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IoT-Driven Smart Trolleys and Robots: Transforming Retail with Edge Computing

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ABSTRACT

Time is an expensive resource in our fast-paced society, and people frequently lose a good deal of it waiting at supermarket and shopping mall checkout counters. An automated intelligent shopping cart has been designed for supermarkets to solve the shortcomings of the current billing systems. This trolley reduces the amount of time customers spend at the checkout counter, improving convenience and saving time, by scanning products using the Atmega 328 controller and RFID tags. Customers can better their shopping experience by monitoring the amount of items and the overall cost thanks to the digital document shown on an LCD. With electronic bills sent via email and thorough purchase information available through the shop's website, the intelligent cart manages shopping and payment procedures, allowing customers to buy things and leave the store fast. In order to manage product and customer information, this system needs an Arduino board, an RFID reader, an RFID tag, an LCD display, a database manager, and a website. Leveraging the Internet of Things (IoT) for smooth connection with the worldwide network, the administrator can access this information anywhere.

Keywords: Arduino UNO; Ultrasonic sensor; IR sensor; DC motors; RFID reader; LCD display; Atmega328 controller; Motor drivers.

1. Introduction

Smart trams have successfully addressed the problem.The main objective of this initiative is to reduce the length of time that customers have to wait before they can pay their bills [1]. The pricing and billing for the items in the cart are automated. This application comprises an Arduino Uno, an LCD display, a buzzer, RFID tags, and an RFID reader. The Arduino development board used in this system has fully accessible input/output pins to enable communication with the reader. The trolley is outfitted with an RFID reader, and each product is linked to an RFID tag [2]. Once the products have been placed in the shopping cart, the RFID reader quickly deciphers the tags. The relevant information, such as the product's name, price, and quantity, is then shown on the LCD screen. The user will receive a prompt to scan the product using an automated alert system equipped with a buzzer. As a result, a bill is produced immediately on the cart. The eradication of human error is a direct result of the full automation of the process. Every day, a substantial amount of people are attracted to shopping malls in order to participate in shopping, self-improvement, and entertainment [3]. With the increasing popularity of online shopping, traditional retail stores have faced challenges in maintaining their customer base. Shopping malls have been actively seeking innovative methods to offer a customized shopping experience in order to attract and retain customers. An effective approach involves employing intelligent individuals to monitor and oversee the movement of shopping carts.

Autonomous shopping carts, which are engineered to replicate human locomotion, possess the capability to autonomously track customers, thereby obviating the necessity for them to manually propel the cart [4]. This technology provides shoppers with simplicity and convenience, enabling them to concentrate on their purchases while deriving pleasure from the experience. While a customer is making purchases, their location is monitored by an intelligent trolley that integrates numerous sensors and cameras. The utilization of intelligent shopping carts that monitor human movements provides the benefit of augmenting a customised shopping experience. Patrons are able

to effortlessly traverse the establishment, circumventing the necessity to push their shopping cart or be concerned with its misplacement. By effortlessly concentrating on the products they are interested in purchasing, they are able to dedicate more time to perusing [5].

Customers with limited mobility or disabilities get an added level of assistance from intelligent shopping carts that track and follow them. These customers may find it difficult to propel a shopping cart. Nevertheless, the intelligent trolley presents a viable resolution that holds the capacity to augment the ease and pleasure derived from the act of shopping [6]. In addition, the integration of intelligent shopping carts—which possess the capability to independently navigate and accompany customers—substantially augments the shopping experience in terms of convenience and effectiveness. Consumers are able to effortlessly locate the desired products, incorporate them into their shopping carts, and proceed to the subsequent item without the necessity of monitoring their carts. As a result, patrons are able to enhance their shopping experience through time conservation and a reduction in the customary anxiety linked to the procedure [7].

By maintaining a linear trajectory, the robot is capable of traversing the lane of shopping racks with ease. An ultrasonic sensor is additionally affixed to the front of the robotic vehicle. The sensor is utilized to determine the user's proximity to the robot [8]. The customer is monitored by the robot from a predetermined distance as they navigate the shopping lane. The system therefore recommends a sophisticated shopping cart for contemporary shopping malls. A smart shopping cart that makes use of Internet of Things (IoT) technology is the proposed concept [9]. A versatile application and Radio Frequency Identification (RFID) sensors are integrated into it. Additionally, an Arduino microcontroller is also present. RFID sensors operate via wireless transmission. The process consists of two essential elements: an RFID tag affixed to every item and a user-specific RFID reader that efficiently scans the item data. The corresponding data for each item is then displayed within the mobile application. The client effectively oversees the shopping list using the adaptable application in accordance with their personal preferences. The shopping information is subsequently transmitted remotely to the employee, who generates the charges. The primary aim of this testing framework is to eliminate arduous shopping processes and technical administration complications. Subsequently, the proposed framework may be readily deployable and verifiable in an extensive operational setting [10]. This clarifies the rationale behind the proposed model's higher level of stringency in comparison to alternative methodologies.

