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Research Paper

Smart Robotic Cart - the Intelligent Follower

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Abstract: ***Improving the shopping experience has become important in modern retail environments, where customers often face difficulty in handling carts and waiting at billing counters. This paper presents a Smart Robotic Cart – the Intelligent Follower, which combines automation and Radio-Frequency Identification (RFID) technology to simplify the shopping process. The cart is designed to automatically follow the customer using ultrasonic sensors and incorporates an obstacle avoidance mechanism that stops the cart when objects are detected, ensuring safe movement. The proposed system uses an RFID-based identification method, where each product is attached with an RFID tag. An RFID reader integrated into the cart scans the products, and the item details are displayed on an LCD screen while simultaneously updating on a mobile interface through a Wi-Fi module. The system supports both addition and removal of items by switching modes and rescanning the RFID tags. To complete the purchase, a dedicated payment RFID tag is used, which confirms the transaction, clears the cart data, and displays a payment success message. This approach eliminates traditional checkout procedures and reduces waiting time. The system provides a cost-effective and user-friendly solution using embedded systems and IoT concepts, improving overall efficiency and customer convenience in retail shopping.***

Keywords: Smart Robotic cart, RFID system, Ultrasonic sensing, Obstacle detection, IoT, Automated billing.

I . INTRODUCTION

The retail industry is undergoing rapid transformation with the adoption of advanced technologies aimed at enhancing customer convenience and improving operational efficiency. Conventional shopping systems require customers to manually handle carts, select products, and wait in long billing queues, which leads to increased physical effort and time consumption, particularly in crowded retail environments. These limitations highlight the need for intelligent and automated solutions to optimize the overall shopping experience.

To address these challenges, this work proposes a **Smart Robotic Cart – the Intelligent Follower** System that integrates embedded systems and Internet of Things (IoT) technologies. The proposed cart is capable of automatically following the customer using ultrasonic sensors, thereby minimizing the need for manual cart handling. Additionally, the system incorporates an obstacle avoidance mechanism that detects objects in the cart's path and ensures safe navigation by stopping the cart when necessary.The system further employs Radio-Frequency Identification (RFID) technology for efficient product identification and billing. Each product is equipped with an RFID tag, which is scanned using an RFID reader mounted on the cart. The scanned information is displayed on an LCD module and simultaneously updated on a mobile interface through a Wi-Fi module, enabling real-time monitoring of selected items. The system also supports dynamic cart management, allowing users to add or remove items by switching operational modes and rescanning the corresponding RFID tags.

For transaction completion, a dedicated payment RFID tag is utilized to confirm the purchase. Upon scanning, the system finalizes the transaction, clears the stored data, and displays a confirmation message on the LCD screen. By eliminating traditional checkout procedures and reducing manual effort, the proposed system significantly enhances shopping efficiency and user convenience.

This study demonstrates the implementation of a smart retail solution that combines sensing, communication, and automation technologies, contributing to the development of efficient, user-friendly, and intelligent shopping systems.

