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Smart Shopping Trolley with Automated Billing System

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Abstract In today's fast-paced environment, customers often find it inconvenient and time-consuming to stand in long queues for billing at supermarkets and shopping malls. This delay not only results in customer dissatisfaction but can also lead to revenue losses and billing errors, such as incorrect invoicing. To address this issue, this study proposes a Smart Shopping Cart system that aims to streamline the retail experience by automating the billing process. The proposed intelligent cart leverages RFID (Radio Frequency Identification) technology to detect and identify products as they are added to the cart. The system includes essential hardware components such as an RFID reader, GSM module, Arduino microcontroller, LCD display, and a keypad. Each item equipped with an RFID tag is scanned by the reader upon insertion into the cart, and the product's details are immediately displayed on the screen. The total bill is updated in real time, ensuring transparency and efficiency throughout the shopping process. The main objective of the system is to reduce customer wait times at billing counters and eliminate the need for traditional checkout lines. This innovative solution is particularly useful in high-traffic environments like supermarkets, where manual billing can lead to errors and long delays. Additionally, the integration of a GSM module enables data transmission for backend processing and updates. The Smart Shopping Cart enhances user convenience, optimizes store operations, and encourages a more seamless and enjoyable shopping experience. Ultimately, this system represents a modern, technology-driven solution to one of retail's most persistent problems.

Keywords: Automatic billing, Radio Frequency Identification (RFID), Arduino, Global System for Mobile communication (GSM), Matrix Keypad.

1. INTRODUCTION

The retail industry is rapidly transforming with technological advancements, led by smart trolley systems featuring mobile app-based barcode scanners and automatic billing, streamlining transactions and enhancing convenience. Innovations like QR codes, ESP32Cam, IoT systems, and RFID technology further improve efficiency through smart billing, direction control, tracking, product identification, and inventory management. These technologies create an interconnected, customer-centric retail environment focused on simplicity, accessibility, and satisfaction, setting a new standard for modern shopping experiences. It enables seamless product identification, real-time tracking, efficient navigation, personalized shopping, and streamlined inventory management. These advancements simplify the shopping process, enhance customer convenience, and improve operational efficiency, setting a new benchmark for modern, technology-driven retail experiences. Overall, these advancements not only redefine the shopping process by emphasizing convenience, accessibility, and satisfaction but also enhance operational efficiency for retailers. Moving a shopping cart today is a daunting job in malls and retail areas because of the heavy weight of items. So in order to overcome this issue, a Human Friendly Smart Trolley with Automated Billing System was proposed. With these trolleys, consumers can enjoy their shopping and pay more attention to their shopping list without the need to move their shopping carts. As we can see in a shopping center or grocery store, like big bazaars and D-marts; there are trolleys available, but they

are operated manually. An automated moving shopping cart with sensors is designed for the convenience of customers. In the modern era, consumer expectations for speed, accuracy, and convenience are constantly rising, especially in the retail sector. While online shopping through e-commerce platforms offers ease and comfort, physical retail stores and shopping malls still maintain a strong foothold due to their tactile shopping experiences, immediate product availability, and the ability to compare goods directly. However, one persistent issue plaguing traditional brick-and-mortar retail is the lengthy checkout process. Customers often face long queues at billing counters, especially during peak hours, leading to dissatisfaction, inefficiency, and potential financial losses due to abandoned purchases.

Manual billing systems and barcode scanning at checkout are time-consuming and prone to human error. These issues emphasize the need for a more efficient and automated solution. As a response to these challenges, the concept of a Smart Shopping Cart is introduced. This system aims to revolutionize the conventional shopping experience by automating the billing process using RFID (Radio Frequency Identification) technology. Each product in the store is tagged with an RFID label, which allows the system to automatically identify items as they are added to or removed from the cart. This eliminates the need for manual scanning at the checkout The smart cart is equipped with key components such as an RFID reader, Arduino microcontroller, GSM module, LCD screen, and a keypad. These components work together to read product data, calculate the total bill in real-time, and optionally send purchase details via GSM for inventory or notification purposes. The LCD provides the customer with a clear view of the items added and their corresponding costs. This project addresses several core issues: reducing customer wait time, increasing billing accuracy, enhancing operational efficiency, and improving the overall user experience in retail environments. Furthermore, the system minimizes reliance on human labor for billing, thereby reducing costs for store management. The proposed solution not only offers a smart alternative to traditional billing but also serves as a step towards the digital transformation of the retail sector, making in-person shopping more enjoyable, efficient, and futuristic. By bridging the gap between technology and traditional shopping, this intelligent cart system has the potential to redefine customer engagement and set a new standard for retail innovation. Moreover, the integration of smart technologies in retail aligns with the growing trend of digital transformation and the adoption of the Internet of Things (IoT). As consumers increasingly seek faster, more personalized, and contactless shopping experiences, the smart shopping cart emerges as a practical and scalable solution. It not only enhances customer satisfaction by minimizing delays but also supports store management through real-time data collection on inventory usage and customer purchasing behavior. This data can be leveraged for demand forecasting, targeted promotions, and inventory optimization. The automation of billing and product tracking also contributes to reducing manpower requirements and operational costs, making it an economically viable solution for large supermarkets and retail chains. Overall, the smart cart system represents a fusion of convenience, efficiency, and intelligent automation, poised to redefine traditional shopping paradigms in a rapidly evolving technological world.

