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Edge-Enabled Smart Shopping Cart with IoT-Based Item Tracking and Cost Estimation

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ABSTRACT: The evolution of retail environments has accelerated with the integration of Internet of Things (IoT) technologies. Smart trolleys and shelf systems are now revolutionizing the shopping experience by enhancing automation, reducing human labor, and improving inventory management. This survey paper explores various IoT-based implementations in retail, highlighting innovations in smart trolley and shelf systems. We analyze existing methodologies, review recent research contributions, and propose how these technologies can be adapted and enhanced for real-world deployment.

KEYWORDS: IoT, Smart Trolley, Smart Shelf, RFID, Retail Automation, Shopping Systems

I. INTRODUCTION

The global retail industry is constantly evolving to meet the demands of convenience, efficiency, and personalization. Traditional shopping methods often suffer from long checkout queues, inventory mismatches, and customer dissatisfaction. IoT-based smart systems, including intelligent trolleys and shelves, offer a solution by automating key processes such as product scanning, real-time inventory updates, and autonomous billing. These systems utilize technologies like RFID, weight sensors, infrared modules, and mobile applications to create a seamless shopping experience. This paper surveys key developments in this domain and assesses how existing solutions can inform new projects.

II. METHODOLOGY

This survey examines five key research papers that explore the design and implementation of smart retail systems. A common approach across these studies is the use of RFID technology, where RFID tags and readers are employed to automatically detect items as they are placed in trolleys or on smart shelves, with the scanned data updating both the virtual shopping cart and the store's inventory database [3][4]. To further enhance accuracy in detecting product placement or removal, several systems incorporate infrared (IR) sensors and load cells, offering a secondary layer of validation for physical item movement [1][2]. Central to these systems is the integration of microcontrollers such as Arduino Uno, NodeMCU (ESP8266), or Raspberry Pi, which serve as the core processors managing communication between sensors and the database [2][3][5]. Real-time data processing and storage are often achieved using IoT cloud platforms like Firebase, Blynk, or custom dashboards, ensuring that inventory and billing data are updated live and accessible from remote locations [1][5]. For end-user interaction, many of these solutions also include mobile apps or web interfaces that allow customers to track their purchases, view billing details, and receive relevant notifications during their shopping experience [2][4]. The Fig.1. shows the Functional Block Diagram of the Smart Shopping Cart, which is proposed in the reference.

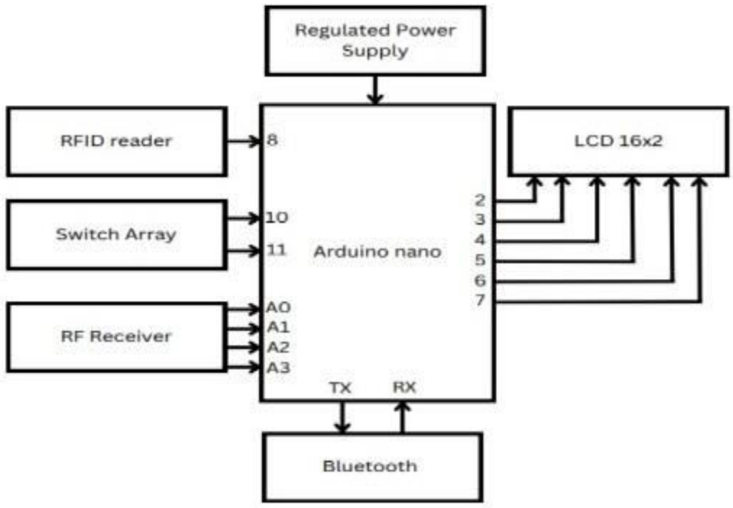

Fig.1. Functional Block Diagram of the Smart Shopping Cart

Reference	Device used	Main Technology	Accuracy	Notable Features
[1] Enhancing Retail Efficiency: Design and Implementation of Smart Shelf and Trolley Systems Utilizing IoT	ESP32, RFID Reader, Ultrasonic, Arduino	IoT + RFID + Ultrasonic	95%	Real-time billing, inventory tracking
[2] Transforming Shopping with IoT: Exploring the Intelligent Way to Design the Smart Trolley using IoT	Arduino Uno, RC522, LCD, Wi-Fi	IoT + RFID	92–94%	Self-checkout, mobile cart tracking
[3] Automated Smart Trolley System using RFID Technology	NodeMCU, MFRC522, OLED	RFID with OLED display	90–93%	On-cart billing, rescan to remove item
[4] The IoT-Based Smart Shopping Trolley System	Arduino Uno, NodeMCU, LCD, RFID Reader	IoT + Cloud + Mobile App	90-92%	Cloud analytics, mobile view, alerts
[5] Smart Shopping Trolley (IJMRSETM)	Arduino Uno, RFID, ZigBee, Buzzer	RFID + ZigBee	90-93%	Offer zone alerts, wireless checkout

