Implementation of a Human-Following Smart Trolley using RFID with Automated Product Scanning

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***Abstract*—Shopping convenience and automation have gained much priority in the retail industry, especially with the advent of RFID and IoT. This paper presents a Human-Following Smart Trolley using RFID, together with automated product scanning, to remove general shopping hassles in the form of manual handling of a cart and delay during checkout. It proposes the integration of RFID technology for authentication, real-time scanning of products, ultrasonic sensors for tracking humans autonomously, and a microcontroller-based system to handle all operations together. This trolley follows the user at a distance and detects the items that are placed inside it with the help of an RFID tag. The overall bill is projected to calculate the value of the LCD display. The implementation demonstrates the capability of the system to work autonomously in dynamic retail environments for accurate billing and efficient navigation. It cuts down shopping time while increasing customer convenience. The system design is modular; hence, it is scalable and easy to adapt for future improvements. Besides assured accuracy, the system is cost-effective, with Arduino microcontrollers, RFID modules, and ultrasonic sensors fairly inexpensive and hence suitable for small to mid-scale retail setups. The present study investigates how the combination of automation and smart technologies is enabling the redefinition of the retail shopping experience. Further development will likely focus on obstacle avoidance, machine learning for personalization, and full checkout-free capability through mobile payment integrations that will characterize smarter, efficient retail automation in the years to come.**

Index Terms - RFID, Arduino Microcontroller, Retail Automation, IoT Integration

I. Introduction

With robotization and smart technology, retail shopping gests are changing. The shift is from traditional homemade systems to largely automated intelligent results. [1] Smart retail systems are centered on making shopping more effective and accessible using technologies similar as RFID, IoT, and robotics. Some of the features these systems offer include automatic identification of products, real- time billing, and tone- navigating wagons or trolleys. [2] This change encompasses the conception of a mortal- following trolley with automated billing, therefore minimizing the work put by guests in handling trolleys and holding on time at the checkout. mortal- Following Smart Trolley with RFID Product Scanning and Billing System addresses the problems of retail stores, especially those that experience a lot of business because a client spends further time holding on for billing and to move around pushing heavy wagons. The main invention of this design lies in the integration of mortal- following capabilities with automated billing to deliver a completely flawless, hands-free shopping experience. A trolley that autonomously follows the client and uses RFID for scanning and calculating product prices will make this system much better than any other system for helping the shopping process, which will be briskly and more stoner- friendly. [3] One of the major primary objects of this design is to introduce a smart trolley that supports the robotization of two pivotal functions mortal- ensuing and billing. Some specific crucial objects are reduce homemade trouble as the shopping wain follows the client along with not having to demand the client to push through aisles. Bill robotization objectification of RFID product scanning lets the trolley directly include prices of the products within its accretive aggregate, and thus spend lower time on the checkout. effectiveness Combining the functionalities of mortal- following and bill robotization, the trolley aims to simplify the buying process, hence accelerating comfort in general and downsizing await time. Modular Functionality The design demonstrates a modular design using both ESP32 for RFID processing and billing and Arduino Uno for mortal- following and motor control, thereby making the system adaptable and scalable for farther advancements. The traditional retail terrain still largely depends on homemade shopping wagons and checkout processes. In the existing system Manual Wagons Shoppers have to manually push and control the trolley while choosing particulars. This can get arduous, especially in crowded aisles or with heavy loads. Checkout and Billing Detainments At the end of the shopping trip, guests line up for billing, where each point is scrutinized manually by a cashier or by the client at a tone- service pavilion. This process frequently results in long delay times, particularly during peak hours. Lack of robotization There's minimum robotization involved in both the product scanning and wain control processes, leading to inefficiencies and increased labor costs for stores. utmost retail outlets still do n't use smart intelligent systems that combine navigation and bill robotization. Indeed though some of the stores would have used RFID for security or force purposes, tying up the analogous RFID for client-driven billing is hardly seen. This involves a big invention occasion in filling the gap by developing a smart trolley for these purposes. Various limitations found in the existing implementation of smart trolleys for retail automation provide ample scope for improvement. Most of the systems are based on simple ultrasonic sensors for human following, which lacks precision in crowded or dynamic environments, often resulting in tracking inaccuracies. Although RFID works well for the authentication and scanning of products, it has a very small detection range of 10–15 cm and is highly susceptible to interference with metals and liquids, hence not that scalable or reliable. Most obstacle detection mechanisms are sensor-based and have not utilized advanced technologies such as LiDAR or stereo vision to perform navigation and path planning. In addition, power consumption is added, whereby many of these systems have not been optimized for energy efficiency and can therefore support very limited times of operation. Most user interfaces are bound to very basic LCDs, lacking advanced interactive features such as a mobile app companion or even voice-controlled assistance. Many more implementations use static logic and lack the machine learning necessary to enable run-time adaptation, such as user behavior predictions or enhancements of the obstacle avoidance features. In addressing these gaps, future systems may include AI-based human tracking, IoT for inventory management, and scalability through modular design. The system could also integrate renewable energy sources such as solar power and advanced interfaces using augmented reality or mobile applications, which enhance usability and efficiency. These, therefore, would turn the smart trolley into holistic scalable solutions for modern retailing, enhancing user experience and operational efficiency.

