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TechTrolley-enhancing the retail experience

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ABSTRACT

In the modern era, convenience and efficiency have become essential aspects of daily life, and grocery shopping is no exception. The traditional shopping experience, characterized by long queues and time-consuming checkout processes, can be frustrating and inefficient. To address these challenges, the TechTrolley has emerged as an innovative solution, leveraging Bluetooth and radio frequency identification (RFID) technology to revolutionize the grocery shopping experience. With the help of TechTrolley, customer can seamlessly complete the shopping by scanning and purchasing the products, controlling the trolley with the use of controller integrated in application, getting details of the products and price in the application and over LCD display embedded on the trolley, complete the checkout process at billing counter. With the need to implement, we need an RFID tag, ESP32, LCD display, L298N motor driver and battery to implement the motion features of a trolley, database for storing the user and product details, a bridge network through router to establish the network between admin, user and the trolley in order to invoke the real time updates.

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1. INTRODUCTION

The traditional grocery shopping experience is often hindered by long queues, manual billing errors, and inefficiencies that frustrate customers. Despite advancements in retail technology, significant gaps remain in streamlining the checkout process and enhancing the overall shopping experience. Existing solutions have focused on product scanning techniques such as radio frequency identification (RFID), barcodes, and quick response (QR) codes, with improvements in automated billing systems and theft prevention methods. However, these systems often lack comprehensive integration, leading to unresolved issues in operational efficiency, data integrity, and user convenience.

The integrated smart trolley system utilizing Arduino Nano and RFID for automated billing, enhanced by weight sensors to verify item placement. The integration of Arduino microcontrollers allows seamless communication between components, while internet of things (IoT) enables real-time data transmission and remote monitoring. Limitations include scalability issues, potential RFID misreads, dependency on weight sensor accuracy, and higher costs due to additional hardware [1]. Mundada *et al.* [2] proposes smart trolley system enhanced with load cell technology for improved item detection and billing accuracy, controlled by Arduino. Some of the disadvantages include high dependency on load cell calibration, potential mechanical failures, increased system complexity, and higher maintenance requirements.

Smart trolley system using Raspberry Pi and cloud-integrated wireless sensor networks to enhance shopping experiences via IoT. Network dependency, potential latency issues, data privacy concerns, and higher setup costs due to cloud integration can deteriorate the operational efficiency of the system [3].

RFID-based automatic billing trolley system, Perumal *et al.* [4] streamline the supermarket checkout process. Limitations include RFID tag collision, limited reader range, potential interference from other electronics, and security concerns regarding RFID data. This research outlines an IoT-based smart shopping trolley that uses various sensors and IoT technologies for an improved shopping experience and automated billing [5]. System that employs QR code mapping for position localization, combined with computer vision and IoT for enhanced functionality. Limitations include dependency on camera accuracy, potential QR code scanning issues, higher computational requirements, and real-time processing challenges [6]. IoT-based smart shopping trolleys with automated billing and item detection features to enhance shopping convenience. Limitations include dependency on mobile apps, potential system failures, high implementation costs, and integration challenges [7], [8]. Smart trolleys aimed at preventing theft and ensuring social distancing, along with integrating LPG level monitoring for safety. Limitations involve high initial costs, potential privacy concerns, dependency on continuous monitoring, and integration complexity [9]-[11].