II.LITERATURE REVIEW

We have studied some of the papers before starting this project and would mention some of the key information about those papers. The first paper titled "An Analysis of Li-Fi Based Prevalent Automated Billing Systems in Shopping Malls" by Shipra Aggarwal and Himani Pangasa analyses Li-Fi based automated billing systems for shopping malls. The study compares Li-Fi with traditional technologies and highlights its potential for faster data transmission and reduced billing time. It explains how light-based communication can be used for secure and high-speed data transfer in indoor environments. The authors also discuss how Li-Fi reduces interference compared to radio-based communication systems. However, the system requires line-of-sight communication and has limited practical implementation in crowded retail environments. Additionally, installation cost and infrastructure changes make it difficult for large-scale adoption. [1] The second paper titled "Automated Billing Cart" by Muhib A. Lambay et al. proposes an automated billing cart using RFID technology to eliminate manual barcode scanning. The system improves billing speed and reduces human errors. It explains how RFID readers can automatically detect items placed inside the cart and update the total bill instantly. The authors highlight the importance of reducing checkout queues in supermarkets. However, it lacks advanced features such as mobile integration and automated cart movement, limiting user convenience. The system also does not address security issues like theft detection or item verification. [2] The third paper titled "An Intelligent Shopping Cart with Automatic Product Detection and Secure Payment System" by Sudipta Ranjan Subudhi and R. N. Ponnalagu presents an intelligent shopping cart with automatic product detection and secure payment features. The system integrates RFID with a payment module to enable faster checkout. It focuses on providing a secure transaction mechanism to avoid billing fraud. The paper also explains how automation can improve customer satisfaction by reducing manual effort. Although it enhances efficiency, challenges such as system cost and RFID reliability affect its performance. Additionally, dependency on proper tag detection may lead to errors in crowded shopping conditions. [3] The fourth paper titled "IoT Application on Secure Smart Shopping System" by Vishwas et al. discusses an IoT-based secure smart shopping system. The system enables real-time product tracking and communication using IoT technologies. It allows store management to monitor customer activity and product movement through connected devices. The authors emphasize improved inventory control and reduced manual supervision. It improves monitoring and reduces billing delays, but network dependency and security concerns remain key limitations. Furthermore, continuous internet connectivity is required for proper functioning of the system. [4] The fifth paper titled "Android Based Automated Cart System Using Raspberry Pi and GSM" by Suprabha Jadhav and Shailesh Hambarde introduces an Android-based automated cart using Raspberry Pi and GSM modules. Thesystem provides billing updates and notifications through mobile devices. It enables communication between the cart and the user via SMS or mobile application. The authors focus on improving user interaction and convenience during shopping. However, GSM communication delays and lack of automation in cart movement reduce efficiency. The system also lacks real-time responsiveness compared to Wi-Fi-based systems. [5] The sixth paper titled "IoT Application of Secure Smart Shopping Cart" by Runian Li and Tianyi Song proposes an IoT-based secure smart shopping cart using RFID technology. The system improves billing accuracy and enhances customer experience by reducing checkout time. It explains how IoT connectivity helps in maintaining real-time communication between carts and central servers. The paper also highlights improved data management and monitoring. However, it faces issues such as RFID interference and system scalability in large stores. Additionally, handling multiple carts simultaneously creates communication challenges. [6] The seventh paper titled "Smart Shopping Cart" by Akshay Kumar et al. presents a smart shopping cart that uses RFID for automated billing and LCD display for user interaction. The system reduces manual effort and improves transparency. It provides customers with real-time updates of their purchases and total cost. The authors emphasize ease of use and simple implementation. However, it lacks advanced features such as payment integration and wireless communication. The absence of connectivity limits its application in modern smart retail environments. [7] The eighth paper titled "IoT Based Smart Shopping Trolley with Mobile Cart Application" by S. Kowshika et al. proposes an IoT-based smart shopping trolley integrated with a mobile application. The system allows users to track their purchases in real time and improves shopping convenience. It also provides better interaction between the cart and the user through mobile devices. The authors highlight the benefits of digital monitoring and automated billing. Despite its advantages, it depends heavily on internet connectivity and faces challenges in handling multiple carts simultaneously. Network failure can affect system performance significantly. [8]

III.METHODOLOGY

A . Components

1. Power Supply – Provides the required electrical power to all components of the system. It ensures stable voltage for the Arduino, sensors, RFID module, and other hardware, enabling smooth and continuous operation of the smart cart.

2. Arduino UNO – Acts as the main controller of the system. It processes data from the RFID module and ultrasonic sensor, controls the motor driver, updates the LCD display, and manages communication with the Wi-Fi module for mobile interface integration.
3. LCD (Liquid Crystal Display) – Used to display product details such as item name, price, and total bill. It also shows system messages like item added, item removed, and payment confirmation to provide real-time feedback to the user.
4. L293D Motor Driver – Controls the movement of motors used in the cart. It receives signals from the Arduino and drives the motors accordingly, enabling the cart to follow the customer and stop when an obstacle is detected.
5. RFID Module (MFRC522) – Used to scan RFID tags attached to products. It reads the unique ID of each product and sends the data to the Arduino, which processes it to add or remove items from the cart.
6. RFID Tags - They are a type of tracking system that uses smart barcodes to identify items. RFID, short for "radio frequency identification," utilizes radio frequency technology. It is also referred to as an RFID chip. There are two main types of RFID tags:
   I. Battery-operated RFID Tags: It contain an onboard battery as a power supply. They might also be called active RFID tags.
   II. Passive RFID Tags: They are not battery-powered and instead work by using electromagnetic energy transmitted from an RFID reader.
7. Ultrasonic Sensor (Obstacle Sensor) – Detects the distance between the cart and the customer or obstacles. It helps the cart to follow the user and stop automatically when an object is detected in its path, ensuring safe navigation.
8. Mode Selection Switch (ON/OFF) – The ON/OFF switch is used to select the operation mode of the smart robotic cart. When the switch is in the ON position, the system operates in Add Mode, allowing products to be added to the cart when RFID tags are scanned. When the switch is in the OFF position, the system operates in Remove Mode, enabling the removal of products from the cart upon scanning. This switch provides a simple and effective way to control product addition and removal.
9. Mobile Dashboard (User Interface) – Displays products, prices, and total bill in real time on the user's smartphone. It connects via Wi-Fi and provides a convenient digital billing experience.
10. Node MCU (Wi-Fi Module Controller) – Enables Wi-Fi communication between the cart and mobile dashboard. It sends product and billing data for real-time monitoring.

