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Smart Trolley Billing System

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Abstract

The Smart Trolley Billing System is an advanced automation solution designed to enhance retail efficiency by integrating IoT, embedded systems, and real-time data processing. Utilizing a GROW GM65 Barcode Scanner Module, Raspberry Pi 4, and a Capacitive Touchscreen display, the system streamlines checkout by capturing product data, dynamically updating a preloaded SQLite database, and displaying an itemized bill in real-time. Its Python-based software stack ensures efficient barcode processing, database management, and UI interactions, while edge computing principles minimize processing latency. Additional technical advantages include RFID compatibility, NFC-based payment integration, cloud connectivity for remote inventory tracking, and AI-powered demand forecasting. The system's low-power architecture and modular scalability make it suitable for diverse retail environments, reducing labor costs and operational inefficiencies while enhancing the customer experience through seamless, contactless transactions. This project exemplifies how automation and IoT integration can revolutionize conventional retail shopping.

Keywords: Smart trolley, IoT, embedded systems, edge computing, barcode scanner, cloud integration, AI forecasting, contactless transactions

INTRODUCTION

The evolution of the retail industry from traditional manual billing to automated checkout solutions has been driven by technological advancements and increasing consumer expectations. The limitations of manual checkout systems, including long queues, billing errors, and high labor costs, necessitate the adoption of intelligent, automated alternatives. While Radio Frequency Identification (RFID) was initially explored as a potential solution, issues such as high infrastructure costs, signal interference, and scalability challenges have hindered its widespread adoption.

Modern research emphasizes the viability of barcode-based systems combined with IoT and embedded computing to enhance automation and reduce manual intervention. The Smart Trolley Billing System presented in this work leverages a Raspberry Pi 4-based architecture, integrating a Wave share Barcode Scanner and a capacitive touchscreen display to create an interactive and efficient retail experience. Unlike traditional checkout methods, this system enables real-time barcode scanning, database retrieval, and automatic bill computation using an optimized Python-based software stack.

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The novelty of this work lies in its real-time data processing architecture, edge computing optimization, and seamless integration with potential cloud-based analytics. The proposed system reduces reliance on human-operated billing counters, offering a contactless, low-latency, and scalable alternative for diverse retail environments. Furthermore, it introduces modular expansion capabilities, allowing future integration with AI-driven demand forecasting, NFC-based payment systems, and blockchain-backed transaction security.

This study aims to establish a technically robust, scalable, and efficient solution by presenting an original, data-driven methodology for implementing automated billing in retail. By addressing existing challenges with a cost-effective, low-power, and high-speed embedded system, the work sets a foundation for future innovations in smart retail automation. Additionally, to support the claims and strengthen the technical soundness of the presented research more detailed investigations are required.

LITERATURE REVIEW

The evolution of smart trolley billing systems has been marked by continuous advancements in automation, sensor integration, and real-time data processing. Various approaches have been proposed, leveraging technologies such as RFID, IoT, AI, barcode scanning, and QR code processing to enhance the efficiency and convenience of retail shopping. While RFID-based systems facilitate seamless item detection and automated billing, their adoption is hindered by high implementation costs and signal interference. IoT integration offers enhanced functionalities such as inventory tracking and autonomous navigation but increases system complexity. Barcode and QR code-based solutions provide cost-effective alternatives that align well with existing retail infrastructure. The increasing integration of AI in smart trolley systems also paves the way for advanced features such as personalized recommendations, real-time analytics, and predictive inventory management. This literature review critically analyzes previous works on smart trolley systems, highlighting their strengths, limitations, and potential for further research and innovation.

RFID-Based Smart Trolley Systems

Smart Shopping Trolley with Automated Billing using AI (2024)

This study explores the integration of AI algorithms with smart trolley systems, enabling automated checkout and personalized recommendations. By leveraging AI-powered image recognition, the system identifies products and updates the virtual shopping cart in real time. The study highlights AI's role in enhancing inventory management, dynamic pricing, and predictive analytics [1].

RFID-Based Smart Trolley for Automatic Billing System (2023)

This study explores RFID technology for item detection and billing, emphasizing its benefits in streamlining inventory management and reducing checkout time. However, the study identifies challenges such as high deployment costs and interference in large-scale retail environments [2].

IoT-Based Smart Trolley System for Automated Billing Using RFID (2023)

Integrates IoT and RFID for real-time billing and inventory updates. The system includes ultrasonic sensors for autonomous navigation. Despite its advantages, high initial setup costs and connectivity challenges limit adoption [3].