The integration of state-of-the-art technologies into a smart shopping cart is intended to revolutionize the traditional shopping experience in multiple ways. It optimizes operational effectiveness through the provision of user-friendly functionalities that streamline the process of item retrieval and diminish the duration of shopping [11]. Digital shopping lists, automated item scanning, and user-friendly payment methods substantially enhance convenience. By encouraging the use of reusable bags, reducing plastic waste, and informing customers about sustainable products, the cart promotes sustainability. By providing customers with real-time pricing comparisons, discounts, and promotions, cost-effectiveness is achieved and they are able to make more informed decisions. The shopping cart incorporates accessibility features that accommodate a diverse array of customers, including individuals with disabilities. Customer access to recipes, nutritional information, and personalized recommendations, while retailers gain insights into consumer behavior, purchasing patterns, and inventory management that are driven by data.

Ensuring safety through the implementation of secure locking mechanisms, RFID technology for item tracking, and hazard alarms, seamless connectivity with mobile devices is provided. Constant advancements in functionality and design ensure that the shopping cart remains at the forefront of market trends, with the ultimate goal of improving the customer experience by providing a seamless, enjoyable, and expedient journey that cultivates loyalty towards the retailer.

2. Related Works

Hadj et al. conducted a study that examines the development and deployment of a cutting-edge shopping cart that incorporates RFID technology and an intuitive interface [12]. The primary aim is to optimize the shopping experience for patrons as a whole. The authors of Kumar et al.'s "Intelligent Shopping Cart System Using RFID Technology" describe a system that provides retail stores with automated checkout, personalized recommendations, and enhanced inventory management via RFID technology. This study presents a smart trolley system that incorporates Internet of Things sensors to evaluate consumer behavior, monitor product availability, and optimize store layouts to improve customer satisfaction and operational efficiency [13]. The study [14] examines the effects of smart trolley technology on customer loyalty, purchasing behavior, and satisfaction. This underscores the advantages of real-time promotions and personalized recommendations.

The objective of this research is to present a smart shopping trolley system that incorporates RFID tags for the purpose of automating invoicing, real-time inventory monitoring, and improved operational efficiency for retail establishments. According to the findings of Li et al., consumers have the ability to conveniently utilize a smart trolley system that incorporates mobile application support in order to perform tasks such as accessing digital shopping lists, receiving product recommendations, and making payments [15]. The present research investigates the capacity of intelligent shopping carts to revolutionize the retail sector through the enhancement of customer interaction, the streamlining of store procedures, and the augmentation of revenue via customized experiences and focused advertising [16]. The system that creates an IoT-based smart shopping cart via sensor technology. Customers are granted streamlined checkout processes, location-dependent promotional offers, and up-to-date product details through this system.

The deployment of current smart shopping trolley solutions entails substantial upfront costs, including hardware, software development, and integration with existing systems, which may deter some stores from adopting them [17]. These systems can also be complex for retailers and customers, leading to confusion and frustration due to intricate interfaces, technical issues, and maintenance requirements. Limited integration capabilities with other retail systems, such as inventory management, point-of-sale (POS), and customer relationship management (CRM) platforms, can hinder seamless operations and data synchronization [18].

Privacy concerns arise as customers worry about the collection of their location, shopping habits, and other personal information, necessitating robust security measures and transparent data usage policies from retailers. Dependability issues, such as sensor malfunctions, connectivity problems, and software flaws, can negatively impact the shopping experience and erode customer trust. Scalability is another challenge, as some systems may not be easily adaptable to growing or changing retailer needs or peak shopping periods. Additionally, resistance to

change from customers and businesses can hinder widespread adoption, requiring education and awareness efforts to promote acceptance. Lastly, while smart shopping carts aim to enhance sustainability through features like reusable bags, the environmental impact of producing and disposing of their electronic components must be managed properly.