II. Literature Review

A literature survey on human-following smart trolleys with RFID-based billing has been carried out that shows several advancements in retail automation, focusing on RFID technology, human-following mechanisms, and multi-controller systems. [3] RFID has been studied widely for its efficiency in inventory management and automated billing applications. For instance, Sharma et al. (2018) utilized RFID in smart trolleys to scan products and calculate the bill instantly, thus saving time at checkout. Although this system highly reduced the complexity of making a bill, it totally failed to merge with movement, which means customers used to push the trolley. Ghatol, S. D., Jahagirdar, V. S., Kale, P (2015) also studied RFID based automated billing. In such a system, only automatic identification of the product would be done without the control of movement of trolleys and even the interactions of customers. [4]These studies show that though RFID will be properly suitable for automation of billing, applications to a completely self-service shopping process are limited

. In parallel to this, research in human-following robotics focused its efforts on the use of redundant sensors to ensure a reasonable distance from a moving target. Ultrasonic sensors have been used, for instance, for detecting human presence and to measure distance; hence these are widely used for simplistic human-following systems, as shown in Patel et al. For example, ultrasonic sensors combined with motorized control allowed the capability of robots to follow a person at safe distance by (2019). [5] However, such systems typically worked only in controlled environments and failed when subjected to crowded and dynamic conditions; here, it is challenging to maintain precision human following amidst numerous obstacles and people interfering. However, for cost-effective applications of human-following, ultrasonic sensors remain preferred. Others state that dual microcontroller systems are advantageous in multifunctional designs. Almost all previous work relies on a single-controller setup where one microcontroller manages all the tasks involved, reducing the efficiency and scalability of the system. Dual-controller setups provide modularity as well as good resource management. This project was similar in proposing a modular approach, which used ESP32 for managing RFID product scanning and billing, with Arduino Uno managing human-following and motor control. In this setup, the processing is more efficient as each controller can focus on dedicated tasks, thus less lag and more responsiveness.

One important gap in the literature is that there is no comprehensive testing in real-world retail environments. Current systems are mostly tested in controlled environments and do not consider variables such as crowded aisles, high noise levels, and mixed customer movement. Power management is another critical area that is largely overlooked; many smart trolleys and robots lack effective energy optimization, which has an impact on their suitability for prolonged use in a retail setting.

In summary, despite the fact that RFID and human-following technologies are individually promising for automating retail, few studies successfully combined these technologies into one smart trolley system. The present project fills in the identified gaps by integrating RFID-based billing with a human-following mechanism, powered by a dual-controller setup that would be better for management and efficiency. This unique combination presents a scalable and practical solution, designed for real-world retail environments, which has the potential to improve customer convenience, reduce manual labor, and streamline the shopping experience.

III. Proposed System

The proposed Human-Following Smart Trolley system is devised to overcome the drawbacks of traditional shopping by the enabling RFID-based automated billing and human-following technology. [6] The Figure 1 shows a Human