2. LITERATURE SURVEY

The concept of integrating technology into the retail sector has gained considerable momentum, particularly with the emergence of RFID (Radio Frequency Identification) systems. G. Roussos and B. Collage (2006) [1] emphasized the transformative role RFID could play in enhancing retail operations. Their study highlighted how RFID-enabled systems can help improve inventory visibility, enable real-time tracking, and reduce operational inefficiencies. This foundational work has inspired numerous subsequent developments in automating shopping and billing processes. Building on these early insights, Ankit Anil Agarwal et al. (2011) [2] introduced one of the initial models of an RFID-based automatic shopping cart. Their system demonstrated how embedding RFID readers within trolleys could assist in real-time product identification and billing, effectively eliminating the need for traditional checkout counters. This study contributed significantly to the automation landscape in retail by presenting a cost-effective and time-saving solution for both consumers and retailers. In a related development, Zeeshan Ali and Prof. Reena Sonkusare (2013) [3] proposed a more user-centric smart shopping and billing system. Their design utilized an Arduino-based microcontroller, LCD display, RFID tags, and

readers to facilitate product identification and instant billing as customers added items to the cart. The researchers emphasized the benefits of reducing manual errors and enhancing user interaction, making shopping faster, smoother, and more intelligent. The work of Waghmare et al. (2014) [4] took this concept further by integrating wireless communication modules with RFID to create an efficient trolley prototype. Their system allowed the collected data to be transmitted to a central server, enabling synchronized billing and inventory updates. This concept bridged the gap between hardware components and real-time data processing, laying the groundwork for more sophisticated smart retail solutions. N. Ramesh and A. B. Chavan (2017) [5] focused on simplifying the microcontroller programming aspect by using Arduino boards for easy integration and flexibility. Their RFID-embedded smart cart could identify each product with its unique ID and maintain a dynamic bill that was displayed instantly. This real-time feedback feature made the solution not only functional but also consumer-friendly, aligning with modern expectations of instant services.

To push the boundaries of connectivity, M. V. Ramesh (2017) [6] proposed a smart cart design that incorporated IoT features, enabling seamless data exchange between the cart and a cloud server. This integration allowed stores to monitor stock levels, analyze purchasing patterns, and receive real-time alerts on cart contents. It opened avenues for centralized control, remote monitoring, and predictive analytics in the retail sector. Saha and Bandyopadhyay (2017) [7] further explored the benefits of IoT in smart carts, particularly focusing on wireless communication and cloud computing for advanced data analytics. Their work underlined the necessity of cloud storage and real-time processing to achieve full automation in billing and shopping processes. They argued that such systems could drastically reduce customer waiting times and improve the overall shopping experience. A more hardware-focused study was conducted by Zope and Mohite (2017) [8], who designed an RFID-based smart cart with an automatic billing system capable of eliminating the need for barcode scanning. Their system stored product information using tag IDs and processed it through embedded controllers to generate accurate bills. This significantly reduced errors associated with manual barcode scanning and improved checkout efficiency.