Human-friendly smart trolleys with automatic billing and e-health integration, aiming to enhance shopping efficiency and overall experience. Additionally, mobile applications linked to these trolleys provide online shopping options, product availability updates, and streamlined payment processes, catering to both in-store and remote shoppers. Various studies have implemented RFID readers and infrared (IR) sensors to track product addition and removal, improving both security and convenience. The use of RFID and ZigBee technology has been utilized to create shopping cart frameworks that automatically track and charge items for clients, and a framework utilizing a Raspberry Pi device, barcode scanner, and LCD display has been implemented to automate sales, especially during peak times Yadav *et al.* [12], Hanooja *et al.* [13]. Anand *et al.* [14] present a smart trolley that follows lines using RFID technology, with a focus on navigation and tracking capabilities enhanced by Mecanum wheels for improved movement [15]. Naveenprabu *et al.* [16] discuss an IoT-enabled smart trolley system featuring RFID and Bluetooth for automated billing, direction control, obstacle avoidance, and integration with an Android app. Perarasi *et al.* [17] introduce a smart billing trolley that uses IoT technology, incorporating RFID, LCD displays, and limitations include dependence on internet connectivity, potential direction control failures, complexity in integration, and higher costs due to additional hardware. “Cartsmart,” a trolley that follows customers using RFID and a Raspberry Pi, displaying information on an LCD to enhance the shopping experience [18]. Patel *et al.* [19] propose an advanced trolley system for retail shopping, utilizing RFID and sonar navigation to follow users and avoid obstacles while maintaining data privacy. An artificial intelligence (AI) based trolley for assisting visually impaired shoppers, incorporating RFID, Bluetooth, and object recognition for improved shopping assistance [20]. Gadgay *et al.* [21] create a smart shopping trolley that uses RFID, Bluetooth, and Arduino UNO for automated movement, displaying information on an LCD. Sutagundar *et al.* [22] describe an IoT-based system for shopping malls, employing RFID, ESP8266 Wi-Fi, and a central billing unit to enhance the shopping process. Mobile autonomous robotic trolley for shopping malls, featuring RFID detection and alerts for expired products [23]. Devipriya *et al.* [24] develop a smart store assistant for visually impaired customers, combining RFID technology and a smart glove with Bluetooth for enhanced shopping navigation. Smart shopping cart equipped with IoT capabilities and a robotic arm, using RFID and a node MCU controller for efficient navigation and item management, facing challenges like robotic precision, mechanical failures, and high costs [25].

Challenges remain with the TechTrolley system, particularly with RFID reliability in cluttered environments and potential Bluetooth connectivity issues. Existing system possess the capability of storing the limited records and also the security of the system is not upto the mark. The system also lacks scalability for large inventories and integration with existing store systems. Future improvements could address these by enhancing the database accessibility of the information of users being stored, making the contactless payments can play a vitol role in giving the optimized services. Also the use of latest technologies in terms of database manipulation in order to create, update and access the TechTrolley which increases the operational efficiency of the system. Considering all the limitations being analyzed and the TechTrolley interprets the use of API through which the updates can be done within a second. Network devices such as router can be used as to establish the local connection between the user, admin and the trolley, utilizing the mean of connection-less services. This system introduces a local server for secure user registration and checkout, real-time API updates, and an automated cart management system using a servo motor.

2. METHOD

TechTrolley system begins with defining system requirements and designing the architecture, as depicted in the provided diagram. The key components of the system include the ESP32 microcontroller, RFID reader, Bluetooth module, LCD display, buzzer, motor driver, and servo motors. The hardware setup involves meticulous wiring and integration of these components to ensure seamless operation. While implementing the TechTrolley, ensuring the right use of hardware component can lead to the better solution.

2.1. System architecture

ESP32 microcontroller acts as the central controller, receiving inputs from the RFID reader and Bluetooth module and sending commands to the motor driver, servo motors, LCD display, and buzzer. RFID reader configured to automatically detect RFID tags attached to products, allowing for quick and efficient item scanning. Bluetooth module facilitates communication between the ESP32 and an Android smartphone, enabling remote control of the trolley via a dedicated app. LCD display: shows real-time information, including scanned items and user messages, enhancing the user experience. Buzzer provides auditory feedback when products are scanned. Motor driver and servo motors control the trolley's movement and the opening/closing of the cart for product addition/removal. Local server stores and manages user information, product lists, and purchase histories. Android application interfaces with the trolley for control and real-time updates. As shown in Figures 1 and 2, the TechTrolley system architecture comprises ESP32, RFID, and Bluetooth modules, integrated for efficient functioning as general components and circuit diagram.