B . Circuit Diagram

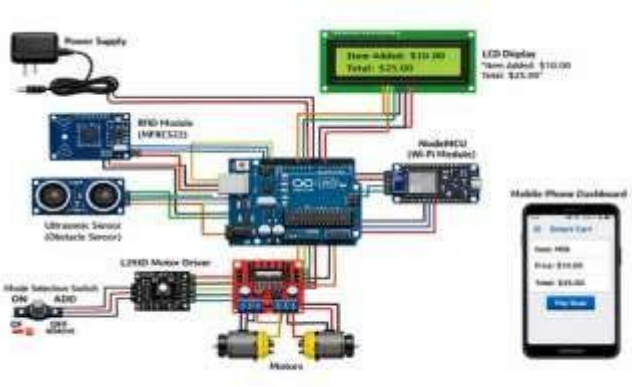

Fig-1 : Circuit Diagram for Smart Robotic Cart

C . Flowchart

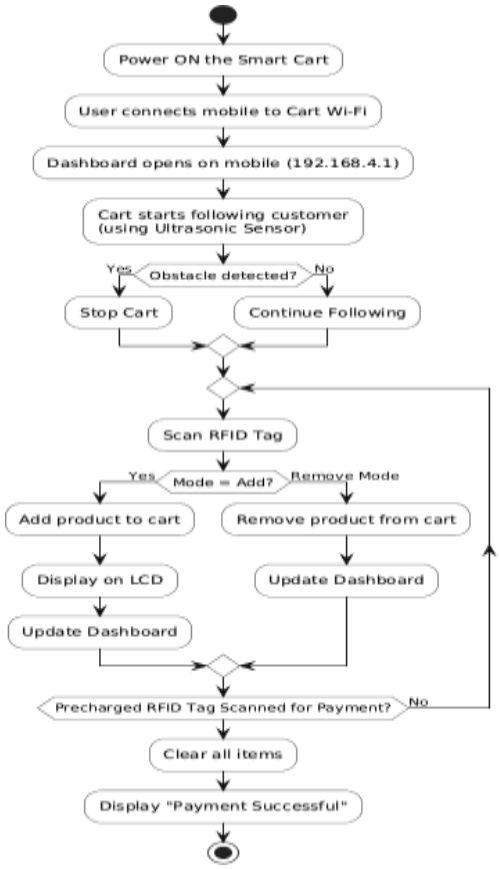

Fig – 2 : Flowchart for Smart Robotic Cart

The system begins with powering on the smart cart and establishing a connection with the mobile interface through Wi-Fi. Once initialized, the cart starts following the customer using ultrasonic sensors. The obstacle detection feature continuously monitors the path, and the cart stops automatically when any obstacle is detected, ensuring safe movement.

After that, the user scans products using the RFID module.Each scanned product is identified and added to the cart, with details displayed on the LCD screen and updated on the mobile application in real time.

The system provides flexibility by allowing users to remove items by switching to remove mode using a push button and rescanning the same RFID tag. The corresponding product is then removed from the cart and updated on both the LCD and mobile interface. This process continues until all desired items are selected.

Finally, when the payment RFID tag is scanned, the system completes the transaction by clearing all items from the cart and displaying a "Payment Successful" message on the LCD screen, indicating the end of the shopping process.