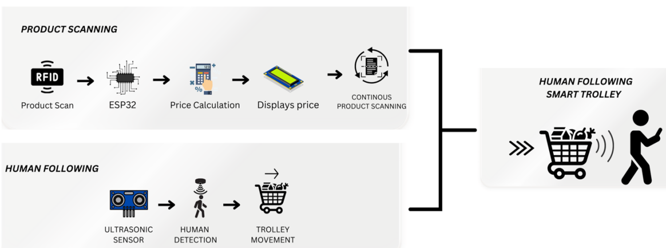

Fig. 1. Proposed Architecture

Following Smart Trolley that is engineered towards enhancing one's time for shopping. It integrates two major functionalities: scanning of products and following the human. In the scanning of products, there is the scanning of RFID-based devices, where such scanning data would be processed by an ESP32 microcontroller, thus computing the price. All these are then displayed on a screen. Continuous scanning of products ensures real-time updates. The other human following feature allows the ultrasonic sensors to capture the position of the user and permits the trolley automatically to track and follow a user. These features result in an intelligent trolley that simplifies shopping with automatic following of the user while keeping close record of the real-time cost of items. [7] In the Human-Following Mechanism, the module uses ultrasonic sensors controlled by Arduino Uno to measure the distance of the customer with the trolley. It will forward, stop, or even slow down the trolley based on the movement of the customer for an automatic experience without depending on the customer's hands. L298N motor driver allows smooth movement through the trolley with the aid of Arduino Uno by controlling DC motors. Automated Billing Using RFID is achieved by the ESP32 microcontroller that scans every product placed in the trolley through an RC522 RFID reader. As products are scanned the ESP32 reads the RFID tags, calls up the price details and other essentials of the product and this allows it to update the total bill online, which appears real-time on a 16x2 I2C LCD screen displayed on the cart.This eliminates the need for customers to go through a traditional checkout, since the total amount is available for payment. In the Modular System Design, the microcontrollers are used in a dual setup for the project to properly segregate the functionalities. ESP32 takes care of billing, scanning of products, as well as handling display functions. Arduino Uno is taken care of movement and navigation. Thus, it is ensured that each task, whatever it might be is duly managed by that respective microcontroller only, ensuring better efficiency for the system, more scalability, and easy debugging. This advanced design eliminates the tedious labor of long queues and waiting at checkout points. It, therefore, represents a complete solution for the contemporary retail scenario. It is the innovative application of the Internet of Things along with automation technologies in the retail arena, focusing on human-following functionality with an automated RFID billing system. The future version might feature more developed versions of obstacle avoidance along with mobile app integration to provide customers with a full-connected experience in shopping.

IV. Methodology

The Human Following Smart Trolley system is an IoT-driven, modular solution designed to automate shopping tasks by integrating hardware and software for autonomous movement and real-time billing. The system leverages ESP32 and Arduino Uno microcontrollers programmed with MicroPython and Arduino IDE to manage specific modules, including product scanning, billing, human-following, and movement control. [8]The product scanning module uses an RC522 RFID reader connected to the ESP32 to identify products and calculate their cost, which is displayed in real time on a 16x2 I2C LCD screen.Arduino was chosen to develop the Human Following Smart Trolley with Product Scanning as the platform is very flexible, reasonably priced, and appropriate for the conditions needed by this project. In addition, Arduino is very friendly for beginners, having vast documentation and an enormous community, which makes it easier to rapidly prototype. This ensures the cost-effectiveness of the project to keep it budget-friendly. It will have enough I/O pins that can support various components in a single PCB, including ultrasonic sensors, RFID readers, LCDs, and motor drivers. Arduino will prove to be reliable because it is a system-on-chip microcontroller board with real-time processing capabilities that are compatible with many modules; consumes low power; and it is open source.

The billing module updates the total cost dynamically as new items are scanned. The human-following module, managed by Arduino Uno and HC-SR04 ultrasonic sensors, tracks the customer's position to maintain a safe distance, enabling hands-free control. [9] The distance of the client can be measured using ultrasonic sensors HC-SR04-working based on the principle of reflection of sound waves. So basically, a sensor emits an ultrasonic pulse that travels through the air and is reflected upon hitting an object in this case, the client. This process is repeated continuously, enabling the trolley to maintain a safe following distance. The measured distance is processed by the Arduino for real-time adjustments to the trolley's movement. The movement control module uses DC motors powered by an L298N motor driver to adjust the trolley's speed and direction based on input from the human-following module. Key components such as ESP32 for