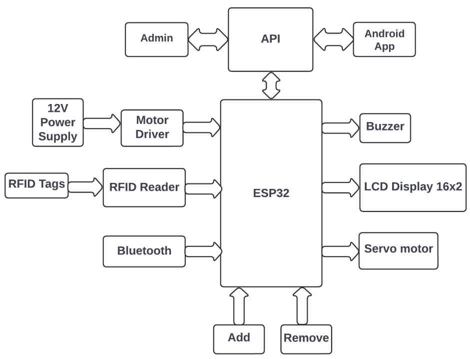


Figure 1. General components

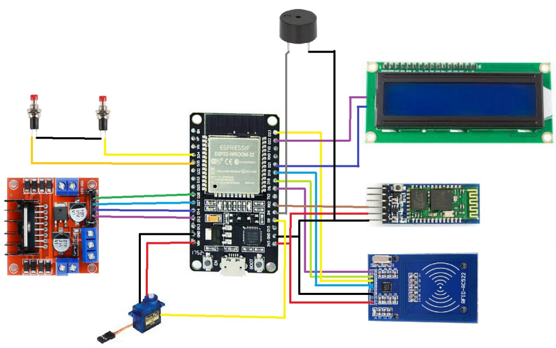


Figure 2. Circuit diagram

The TechTrolley system incorporates a comprehensive array of hardware components meticulously integrated to enhance the shopping experience. At the heart of the system is the ESP32 microcontroller, serving as the central processing unit. The ESP32 is chosen for its versatility, combining Wi-Fi and Bluetooth capabilities, which are essential for real-time communication and control. This microcontroller manages data from various sensors and controls the movement of the trolley. As shown in Figures 3 to 5, the system hardware includes the ESP32 microcontroller, L298N motor driver, and HC-05 Bluetooth module.

Each user is assigned a unique RFID card, which initiates the shopping process by interacting with the RFID reader integrated into the system. The RFID reader, capable of reading both passive and active tags, ensures efficient and accurate tracking of items placed in the trolley. This reader can scan tags without requiring direct line-of-sight, enhancing user convenience and operational efficiency.

L298N motor driver module can drive up to four DC motors or two DC motors with directional and speed control, thanks to its L298 motor driver IC and 78M05 5V regulator. The motor driver receives commands from the ESP32, facilitating smooth and responsive navigation of the trolley. This setup is powered by a robust battery module, ensuring all components function seamlessly throughout the shopping process.

The HC-05 Bluetooth module plays a crucial role in facilitating duplex communication between the user's mobile device and the trolley. This module allows users to control the trolley's movements through a dedicated mobile application, providing commands such as forward, backward, or turning directions. The real-time interaction between the user and the trolley is further enhanced by a 16x2 LCD display mounted on the trolley. Initially displaying a "waiting for user" message, the LCD screen transitions to a personalized welcome message once the user scans their RFID card. It continues to update the user with details of scanned products and the total cost, ensuring constant awareness of their shopping progress. Additionally, the system includes a buzzer for auditory feedback when products are scanned, and two buttons for incrementing or decrementing product counts in the cart. A servo motor is used to control the cart's opening and closing mechanism, adding another layer of convenience for the user. All these components are networked through a local server that stores and manages user information, product lists, and purchase histories. This server ensures continuous data synchronization with the mobile application via an API, providing a cohesive and user-friendly shopping experience. The integration of these diverse yet complementary hardware components is pivotal in realizing the efficient and innovative functionality of the TechTrolley system.

Figure 3. ESP32 microcontroller

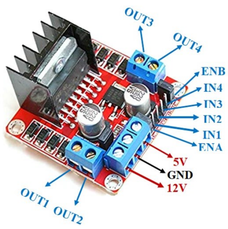


Figure 4. L298N motor driver

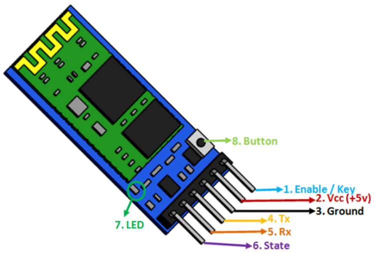


Figure 5. HC-05 Bluetooth module

2.2. Working environment

The PostgreSQL database environment is the backbone of data management in the smart shopping trolley system. Figure 6 ensures that the database is hosted locally and configured to ensure secure and efficient data retrieval. The database is structured to handle various entities, including users, products, and transaction records. Tables are created for each entity, with fields corresponding to attributes such as user ID, product ID, timestamps, and transactional data. The database is hosted locally and configured to ensure secure and efficient data retrieval, insertion, and updates. The use of SQL queries enables precise control over data interactions, supporting complex operations such as product lookup, user verification, and checkout processing.

The flask framework was employed for developing the API, which acts as the intermediary between the user interface and the backend database. The API endpoints, shown in Figure 7 are designed to handle HTTP requests for various operations, including user authentication, product scanning, and transaction completion. The Android application, serving as the user interface, interacts with these API endpoints to display relevant information on the user's device. The UI is crafted to be intuitive, guiding users through the shopping process with real-time updates on product details, cart contents, and total cost. The seamless integration of the API with the UI ensures that data flows smoothly between the trolley, user devices, and the admin system.