3. Proposed System

The objective of our proposed intelligent shopping cart system is to address the limitations of existing methods by maximizing advantages for both retailers and consumers. By employing cutting-edge technology and focusing on user-centered design, it improves consumer satisfaction, operational efficiency, and the overall shopping experience. Notable characteristics encompass user interfaces that are easy to understand and navigate, instructions that are clear and unambiguous, and settings that can be customized to accommodate a wide range of user requirements. RFID and sensor technology facilitate instantaneous inventory management, automated item identification, and tailored suggestions based on user preferences and previous transactions. The integration of a mobile application enables a smooth and efficient checkout process by incorporating mobile payment methods, thereby eliminating the need for traditional cashier lanes and reducing waiting periods. AI-powered algorithms utilize consumer data to provide customized promotions, pertinent information, and product suggestions that are specifically tailored to individual preferences, dietary requirements, and purchasing behavior. The system encourages environmental sustainability through reminders to use reusable bags, recommendations for sustainable product alternatives, and rewards for reducing plastic consumption. Retailers benefit greatly from comprehensive data analytics, as it offers valuable insights into consumer behavior, purchasing patterns, and inventory management.

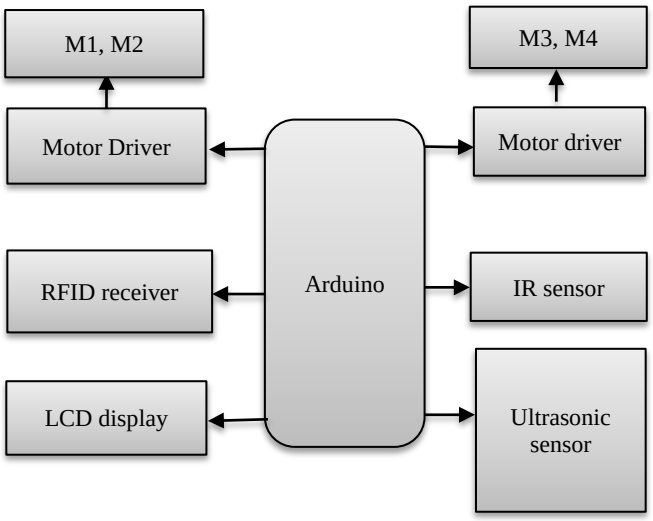

Figure 1. Block diagram

This enables retailers to make data-driven decisions and engage in strategic planning. The design of the system is scalable and modular, which means it can be easily customized, expanded, and integrated with existing retail systems. It can adapt to different store sizes, layouts, and operational requirements. Robust security protocols, such as encryption, authentication protocols, and adherence to data privacy regulations like CCPA and GDPR, guarantee

the safeguarding of customer data and the protection of transactions. Our dedication to ongoing research and development guarantees that the intelligent shopping cart system remains inventive, pertinent, and competitive in the changing retail environment.

The Arduino Uno is a microcontroller board that utilizes the Atmega328P microcontroller chip. The device's conventional design and efficient structure facilitate the prototyping and construction of electronic products, catering to users of all levels of expertise. The board is equipped with a reset button, a power jack, a USB interface for communication and programming, as well as digital and analogue input/output pins.

Liquid crystal display (LCD) screens consist of a pair of transparent electrodes, two polarizing filters, and a liquid crystal solution sandwiched between them. The manipulation of light propagation through the liquid crystal molecules enables the generation of textual content and visual representations on the screen.

The Arduino Uno is a microcontroller board that employs the Atmega328P microcontroller chip. The device's traditional design and streamlined structure enable the creation and assembly of electronic products, serving users with varying levels of proficiency. The board is furnished with a reset button, a power jack, a USB interface for communication and programming, as well as digital and analog input/output pins.

Liquid crystal display (LCD) screens are composed of a duo of transparent electrodes, two polarizing filters, and a liquid crystal solution enclosed between them. The manipulation of light propagation through the liquid crystal molecules allows for the creation of text and visual images on the screen. The Atmega328P is the microcontroller chip utilized in the Arduino Uno. The device's conventional design and efficient architecture facilitate the prototyping and construction of electronic products, catering to users of varying levels of expertise. In addition to digital and analog input/output pins, the board is equipped with a reset button, a power jack, and a USB interface for programming and communication.