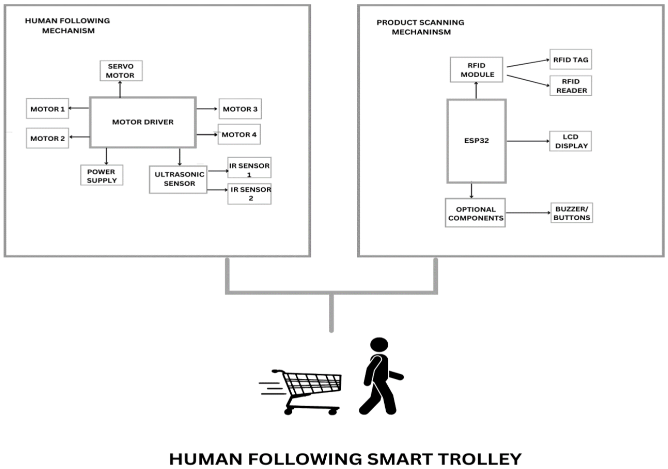

Fig. 2. Methodology Diagram

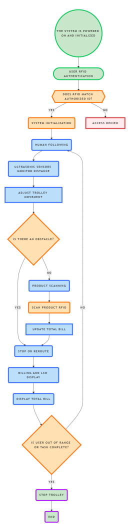

Fig. 3. Flowchart of Module

billing and display, Arduino Uno for movement and tracking, RFID readers for product identification, ultrasonic sensors for proximity detection, and DC motors for mobility ensure seamless integration and functionality. [10] Powered by a Li-ion battery pack, the system is energy-efficient, offering prolonged operation and mobility. The modular design allows independent operation of each module while enabling communication between them, ensuring scalability and ease of troubleshooting. The workflow integrates all modules, enabling the trolley to autonomously track the customer, update billing in real time, and provide a smooth shopping experience with real-time feedback through the LCD display.

V. Result and Inference

The outcome of the system shows its working and effectiveness in its different dimensions. The RFID reader reliably authenticated authorized users and denied access to unauthorized people, ensuring the trolley only responded to the desired user. [11]The human-following mechanism, implemented with ultrasonic sensors, worked effectively at constant following distance within 20–100 cm; however, smooth tracking is still experienced in controlled environments, but this sometimes gets interrupted in crowded scenarios. The obstacle detection system could effectively detect obstacles within a range of 10–50 cm and the trolley was stopped or deviated accordingly, thereby preventing any collision. Also, RFID-based product scanning worked accurately, retrieving the details of the products purchased and updating the total amount bill instantly through the LCD display. [12] The coordination between all components, RFID, ultrasonic sensors, and microcontrollers was well coordinated and proved efficient. The system was characterized as acceptable for power consumption, thus allowing multiple hours of operation without recharging. [13]Users appreciated the ease in interaction with a clear, intuitive operation of the system, particularly the real-time indication of bills. The distance of the client can be measured using ultrasonic sensors HC-SR04-working based on the principle of reflection of sound waves. So basically, a sensor emits an ultrasonic pulse that travels through the air and is reflected upon hitting an object in this case, the client. This process is repeated continuously, enabling the trolley to maintain a safe following distance. The measured distance is processed by the Arduino for real-time adjustments to the trolley's movement.

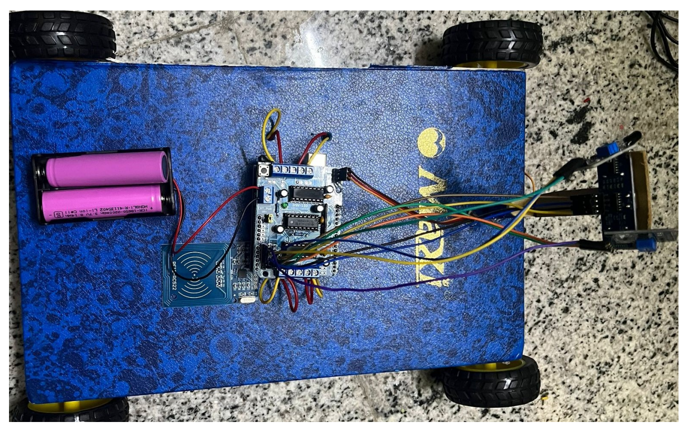

Fig. 4. prototype of the project

Product scanning evaluation of the human-following smart trolley reveals that it is viable for use as a smart product in retail automation for practical applications. The system showed operational feasibility with excellent tracking of users, obstacle avoidance, and scanning of products and thus well suitable for improving the shopping experience in supermarkets and other environments. Good accuracy in user identification and obstacle detection was achieved with the system, but performance may degrade if crowded spaces are involved. the use of low-cost components makes it cost-effective compared to commercially available alternatives, namely Arduino, RFID readers, and ultrasonic sensors. Modular design also fosters scalability for future development with advanced sensors or even machine learning capabilities that enhance tracking and