Code uploaded over ESP32 Through Arduino IDE The ESP32 microcontroller is programmed using the Arduino IDE, which provides a user-friendly environment for writing and uploading code. The code uploaded to the ESP32 is responsible for managing the trolley's operations, including motor control, RFID scanning, and Bluetooth communication. The Arduino IDE allows for easy integration of libraries and modules, enabling the ESP32 to interact with various hardware components efficiently. The code is structured in a way that ensures the trolley responds promptly to user inputs and operates autonomously when required. Debugging and iteration through the Arduino IDE also allow for rapid testing and refinement of the trolley's functionalities.

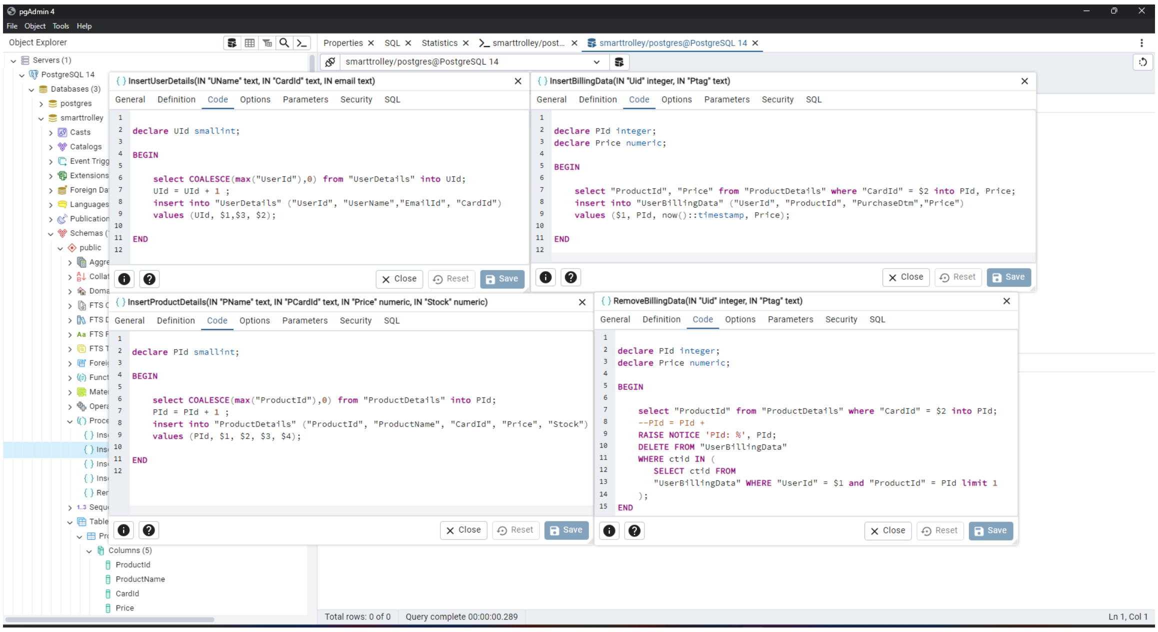


Figure 6. Database setup

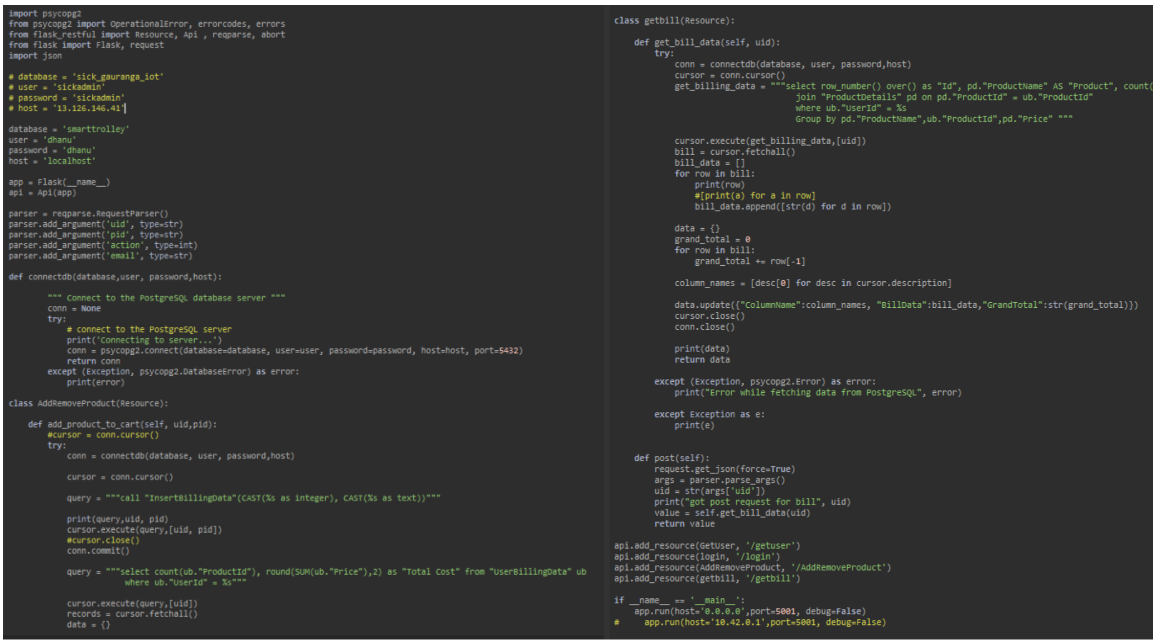


Figure 7. API configuration

A bridge network setup is implemented to ensure that all devices within the system such as the admin computer, user device, and trolley are connected over the same local network. This setup is crucial for maintaining real-time communication between devices, especially when multiple trolleys and user devices are active simultaneously. The bridge network allows for seamless data exchange between the mobile application, the server hosting the API, and the ESP32 microcontroller. Configuring the network to support both wired and wireless connections ensures flexibility in deployment, while maintaining the stability and speed required for the system to function effectively in a dynamic shopping environment. Figure 8 illustrates the process of user connection and the checkout system integrated within the mobile application.

The TechTrolley begins with the user logging into the mobile application using their IP address and email. This step initiates the connection between the user's mobile device and the trolley. Once logged in, the user is prompted to turn on Bluetooth on their device. The application then displays a list of available devices, from which the user selects the "HC-05" Bluetooth module associated with the trolley.