III. LITERATURE REVIEW

This section reviews the selected papers and their unique contributions. Dhruv Arora et al. (2024) [1] present a dual system integrating smart shelves and trolleys using load cells and NodeMCU, emphasizing real-time product weight tracking, shelf stock alerts, and a mobile interface for billing and monitoring. This approach significantly enhances both customer experience and backend efficiency. Jayaprakash et al. (2024) [2] focus on consumer convenience by designing a system with RFID-based scanning, real-time price calculation, and voice feedback. Their implementation uses Arduino Uno, IR sensors, and an LCD display to keep customers continuously informed throughout the shopping process. Rahul R et al. (2023) [3] propose a simple RFID-embedded trolley model with centralized billing, aiming to reduce checkout time and human effort, thereby offering an efficient solution for supermarket environments. Sakshi Maurya et al. (2023) [4] suggest an IoT-integrated trolley system that combines RFID product identification and wireless communication to relay data to a central server, featuring a user-friendly interface that displays real-time total cost to the customer. Lastly, Rashmi P C et al. (2023) [5] outline a more generalized smart cart architecture that shows potential for integration with machine learning and predictive analytics, enabling advanced retail applications such as demand forecasting and customer behavior analysis.

IV. RESULT AND DISCUSSION

By synthesising insights from the selected papers, several key takeaways and opportunities for improving smart trolley systems emerge. One of the most significant advancements is the use of hybrid sensor combinations integrating RFID with load cells and infrared sensors to ensure accurate detection of item placement, thereby minimising scanning errors and potential fraud, as demonstrated in the work by Arora et al. and Jayaprakash et al. [1][2]. Scalability is another major advantage highlighted in systems that leverage cloud platforms and mobile or web applications, allowing seamless real-time updates and efficient management of multiple smart trolleys[1][4]. Additionally, energy efficiency plays a crucial role in practical deployment; using lightweight microcontrollers like the ESP8266 instead of power-hungry alternatives such as Raspberry Pi has proven to reduce both energy consumption and overall costs [1][5]. Enhancements in user experience are also explored, such as the inclusion of voice prompts to guide shoppers, particularly benefiting visually impaired users, which is effectively proposed in [2]. Lastly, the potential integration of artificial intelligence, as suggested by Rashmi P C et al. [5], opens the door to more advanced features like personalised shopping recommendations, predictive stock monitoring, and automated inventory restocking.

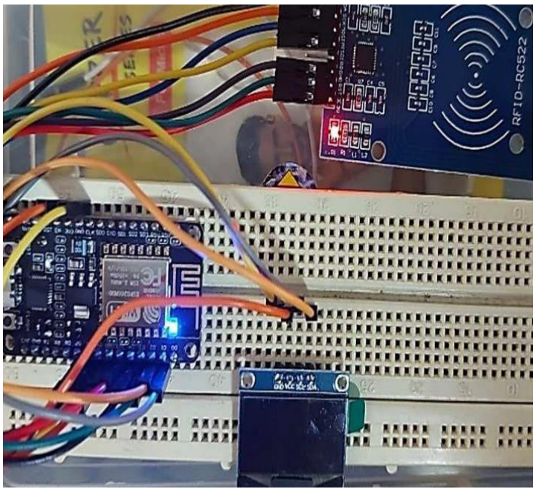

Fig. 2. Connection of Each Module

Fig. 3. Purchased product displayed.

V. CONCLUSION

IoT-enabled smart trolleys and shelves represent the next wave of innovation in retail automation. By studying existing literature and real-world prototypes, we gain valuable insights into efficient design, implementation strategies, and the challenges of deploying such systems at scale. These systems have the potential to transform how consumers shop and how retailers manage logistics. Moving forward, incorporating hybrid sensor systems, intuitive UIs, and cloud connectivity will be essential. Additionally, AI-powered features could bring predictive intelligence to future implementations.

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