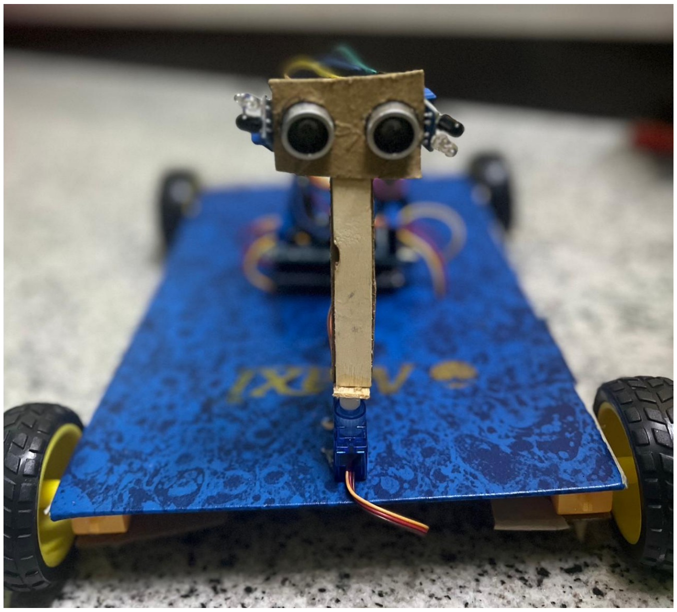

Fig. 5. model of the project

obstacle avoidance. However, future work is still necessary for developing improvements in power management and in the functionalities of the sensor range, particularly for RFID and ultrasonic sensors, to make it more robust in dynamic environments.To maneuver the Human Following Smart Trolley, DC motors are used together with a motor driver module, such as the L298N, and with inputs from the ultrasonic sensors. The Arduino would then process that distance data sent back by the ultrasonic sensors in order to conclude whether it will move forward or stop and reverse. PWM signals control the speed and direction of movement for the DC motors coming out of the Arduino motor driver. During turns, differential motor controls are utilized; that is, one motor runs or brakes a little more slowly or more quickly than the other. It is a set-up which would give smooth, responsive movement according to real-time input.

The proposed system is one of the biggest advances in improving the customer experience at the retail point of sale by combining automation and real-time billing. This trolley, designed by Arduino-based technology and RFID systems, will automatically follow the customer, scan the products bought, and compute the total bill without the intervention of the customer. The ultrasonic sensors help the trolley to detect the obstacles very effectively and therefore to navigate the crowded environment without collisions. Furthermore, the product scanning of the RFID ensures a seamless and fast shopping with respect to an automated checkout that has been proven to reduce long wait times and increase operational efficiency in retail spaces. Despite these advantages, the system has some difficulties. In particular, the range of RFID and ultrasonic sensors may impact its performance in larger or more dynamic environments, especially in very crowded areas. In addition, although it ensures low-cost automation with Arduino and basic sensors, its scalability and real-time capability can be improved through the employment of advanced technologies like LiDAR, computer vision, or machine learning to better track humans and avoid obstacles with high precision. In the future, further development of the system may include optimized battery usage, integration with mobile applications for remote control, and further advanced human detection algorithms in handling multiple customers simultaneously. These improvements could further position human-following smart trolley as a smart retail solution not only simplifying a shop but also adding to the efficiency, effectiveness, and convenience of enjoying a more modern shopping experience. Thus, in sum, although the system works well and is cost-effective, improvements in sensing capabilities and power management, as well as multi-user interaction, would increase its applicability in dynamic retail environments.

VI. Conclusion

The Human Following Smart Trolley with Product Scanning is an innovative solution in the retail shopping experience, integrating automation and smart technologies. While it serves its purpose of mitigating issues such as handling carts manually and lengthy checkouts through the usage of RFID for product scanning, ultrasonic sensors for tracking humans, and microcontroller-based operations, it has a few limitations. [14]This reliance on basic ultrasonic sensors, which most of the time fail to distinguish users or address dynamic situations, compromises tracking accuracy in more crowded environments. Similarly, the short range of detection of RFID and its susceptibility to interference result in reduced scalability and reliability across larger retail spaces. Obstacle detection mechanisms usually rely on simple sensors that often fail to handle complex or irregular objects, while power consumption is still a problem due to the limited optimization of energy. Basic user interfaces, including LCD screens, limit advanced functionalities such as personalization and seamless user interaction. However, these present a very huge opportunity for improvements. This would be further enhanced with advanced tracking technologies, such as computer vision or wearable devices, while the integration of IoT can facilitate real-time inventory management and mobile payment systems. Power efficiency concerns can be overcome by renewable energy solutions like solar panels and energy recovery systems. This could also make them more adaptable through the use of AI and machine learning in obstacle detection and personalized shopping experiences. Besides, it allows scalability through modular design, from small stores to big supermarkets. Meeting these challenges and capitalizing on the same opportunities will make the system smarter, more efficient, and future-ready, thereby redefining retail shopping experiences in this fast-changing industry. The performance of the Human Following Smart Trolley with Product Scanning can be enhanced by integrating advanced tracking technologies like computer vision or wearable devices for accurate user identification. [10]