The system checks for a successful connection between the mobile device and the trolley. If the connection fails, the user is prompted to retry. Upon a successful connection, the system displays a "connected successfully" message on the application, indicating that the trolley is now ready for operation.

Figure 8. User connection and checkout

With the Bluetooth connection established, the user can begin shopping by scanning items using the RFID reader mounted on the trolley. Each scanned item is automatically added to the user's cart, with the details updated in real-time on the mobile application. The user can control the trolley's movement through the application, allowing for smooth navigation while shopping. The app provides a list of all items added to the cart, giving the user a clear overview of their shopping progress. Once the user completes their shopping, they proceed to checkout by clicking on the "checkout" button within the application. The system then prompts the user to scan a QR code at the checkout counter, which retrieves the total amount due for the purchased items. This method ensures a seamless and efficient shopping experience, integrating RFID-based product scanning, Bluetooth-controlled trolley movement, and real-time data synchronization between the trolley and the mobile application.

3. RESULTS AND DISCUSSION

3.1. System implementation and optimization

The implementation of the TechTrolley system in Figure 9 has yielded several significant results. The use of ESP32 and wireless bridge network establishment within the hardware and software, facilitated by API communication, has greatly enhanced the retail experience. These advancements have led to optimized shopping processes, reduced time constraints, and improved user comfort.