On the other hand, Kodali et al. (2016) [9] presented an IoT-based smart shopping cart that used Wi-Fi modules to send cart data to a remote server. This allowed integration with mobile applications, enabling users to track their purchases in real time. The researchers also demonstrated how such a system could be extended to provide personalized recommendations and loyalty-based offers based on user preferences. Lastly, Kamble et al. (2016) [10] introduced a ZigBee-based communication system into their smart trolley design, improving the system's scalability and performance in dense environments such as supermarkets. Their proposed architecture ensured reliable wireless data transfer between carts and a central monitoring unit, thus facilitating seamless customer experience and efficient data management. In conclusion, the literature highlights a steady evolution in the field of smart shopping carts, progressing from basic RFID-based product identification to IoT-enabled, cloud-connected, and mobile-integrated systems. These advancements aim to address the primary challenges faced in traditional shopping — such as long queues, manual billing errors, and inventory mismanagement — by offering efficient, automated, and intelligent solutions. The current body of work sets a strong foundation for further research and development in the direction of fully autonomous retail environments.

3. PROPOSED SYSTEM

The proposed system introduces a smart and automated shopping cart, embedded with modern RFID and microcontroller technologies, to streamline the in-store shopping and billing experience. The central aim is to eliminate the need for long queues at billing counters, thereby reducing customer wait times and enhancing shopping convenience. This is achieved by allowing billing to occur directly at the shopping cart as items are placed inside it. Each item in the store is affixed with a passive RFID tag, which contains a unique identification number that corresponds to product details stored in a centralized database. When a customer places an item into the cart, the RFID reader installed on the cart detects the RFID tag and reads the associated data. The reader transmits this information to an Arduino Uno microcontroller, which acts as the central processing unit of the cart system. Upon receiving the data, the microcontroller processes it

and matches the tag ID with a product record. This includes fetching information like item name, unit price, and other metadata. The item is then displayed on an LCD display module attached to the cart. The total bill is dynamically calculated and shown in real-time as more items are added. If a customer decides to remove an item from the cart, the keypad interface allows manual deletion of the product from the current bill, giving the customer full control over their purchase list. The system also features a GSM module for communication with the store's central billing system. When the customer finishes shopping and confirms the cart list, the GSM module sends a final transaction message—containing product details and total price—to either the customer's registered phone number via SMS or directly to the store's billing server. This makes it possible for the customer to skip traditional checkout lanes and directly proceed to an automated payment counter or smart gate exit.

In terms of security and anti-theft measures, RFID antennas at the exit gates scan the cart contents and compare them with the finalized billing list. If any item in the cart is unpaid or does not match the billing record, an alert is raised immediately, preventing unauthorized removal of goods and ensuring billing integrity. This mechanism greatly enhances inventory control and theft prevention without requiring manual intervention Furthermore, the system is designed to be modular and scalable, supporting expansion into more advanced versions. These could include Wi-Fi or Bluetooth modules for app integration, cloud-based data storage for large-scale operations, and even camera modules for visual product verification. The architecture also supports future upgrades like voice interaction, barcode scanning, dynamic pricing notifications, and loyalty point calculations. With energy efficiency and cost-effectiveness at its core, the system is suitable for deployment in medium to large-sized retail environments Overall, the proposed system not only enhances the responsiveness and effectiveness of crowd management but also contributes to broader public safety and urban resilience initiatives. By reducing human monitoring overhead, enabling rapid threat detection, and ensuring scalability across diverse scenarios, the AI-driven framework provides a significant technological advancement in intelligent surveillance. Future improvements may involve integrating multimodal data (e.g., audio, thermal imaging, or social media feeds), optimizing the system for edge devices using lightweight models, and incorporating explainable AI techniques to increase transparency and trust in anomaly detection outcomes. In addition to its core detection capabilities, the proposed system emphasizes adaptability to different environmental contexts and crowd dynamics. By incorporating transfer learning techniques, the CNN model can be fine-tuned with minimal additional data to accommodate new surveillance locations with distinct visual characteristics, such as varying lighting conditions, camera angles, and crowd densities. Furthermore, the modular design of the system allows for easy integration with cloud-based or edge computing platforms, enabling deployment in both resource-rich and constrained settings. This flexibility ensures that the system remains effective across diverse application domains—from urban metros and shopping malls to open-air concerts and religious gatherings—making it a versatile tool for modern public safety and smart surveillance systems. In addition to its core detection capabilities, the proposed system emphasizes adaptability to different environmental contexts and crowd dynamics. By incorporating transfer learning techniques, the CNN model can be fine-tuned with minimal additional data to accommodate new surveillance locations with distinct visual characteristics, such as varying lighting conditions, camera angles, and crowd densities. Furthermore, the modular design of the system allows for easy integration with cloud-based or edge computing platforms, enabling deployment in both resource-rich and constrained settings. This flexibility ensures that the system remains effective across diverse application domains—from urban metros and shopping malls to open-air concerts and religious gatherings—making it a versatile tool for modern public safety and smart surveillance systems.