Obstacle detection can be improved with LiDAR or SLAM for precise navigation. Energy efficiency can be optimized using renewable energy sources like solar panels and low-power components. User interaction can be elevated with mobile apps, voice control, or augmented reality for better engagement. AI and IoT integration can enable real-time decision-making, personalization, and seamless inventory management. Modular design and scalability ensure adaptability, making the system more efficient, reliable, and user-friendly.

References

[1] T. Hanooja, C. Raji, M. Sreelekha, J. Koniyath, V. M. Ameen, and M. M. Noufal, "Human friendly smart trolley with automatic billing system," in *2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA)*. IEEE, 2020, pp. 1614–1619.

[2] U. Patel, M. Aglodiya, M. Paliwal, A. Shastri, and K. Sabale, "Intelligent trolley system: Revolutionizing retail shopping," in *2024 11th International Conference on Computing for Sustainable Global Development (INDIACom)*. IEEE, 2024, pp. 772–778.

[3] R. Singh, K. Rao, R. Naik, Geetha, K. Anjali, and P. Vineeth, "Smart trolley using automated billing interface," in *2022 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC)*, 2022, pp. 1–5.

[4] S. Shankar, S. Balasubramani, S. A. Basha, S. Ariz Ahamed, and N. S. Kumar Reddy, "Smart trolley for smart shopping with an advance billing system using iot," in *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)*, 2021, pp. 390–394.

[5] Y. L. Ng, C. S. Lim, K. A. Danapalasingam, M. L. P. Tan, and C. W. Tan, "Automatic human guided shopping trolley with smart shopping system," *Jurnal teknologi*, vol. 73, no. 3, 2015.

[6] S. Shankar, S. Balasubramani, S. A. Basha, S. Ariz Ahamed, and N. S. Kumar Reddy, "Smart trolley for smart shopping with an advance billing system using iot," in *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)*, 2021, pp. 390–394.

[7] P. Chandrasekar and T. Sangeetha, "Smart shopping cart with automatic billing system through rfid and zigbee," in *International Conference on Information Communication and Embedded Systems (ICICES2014)*, 2014, pp. 1–4.

[8] M. Shahroz, M. F. Mushtaq, M. Ahmad, S. Ullah, A. Mehmood, and G. S. Choi, "Iot-based smart shopping cart using radio frequency identification," *Ieee Access*, vol. 8, pp. 68 426–68 438, 2020.

[9] ——, "Iot-based smart shopping cart using radio frequency identification," *Ieee Access*, vol. 8, pp. 68 426–68 438, 2020.

[10] T. Divya, A. Soman, and K. Abiraj, "Modelling of future automatic trolley system based on sensors and image processing guidance for supermarket," in *National Conference on Emerging Research Trend in Electrical and Electronics Engineering (ERTE'19)*, 2019.

[11] S. N. Joshi, V. K. Patki, P. S. Dixit, and H. Bhaldar, "Design and development of human following trolley," *International Journal of Innovative Science and Research Technology*, vol. 4, no. 4, 2019.

[12] E. Barkan, D. M. Handshaw, R. Sanders, T. E. Wulff, and M. Drzymala, "Product scanning systems," Mar. 8 2022, uS Patent 11,270,283.

[13] M. Kumar, J. Singh, and V. S. Anju, "Smart trolley with instant billing to ease queues at shopping malls using arm7 lpc2148: a review," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 8, pp. 39–42, 2015.

[14] D. Ryumin, D. Ivanko, A. Axyonov, I. Kagirov, A. Karpov, and M. Zelezny, "Human-robot interaction with smart shopping trolley using sign language: data collection," in *2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*. IEEE, 2019, pp. 949–954.