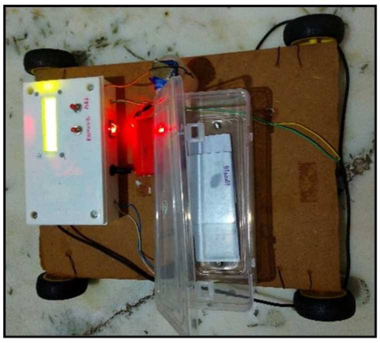
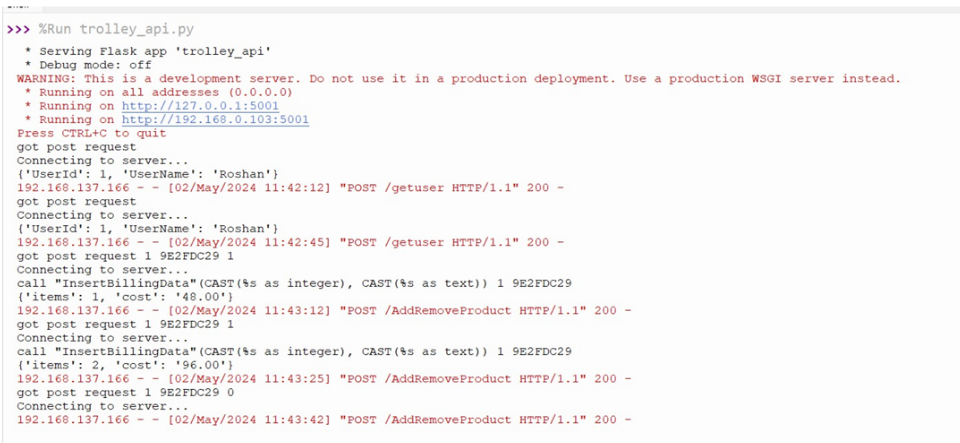


Figure 9. TechTrolley

The advantages of smart trolleys are evident. They facilitate faster checkout times by eliminating the need for manual scanning of each item, thus reducing queues and errors such as double charges [3], [4]. Real-time inventory management in Figure 10 enables stores to gain insights into customer behavior and product trends, which helps in optimizing inventory and improving store layout [7], [8]. Additionally, the system enhances accessibility for people with limited mobility [9].



```
>>> %Run trolley_api.py
 * Serving Flask app 'trolley_api'
 * Debug mode: off
WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
 * Running on all addresses (0.0.0.0)
 * Running on http://127.0.0.1:5001
 * Running on http://192.168.0.103:5001
Press CTRL+C to quit
got post request
Connecting to server...
{'UserId': 1, 'UserName': 'Roshan'}
192.168.137.166 - - [02/May/2024 11:42:12] "POST /getuser HTTP/1.1" 200 -
got post request
Connecting to server...
{'UserId': 1, 'UserName': 'Roshan'}
192.168.137.166 - - [02/May/2024 11:42:45] "POST /getuser HTTP/1.1" 200 -
got post request 1 9E2FDC29 1
Connecting to server...
call "InsertBillingData"(CAST(%s as integer), CAST(%s as text)) 1 9E2FDC29
{'items': 1, 'cost': '48.00'}
192.168.137.166 - - [02/May/2024 11:43:12] "POST /AddRemoveProduct HTTP/1.1" 200 -
got post request 1 9E2FDC29 1
Connecting to server...
call "InsertBillingData"(CAST(%s as integer), CAST(%s as text)) 1 9E2FDC29
{'items': 2, 'cost': '96.00'}
192.168.137.166 - - [02/May/2024 11:43:25] "POST /AddRemoveProduct HTTP/1.1" 200 -
got post request 1 9E2FDC29 0
Connecting to server...
192.168.137.166 - - [02/May/2024 11:43:42] "POST /AddRemoveProduct HTTP/1.1" 200 -
```

Figure 10. Real-time updates

3.2. Results analysis

3.2.1. Performance metrics

The TechTrolley system's performance was evaluated based on several metrics including checkout speed, accuracy, and user satisfaction. The automated checkout process demonstrated a significant reduction in checkout time compared to traditional methods. Accuracy improvements were noted with fewer scanning errors and reduced double charges.

3.2.2. User experience

User feedback indicated a high level of satisfaction with the system's usability and the convenience of automated processes through Figure 11. However, some users encountered challenges during the initial setup, which suggests the need for improved user guides and support.