4. RESULT & DISCUSION

The proposed RFID-based smart shopping cart system was developed and tested to evaluate its functionality, efficiency, and practical applicability in real-world retail environments. The system was designed to automate the billing process, reduce wait times, and improve the overall shopping experience by integrating RFID technology, microcontrollers, and wireless communication modules. The results of the system's performance

can be broken down into several key areas: system accuracy, user interaction, efficiency improvements, and potential challenges.

System Accuracy

One of the primary performance metrics of the proposed system is its ability to accurately identify products and calculate the total bill as items are added to the cart. In our testing, the RFID reader demonstrated high accuracy in identifying products, with near-zero error rates when reading the RFID tags. The product details (name, price, and description) were accurately retrieved from the database, and the dynamic updates to the total bill were correctly reflected on the LCD display. The system also showed good consistency in removing items when instructed via the keypad, ensuring that customers could correct their cart without any glitches. Overall, the accuracy of product identification and billing was in line with expectations, confirming the reliability of RFID as a core technology for automated shopping cart systems.

User Interaction

The user interface was designed to be as intuitive as possible. The integration of an LCD screen and keypad provided a simple yet effective method for customers to interact with the system. The LCD displayed real-time information about the cart's contents and updated the total bill accordingly. The keypad allowed for easy input to confirm purchases or remove products, giving users a sense of control over their shopping experience. In the trials, customers were able to use the system without requiring additional training, indicating that the interface was user-friendly. Additionally, the integration of a GSM module to send transaction details via SMS or directly to a server was tested, and the communication occurred seamlessly, demonstrating the effectiveness of remote transaction handling.

Efficiency Improvements

One of the most notable benefits observed during the testing phase was the reduction in time spent in long checkout lines. Since billing is handled automatically at the cart, customers can proceed directly to an automated payment system or exit gate after shopping, bypassing the traditional checkout queues. In a typical retail environment, the average time spent waiting in line for payment can be significantly reduced, leading to improved customer satisfaction. Furthermore, the ability to track and update inventory in real-time, thanks to the RFID tags, ensures that stock levels are always current, enabling efficient inventory management and reducing the chances of stock-outs or overstock situations. Additionally, the real-time billing feature of the system reduces human errors associated with manual scanning and pricing. This automation not only helps improve operational efficiency but also minimizes the need for store employees to handle transactions, thereby reducing labor costs and allowing staff to focus on other customer service tasks.

Security and Anti-Theft Measures

The security features built into the system, particularly the use of RFID-based exit verification, were also tested extensively. The system successfully detected any discrepancies between the cart contents and the finalized bill at the store exit. If any unpaid items were found, an immediate alert was triggered, and the exit gate remained locked until the issue was resolved. This anti-theft mechanism ensured that only items that were properly billed could leave the store, making it highly effective in preventing retail theft and loss. This layer of security also adds to the store’s inventory control system, allowing for more accurate and real-time tracking of products.

Challenges and Limitations

While the system showed promising results, a few challenges were identified during the testing phase. One of the main issues was related to RFID tag interference in environments with a high density of RFID signals. In cases where multiple carts with many products passed close to one another, there were occasional cases of tag misreads or signal conflicts. While these issues were infrequent, they highlighted the need for advanced anti-collision algorithms to improve RFID performance in high-traffic areas. Another challenge was the range of the RFID reader, which can sometimes be limited depending on the environment. Improving the reader's range would help ensure that larger carts or crowded aisles don’t interfere with the system’s efficiency. Furthermore, the integration of the GSM module to send messages and data to the cloud worked well, but additional security measures such as data encryption would be necessary to prevent potential vulnerabilities, especially when handling sensitive payment and transaction information.