Liquid crystal display (LCD) screens consist of two polarising filters with a liquid crystal solution placed between two transparent electrodes. The manipulation of light traveling through liquid crystal molecules produces textual material and graphic representations on the screen. Typically, an ultrasonic sensor consists of a transmitter and a receiver. Above the range of human auditory perception, beyond 20 kHz, the transmitter emits ultrasonic waves, also known as high-frequency sound waves. As waves traverse through the atmosphere, they rebound off objects in close proximity. The sensor subsequently gauges the duration it takes for the waves to rebound and identifies the reflected waves, thereby ascertaining the distance or existence of the object. A server motor typically consists of a gear train, a control circuit, a feedback mechanism, and a DC motor. Upon receiving a control signal, usually in the form of a pulse-width modulation (PWM) signal, the control circuit adjusts the motor to align with the desired angle. An apparatus utilized for the detection of infrared radiation is referred to as an infrared sensor. The precise location of the obstacle is determined by utilizing an infrared sensor. The motor drivers will receive a signal from the controller to initiate the motors. Subsequently, in order to detect movements in the shopping cart, it will analyze data obtained from ultrasonic receiver circuits and infrared sensors. When an individual places an item in the shopping cart, the LCD screen displays the name, price, and quantity details of the item. The RFID reader scans automatically. Typically, smart shopping trolleys are powered by a combination of a power supply and

rechargeable batteries. The power supply is commonly utilized for both the charging of batteries and the provision of uninterrupted power to onboard electronics, such as sensors, displays, and connectivity modules. This enables continuous safeguarding of functionality while also providing adaptability in navigating the store area.

3.1. Functionality and Features

Smart shopping carts frequently include integrated cameras or scanners for scanning products, allowing users to scan barcodes or QR codes and providing current product information and automated purchase tracking. These carts streamline inventory management by monitoring the items they contain, providing real-time information on stock levels, and improving the efficiency of restocking while preventing inventory shortages. Integrated displays featuring touchscreens offer customers detailed information regarding products, exclusive promotions, recipes, and the precise locations of aisles. This enhances the overall shopping experience and assists customers in making well-informed decisions. Personalized recommendations are created by analyzing scanned products or previous purchases, enabling suggestions for related items and enhancing customer satisfaction by providing opportunities for upselling. Integration of mobile payment enables customers to finalize purchases without the need to physically visit a checkout counter, thereby reducing congestion and saving time. Weight sensors guarantee precise invoicing by identifying the contents of the cart and computing the total cost immediately, assisting customers in monitoring their expenditures. Certain intelligent shopping carts are equipped with navigation systems that direct customers to specific items on their shopping lists, resulting in time savings and an improved shopping experience. Self-checkout functionality enables customers to scan and bag their items while shopping, thereby eliminating the necessity for conventional checkout counters. Security measures such as locking mechanisms or RFID technology act as deterrents against theft or unauthorized removal of items from the cart. Moreover, the analysis of data obtained from these carts offers valuable information about consumer behavior, preferences, and purchasing patterns, which can be used to improve product placement, advertising, and inventory management strategies.

4. Results and Discussion

The intelligent shopping cart signifies a notable progression in retail technology, intended to augment both the customer's experience and the retailer's operational effectiveness. This cutting-edge cart is equipped with a variety of features that together revolutionize the conventional shopping process, making it more efficient, informative, and pleasurable.

The central component of this system is the intelligent shopping cart, which incorporates multiple technological advancements to facilitate a smooth shopping experience. It functions as a platform that integrates multiple interconnected features, each playing a vital role in enhancing various aspects of shopping. A key characteristic of the smart shopping cart is its built-in display, usually in the form of a touchscreen. This exhibit offers a diverse range of interactive features and data that can significantly aid customers during their shopping excursion. The platform displays comprehensive product details, encompassing pricing, ingredients, and nutritional composition, enabling customers to make well-informed decisions. In addition, the display can showcase customized special offers and promotions that are specifically designed to cater to the customer's preferences, thereby improving the overall shopping experience. Additionally, it has the capability to offer recipe recommendations by analyzing the

contents of the shopping cart, assisting customers in optimizing their meal planning. Moreover, the display has the capability to direct customers to the precise aisles where they can locate the desired products, resulting in time savings and alleviating the annoyance of searching for items.

The cart is furnished with a product scanning unit that comprises cameras and barcode or QR code scanners. This technology enables customers to scan items in real-time as they add them to the shopping cart. The scanning unit autonomously monitors each item, delivering real-time updates on the items that have been included. This not only aids in maintaining a precise record of purchases but also offers immediate access to comprehensive product information and prices. This functionality obviates the necessity for manual scanning during the checkout process, thereby expediting the shopping experience.