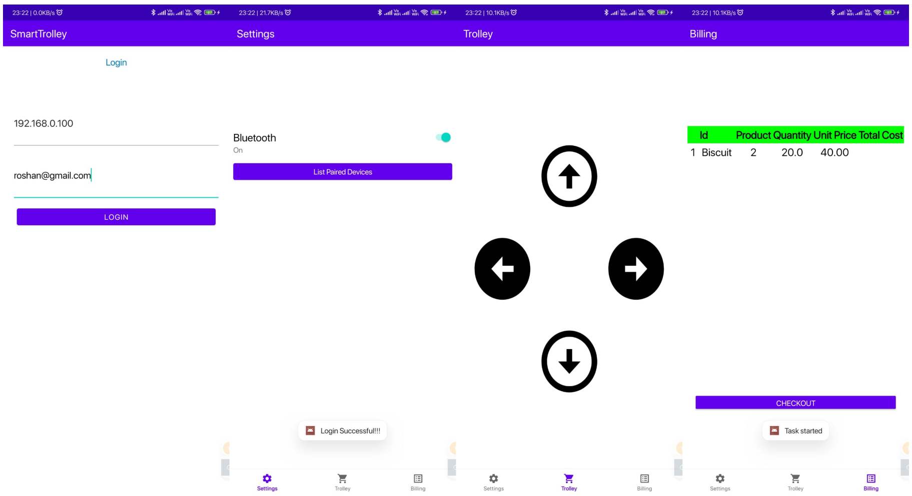


Figure 11. User login and connectivity

3.3. Key findings and interpretations

TechTrolley demonstrates several advancements and improvements over previous studies, particularly in terms of user interface as shown in Figure 12, hardware integration, and data management.

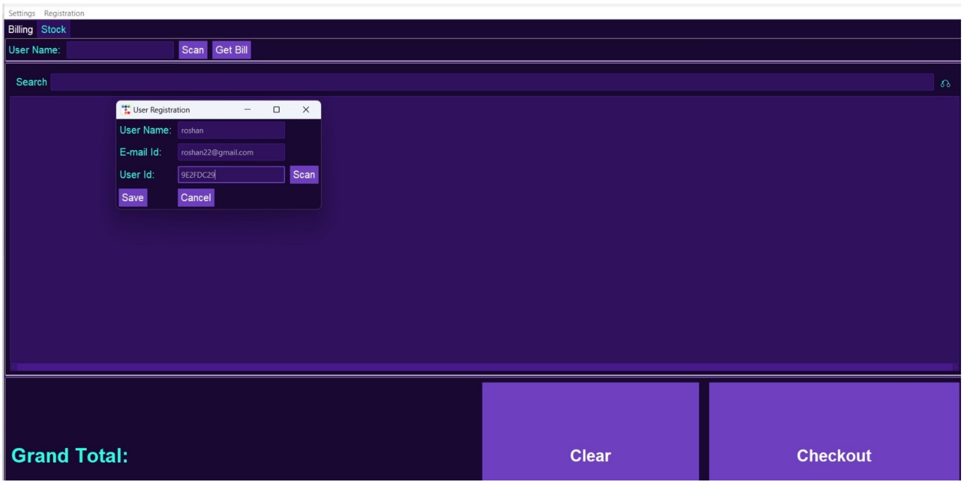


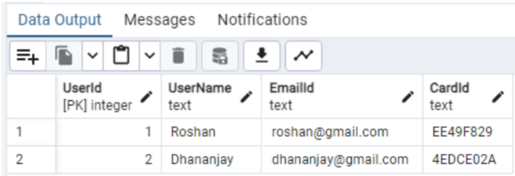
Figure 12. User registration interface

3.3.1. Enhanced user interface and experience

Unlike the RFID-based intelligent trolley system, which relies on ZigBee communication, TechTrolley utilizes a modern Android application with Bluetooth connectivity. This approach simplifies the interaction process and provides real-time updates, offering a more intuitive interface for users. Figure 8 illustrates the user-friendly nature of the TechTrolley app compared to the previous ZigBee-based systems, which were limited in range and user interaction.

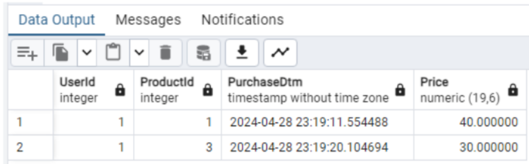
3.3.2. Improved data management

The use of PostgreSQL for database storage, as visualized in Figures 13 and 14, represents a significant improvement over traditional methods used in earlier projects. This advancement allows for more scalable and reliable data management, addressing the limitations of previous systems that used less sophisticated database solutions, and includes user registration and user billing.