IV . RESULTS AND DISCUSSIONS

In previous and present times, each shopping mall has a different billing system. From the customer's point of view, in supermarkets, most of the time is spent in the billing queue and manual checkout process. Therefore, the *"Smart Robotic Cart – The Intelligent Follower"* is designed to solve this problem and improve the shopping experience.

When a customer enters the shopping mall, the smart trolley is activated and begins following the customer using ultrasonic sensors. The trolley continuously tracks the user's movement and moves accordingly. The working prototype of the system is shown in **Figure 3**, which illustrates the complete setup of the smart robotic cart.

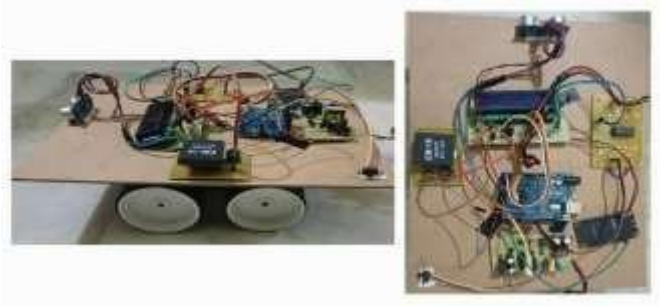

Figure 3: Smart Robotic Cart Prototype

After activation, the cart follows the customer by detecting the user's hand movement placed in front of the sensor. The cart intelligently maintains a safe distance while tracking the user. Additionally, the system includes an obstacle detection mechanism, where the cart automatically stops when an obstacle is detected within a distance of 50 cm, ensuring safety and preventing collisions. This behavior is illustrated in Figure 4a & 4b.

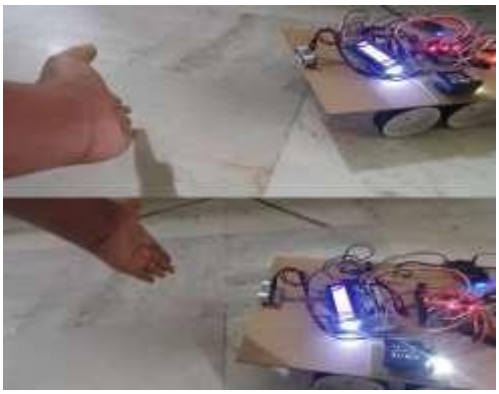

Figure 4 a: Cart following the customer using ultrasonic sensors

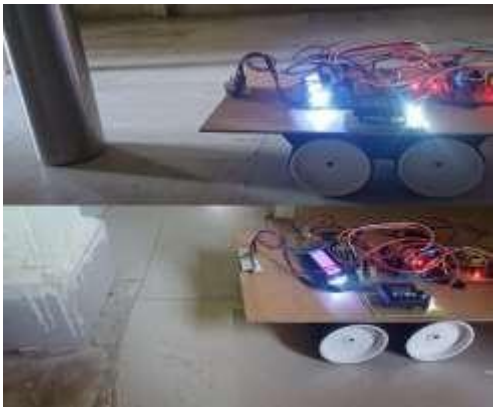

Figure 4 b: Obstacle Detection

The system also includes an obstacle avoidance feature, where the trolley automatically stops if any obstacle is detected in its path, ensuring safety and preventing collisions. After activation, the customer connects to the trolley through Wi-Fi, similar to connecting to the internet. This connection enables real-time monitoring and control through a mobile dashboard, as shown in **Figure 5.**

Figure 5: Wi-Fi Connection Between Smart Cart and Mobile Dashboard

Once connected, the system initializes with the total amount displayed as zero when no products are added. When a customer picks a product, the RFID tag attached to the product is scanned using an RFID module. After successful scanning, product details such as name, quantity, and price are displayed on the LCD screen and updated on the mobile interface. This process of RFID detection and product addition is illustrated in **Figure 6**.

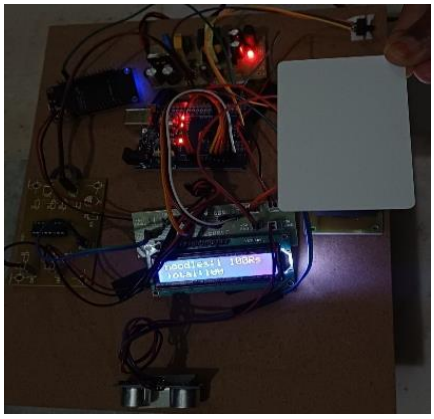

Figure 6: RFID Detection, and Product Addition to Mobile Dashboard

The item is then added to the cart, and the total bill is updated dynamically. To remove unwanted products, the system provides a "remove mode," which can be activated using a button. In this mode, scanning the same RFID tag again removes the item from the cart and updates the total amount accordingly. This removal functionality is demonstrated in **Figure 7**.