The presence of weight sensors in the cart is essential for precise and immediate cost calculations. These sensors quantify the mass of items placed in the cart and establish a connection with the scanned data to avoid any inconsistencies. This system guarantees the accuracy of the total cost displayed, providing customers with a transparent view of their expenses and preventing any unexpected charges during checkout. Integrating RFID (Radio-Frequency Identification) and other sensor technologies greatly assists in inventory management and enhances anti-theft measures. RFID tags attached to products enable the shopping cart to automatically identify items without the necessity of manual scanning. This technology offers retailers immediate inventory updates, which assist in maintaining optimal stock levels and improving the efficiency of the replenishment process. Moreover, it serves as a preventive measure against theft, as objects that are not correctly scanned or labeled can activate alarms. The smart shopping cart employs artificial intelligence to provide tailored recommendations by analyzing the customer's past purchases and scanning behavior. The AI-powered recommendations can encompass supplementary items, exclusive offers, and marketing campaigns that align with the customer's preferences and dietary requirements. This feature not only improves the shopping experience by adding a personal touch, but also offers retailers chances to upsell and boost customer satisfaction.

In order to enhance the efficiency of the checkout procedure, the intelligent shopping cart incorporates integration with mobile payment systems. Customers have the option to make payments for their purchases using their smartphones directly at the cart, without having to go through the usual checkout lines. This functionality alleviates overcrowding at cash registers and greatly expedites the overall shopping experience, enhancing convenience for customers. Some smart shopping carts are fitted with navigation devices that aid customers in finding particular items within the store. These devices offer guidance and instructions, enhancing the efficiency and enjoyment of the shopping experience. This feature is especially advantageous in expansive supermarkets where locating specific items can be a time-consuming task.

The smart shopping cart effectively gathers significant data regarding shopping behaviors, inclinations, and patterns of purchase. This data is vital for retailers as it offers valuable insights that can be utilized to enhance product placement, focused advertising, and enhanced inventory management. Through the analysis of this data, retailers can make well-informed decisions that improve operational efficiency and enhance customer satisfaction. Ultimately, the smart shopping cart incorporates numerous cutting-edge technologies to establish a highly efficient,

personalized, and pleasurable shopping encounter. Interactive displays, automated scanning, AI-driven recommendations, and mobile payment options all contribute to a smooth and improved retail experience for both customers and retailers.

4.1. Future Enhancements

Upcoming developments in artificial intelligence (AI) algorithms are set to improve personalization in smart shopping carts, providing customized shopping experiences and suggestions based on real-time analysis of consumer behavior. These systems will offer customized recommendations for products, suggestions for recipes, and promotions, tailored to individual preferences and previous purchases. By integrating with virtual assistants like Google Assistant or Amazon Alexa, shoppers will be able to interact with smart shopping trolleys using voice commands. This will allow for voice-activated navigation, hands-free shopping, and instant access to product information.

Augmented reality (AR) enhancements will enhance the shopping experience by projecting digital data onto the real world. This has the potential to provide virtual try-on experiences, immersive advertising campaigns, and interactive product information. The connectivity of the Internet of Things (IoT) will play a vital role in facilitating communication between smart trolleys and retail infrastructure. This will enable various features, including enhanced product positioning, stock tracking, and replenishment procedures. Smart trolleys can be equipped with biometric authentication technologies such as fingerprint scanners or facial recognition software. This integration aims to improve convenience and security by enabling customers to securely access their financial details and personalized profiles. The inclusion of predictive analytics in smart carts will allow them to anticipate customer preferences and needs. This will enable the carts to provide real-time recommendations by analyzing data from purchase history, weather patterns, and social media trends.

The integration of robotics and automation will streamline tasks such as restocking shelves and guiding customers, resulting in decreased labor costs and improved shopping experience. Future smart trolley designs may incorporate sustainability features, such as the use of recyclable materials and energy-efficient parts. These designs may also include information about sustainable items and recycling programs, aiming to promote environmentally conscious buying practices. Integrating blockchain technology will enhance the transparency of the supply chain, offering consumers detailed information regarding the origins and ethical procurement of goods. In conclusion, smart trolleys are expected to incorporate mobile and contactless payment methods, enabling smooth transactions using digital currencies, mobile wallets, and biometric payment systems. This will minimize difficulties for customers and streamline the checkout process.

5. Conclusion

In conclusion, smart shopping trolleys represent a significant advancement in the retail industry, offering a multitude of features and benefits for both customers and merchants. By integrating modern technologies such as AI, IoT, and AR, these innovative gadgets have revolutionized the shopping experience. They not only empower customers with convenience and efficiency but also enable retailers to optimize their operations and enhance customer satisfaction. With capabilities ranging from product scanning and inventory management to personalized

recommendations and mobile payment integration, smart trolleys have become indispensable tools for modern retail establishments. As they continue to evolve and incorporate new functionalities, smart shopping trolleys are poised to further reshape the retail landscape, driving business expansion and fostering greater customer engagement.

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis and manuscript writing equally.

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