	UserId [PK] integer	UserName text	EmailId text	CardId text
1	1	Roshan	roshan@gmail.com	EE49F829
2	2	Dhananjay	dhananjay@gmail.com	4EDCE02A

Figure 13. User registration



	UserId integer	ProductId integer	PurchaseDtm timestamp without time zone	Price numeric (19,6)
1	1	1	2024-04-28 23:19:11.554488	40.000000
2	1	3	2024-04-28 23:19:20.104694	30.000000

Figure 14. User billing

3.3.3. Checkout system

The implementation of QR code scanning for checkout in TechTrolley, as illustrated in Figure 15, offers a more advanced and secure method compared to earlier systems that relied on manual or less automated checkout processes. QR codes are better than barcodes because they can store significantly more data and are readable from any angle. This feature not only speeds up the checkout process but also enhances security and accuracy.

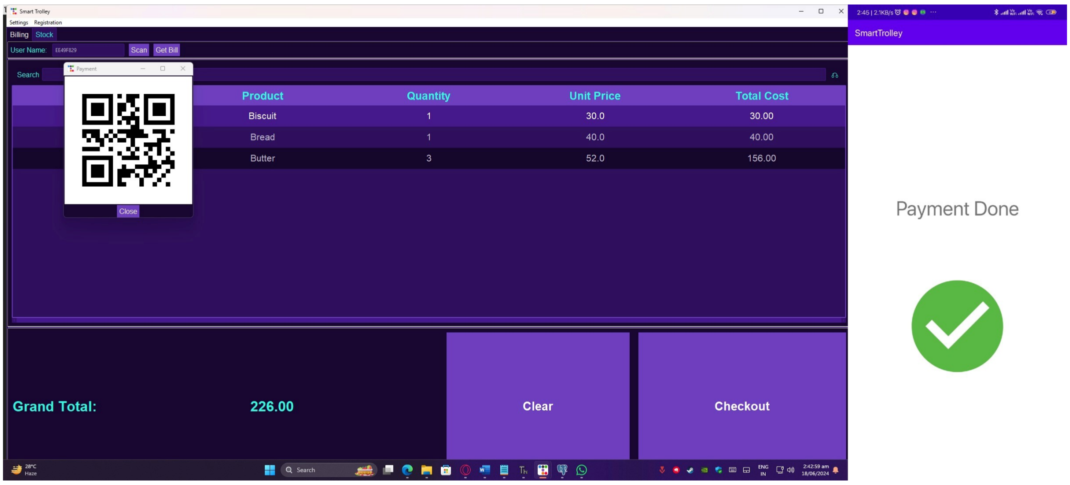


Figure 15. Checkout system

3.4. Summary and implications

The integration of ESP32 and wireless technology in TechTrolley has demonstrated significant improvements over existing smart trolley systems by enhancing efficiency in checkout processes and providing a more intuitive user experience. This system leverages real-time data management and automation, addressing key issues found in previous solutions. However, challenges such as initial setup costs and the need for robust network infrastructure persist. Future research should aim to mitigate these limitations by exploring cost-effective strategies and refining the user interface to further enhance engagement and satisfaction. The study's implications suggest that TechTrolley could be a pivotal advancement in retail technology, offering a more streamlined shopping experience with the potential for widespread adoption as these challenges are addressed.

4. CONCLUSION

The implementation of TechTrolleys marks a significant advancement in the retail sector, seamlessly integrating physical and digital shopping experiences. These technologically advanced carts, equipped with features like automated checkouts, real-time inventory tracking,greatly enhance the efficiency and convenience of the shopping process. The integration of IoT technology has not only improved the overall customer experience but has also optimized stock management, benefiting both retailers and consumers.

The implications of TechTrolley's success are profound, suggesting a future where shopping becomes increasingly personalized and connected. As consumer expectations continue to evolve, future iterations of TechTrolleys could offer even more tailored shopping experiences, with integration into smart home systems and mobile apps providing a seamless, synchronized experience. Additionally, the potential for incorporating environmental sustainability features, such as smart waste sorting and eco-friendly packaging alerts, aligns with the growing emphasis on responsible consumption.

Furthermore, the scope of TechTrolley extends beyond traditional retail environments, with potential applications in warehouse management and logistics. Future research and development should focus on enhancing these systems to anticipate and meet individual preferences, address initial setup costs, and explore sustainable innovations. Ultimately, the findings from this study indicate that TechTrolleys are not just a step forward in retail technology but also hold the potential to reshape consumer interactions in the digital age.

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