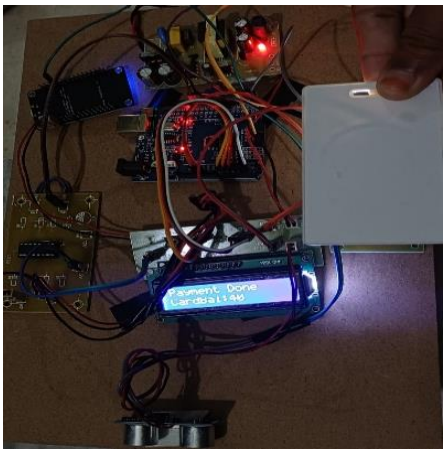

Figure 7: Removing Products Using RFID in Remove Mode

This feature allows customers to modify their selections at any time, providing flexibility during shopping. After selecting all desired products, the customer proceeds to payment. A dedicated payment RFID tag is scanned, which triggers the billing process. Upon scanning, all items are cleared from the cart, the mobile interface resets, and the LCD displays a confirmation message. The payment and cart clearance process is shown in **Figure 8**.

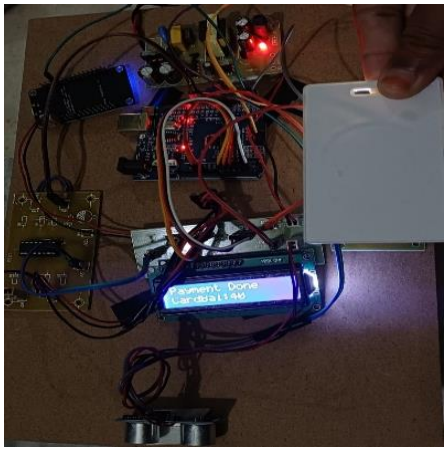

Figure 8: Payment Using Prepaid RFID Tag and Cart Clearance

V. LIMITATIONS

The Smart Robotic Cart system has certain limitations that affect its performance in real-world environments. Ultrasonic sensors may produce inaccurate readings in crowded or reflective surroundings, and RFID scanning requires proper placement of items to avoid missed detections. The system also depends on a stable Wi-Fi connection for mobile updates, which may not always be reliable in large shopping malls. Additionally, the limited sensor range restricts long-distance tracking of the user, while battery life can reduce efficiency during extended usage. Managing multiple carts simultaneously is challenging, and RFID interference may occur when several tagged products are close together. Furthermore, the initial setup cost of the system is relatively higher compared to traditional shopping cart.

VI. FUTURE SCOPE

The future scope of the Smart Robotic Cart includes integrating AI-based vision systems to improve user tracking accuracy beyond ultrasonic sensors. Advanced navigation techniques like SLAM can be implemented for efficient movement in crowded environments. The system can be enhanced by adding digital payment options such as UPI, cards, and mobile wallets for seamless checkout. Using advanced sensors like LiDAR and cameras can improve obstacle detection and path planning. Further improvements include developing a mobile app with budget tracking and recommendations, along with cloud integration for real-time data storage and analytics. Additionally, scalability for managing multiple carts, better battery management, inventory integration, and voice assistant support can significantly enhance the system's functionality and user experience.

VII. CONCLUSION

The Smart Robotic Cart system successfully demonstrates an innovative approach to modern retail shopping by integrating automation, RFID, and IoT technologies. The cart effectively follows the user, detects obstacles, and performs real-time product scanning and billing. It reduces manual effort and eliminates the need for traditional checkout queues, improving overall efficiency. The system also enhances user convenience through real-time display and mobile connectivity. Despite minor limitations, the project proves to be a reliable and user-friendly solution. It highlights the potential of smart technologies in transforming shopping experiences. With further improvements, this system can be widely implemented in supermarkets and malls. Overall, the project contributes to building a smarter and more efficient retail environment

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