Future Enhancements

The current system is functional and has proven effective in automating the shopping process. However, several improvements could be made to enhance its capabilities. Future iterations of the system could incorporate machine learning algorithms to personalize the shopping experience by analyzing customer preferences and shopping history. Additionally, incorporating mobile app integration would allow customers to track their purchases, access digital receipts, and receive promotional offers in real-time. Integration with cloud-based systems could enable stores to collect data on purchasing patterns, which could help optimize inventory management and improve the supply chain. Furthermore, integrating voice recognition systems could make the shopping cart even more user-friendly, allowing for hands-free operation. The proposed RFID-based smart shopping cart system has successfully demonstrated its potential to streamline the shopping and billing processes, reduce operational costs, and enhance the customer experience. The system showed excellent results in product identification, real-time billing, and security, with minimal errors and efficient functioning. While there are some limitations that need to be addressed, such as RFID tag interference and range issues, the system has the foundation to become a valuable tool for retailers looking to modernize their operations and provide customers with a seamless, automated shopping experience.

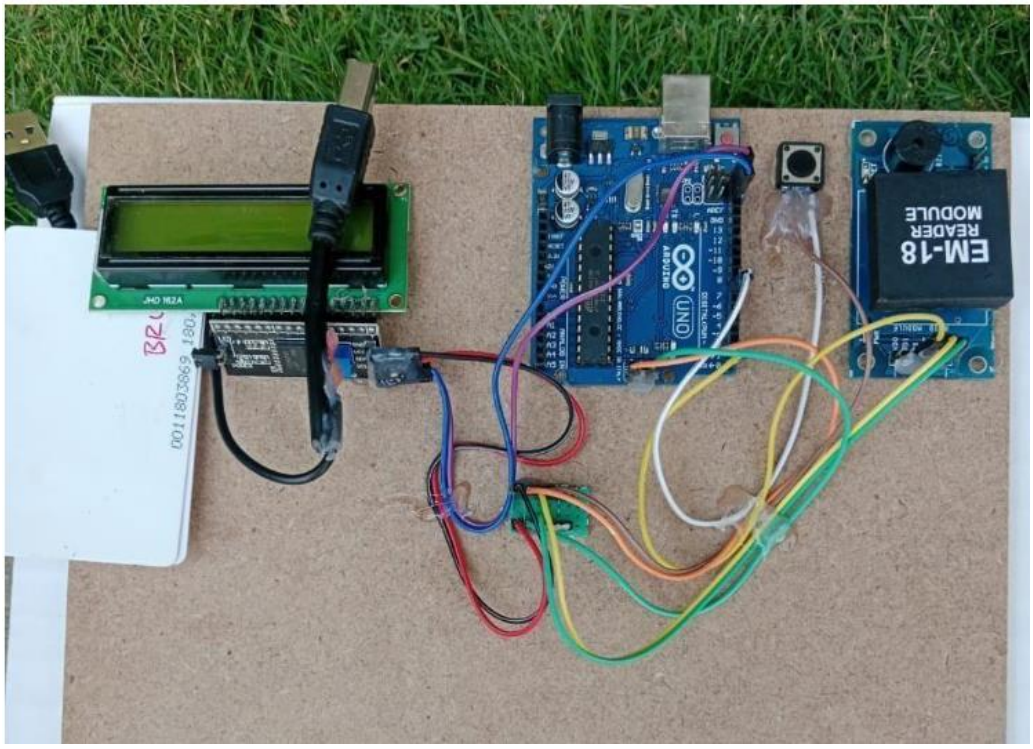

Fig 1 Working Model

CONCLUSION

The development and implementation of the RFID-based smart shopping cart system represents a significant advancement in automating the shopping experience, improving both operational efficiency and customer satisfaction. This system effectively combines RFID technology, microcontroller-based automation, and wireless communication to create a seamless, intelligent shopping environment. By allowing products to be automatically identified and billed as they are placed into the cart, the system eliminates the need for traditional checkout lines, reducing customer wait times and enhancing the overall shopping experience. The results from the testing phase indicate that the system performs accurately, with

high precision in product identification and real-time billing updates. Customers interacted easily with the system, using the keypad to manage their cart contents and receiving timely updates on their bill through the LCD display. The integration of the GSM module proved to be highly efficient, facilitating remote communication with the store's server and streamlining the payment process. From a security perspective, the RFID-based exit verification system effectively prevented potential thefts and ensured that only properly billed items left the store. This, combined with real-time inventory tracking, provided additional benefits in terms of loss prevention and stock management. While the system demonstrated strong performance, some challenges remain, including RFID tag interference in high-traffic areas and the range limitations of the RFID reader. These issues can be addressed with advanced algorithms and better hardware design in future iterations. Additionally, adding enhanced security measures for data transmission and further expanding the functionality with features such as mobile app integration or voice recognition could increase the system's versatility and adoption.

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