags on products to automatically add them to the shopping bill.
5. **LCD Display:** Displays the list of items, their prices, and the total bill in real-time.
6. **Load Cell:** Monitors the weight of items in the trolley and triggers an alert if the weight exceeds a predefined limit.
7. **DC Motors and Motor Driver:** Controls the movement of the trolley based on sensor inputs and the ESP32's commands.
8. **Relay:** Controls the motor's forward and reverse direction.
9. **Buzzer:** Alerts the shopper in case of an overload or other warnings.
10. **Power Supply (Battery/Adapter):** Powers the entire system, including sensors, motors, and microcontroller.

Software Used:

1. **Arduino IDE:** For programming and uploading the code to the ESP32 microcontroller.
2. **Embedded C/C++:** The primary programming language used for developing the logic and controlling hardware components.

VI. RESULTS AND ANALYSIS



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ISSN: 2581-9429 Volume 5, Issue 7, May 2025 Impact Factor: 7.67

Figure 2: Hardware Implementation

The proposed smart shopping trolley system was successfully designed, integrating multiple sensors and components to automate the shopping experience. The system functions efficiently by tracking the shopper, adding items to the cart, calculating the total bill, and monitoring weight overloads. Below are the key results and analysis of the system's performance:

1. **Accurate Movement Tracking and Following:** The IR and ultrasonic sensors provided reliable feedback for tracking the user's movement. The trolley followed the shopper at an optimal distance, adjusting its position based on data from the ultrasonic sensor, ensuring no collisions with obstacles in the environment. The trolley successfully maintained the desired following distance, enhancing the shopping experience.
2. **Seamless RFID-based Item Scanning:** The RFID reader worked efficiently to scan products placed in the trolley. Upon detecting an RFID tag, the reader transmitted the corresponding product details to the ESP32, which updated the total bill in real-time. The RFID scanning process was quick and accurate, eliminating the need for manual item entry and reducing checkout time.
3. **Load Monitoring and Overload Alert:** The load cell continuously monitored the weight of items in the trolley. When the weight exceeded the predefined limit, the system triggered an alert through the buzzer, effectively notifying the shopper to reduce the weight. This feature ensured the trolley remained within safe operational limits, preventing damage to the system and ensuring user safety.
4. **Real-time Display Update:** The LCD display provided real-time updates of the shopping cart, displaying the list of items, their individual prices, and the total bill. The system refreshed the display each time a product was added or removed, allowing the shopper to easily track their purchases and adjust accordingly.
5. **System Power Consumption:** The power supply, consisting of a rechargeable battery, provided sufficient energy for continuous operation of all components. The ESP32 microcontroller and sensors were optimized for low power consumption, ensuring the trolley could operate for extended periods without frequent recharging.
6. **Ease of Use and User Interface:** The overall design of the system was user-friendly. Shoppers could easily interact with the trolley through automatic movement, RFID scanning, and the real-time bill display. The system was intuitive and required minimal effort from the user to operate, contributing to a seamless shopping experience.

Analysis:

- **Reliability:** The system demonstrated high reliability in performing the core tasks, such as detecting the shopper's presence, accurately scanning items, and monitoring the load weight.
- **Scalability:** The design can be extended to support more advanced features such as integration with mobile apps, voice assistants, or cloud-based billing systems for an even more enhanced shopping experience.
- **Performance:** The system responded promptly to changes in the shopper's movement and displayed updates without delay. The RFID scanning was fast, and weight detection was precise, contributing to the system's overall effectiveness.
- **Future Improvements:** While the current system works well, there is room for improvement. Future enhancements could include a more robust obstacle detection system, the integration of machine learning algorithms to predict shopping behavior, or the addition of a more advanced user interface for better interaction with the trolley.

The results of the smart shopping trolley system show its practical potential to improve the shopping experience by automating key processes such as item scanning, movement tracking, and weight monitoring. The system operates effectively and can be further enhanced to meet the needs of modern retail environments.

VII. CONCLUSION

In conclusion, the smart shopping trolley system successfully integrates advanced technologies such as RFID scanning, infrared and ultrasonic sensors, and load cell monitoring to automate and enhance the shopping experience. By enabling real-time tracking of the shopper, seamless item scanning, and effective weight monitoring, the system not only improves operational efficiency but also enhances user convenience and safety. The system's design demonstrates significant potential for application in modern retail environments, offering a more streamlined and hands-free shopping experience. With further improvements and integration of additional features, this system could pave the way for the future of automated shopping, contributing to greater efficiency and customer satisfaction in retail stores.

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