Barcode and QR Code-Based Systems

Smart Shopping Trolley with Automated Billing System (2025)

This research presents a QR code-based smart trolley system using ESP32Cam modules and a central billing system. The system updates the digital cart in real-time and displays product information on a touchscreen interface. The QR-based approach significantly reduces implementation costs compared to RFID alternatives while maintaining efficient inventory tracking [4].

Automated Shopping Trolley for Billing System (2021)

This study implements barcode scanning with Raspberry Pi and LCDs for billing automation. It integrates load cells for weight detection to prevent billing discrepancies. The cost-effectiveness of this system makes it viable for mid-scale retail settings [5].

Development of an Improved Automated Shopping Trolley Payment System (2021)

This research introduces a barcode-based trolley system integrated with weight sensors to prevent fraud. The study emphasizes real-time billing updates and queue reduction at checkout counters.

Smart Shopping Trolley Using Raspberry Pi (2020)

This system leverages Raspberry Pi and barcode scanners to provide a cost-effective, user-friendly shopping experience. It features load cells for theft prevention and weight verification. However, the reliance on barcode scanning limits scalability for large retail environments [6].

Hybrid Systems Integrating IoT and AI

Intelligent Shopping Cart with Automatic Product Detection and Secure Payment System (2019)

A multi-component system integrating Arduino, RFID, fingerprint sensors, and GSM modules for secure and automated billing. The study discusses usability challenges such as fingerprint hygiene concerns and SIM-based maintenance costs [8].

AI-Based Smart Trolley System for Automated Shopping (2024)

This research presents an IoT-enabled smart trolley integrated with AI for real-time purchase tracking and dynamic pricing. AI-driven analytics optimize inventory management and provide personalized shopping experiences [9].

Smart shopping trolley using Arduino UNO (2024)

Proposes an RFID-based system featuring LCD-equipped shopping carts that display the total bill dynamically. The system enhances the checkout process but is constrained by scalability issues in high-traffic retail environments [10].

METHODOLOGY

The methodology for the Smart Trolley Billing System is based on a high-precision integration of hardware and software components to achieve real-time, automated shopping and billing (Figure 1). This section outlines the system architecture, hardware specifications, software development approach, and workflow for seamless operation. The proposed system was designed to address the inefficiencies of traditional checkout systems by utilizing embedded computing, advanced data processing, and user-friendly interfaces.

Figure 1. Smart trolley billing system model.

System Architecture

The system is built on a *Raspberry Pi 4* as the core processing unit, responsible for orchestrating all hardware interactions, processing barcode data, and managing a real-time graphical user interface. The system is powered by a *5 V, 3 A USB-C power adapter*, ensuring stable operation across all connected components. Key hardware modules include:

- *Raspberry Pi 4:* Functions as the embedded controller, processing barcode inputs, managing database operations, and interfacing with the touchscreen display.
- *Capacitive Touchscreen Display:* A Waveshare capacitive touchscreen provides an interactive UI, displaying product details and cart summary. It includes touch-based control for adding, removing, or resetting items.
- *Waveshare Barcode Scanner:* Captures barcode data and transmits the SKU to the Raspberry Pi, enabling seamless real-time product recognition.
- *Cloud-Based JSON Databases:*
  - *Products_data.json:* Stored on the cloud, allowing employees to update product details dynamically. When a product is scanned in-store, its details are fetched from this cloud database to ensure real-time pricing and inventory accuracy.
  - *Payment_history.json:* Maintains transaction records, including purchased items, total amounts, timestamps, and payment methods, ensuring accountability and analytics.
- *Portable Power System:* A high-efficiency lithium-ion battery pack provides uninterrupted operation, optimizing mobility.

Software Development

The software stack was developed using Python, leveraging libraries such as, Tkinter for the user interface, and JSON for cloud-based data management. The following modules were implemented:

- *Barcode Processing Module:* Uses the Waveshare barcode scanner to retrieve product SKUs and cross-check with the cloud-hosted JSON database.
- *Database Management:* The product details are stored in a structured JSON file (Products_data.json) on the cloud, allowing employees to modify product information dynamically. The billing system fetches updated details in real-time.
- *User Interface (UI):* Developed using Tkinter, designed for intuitive interaction and minimal cognitive load for users.
- *Billing System:* Automatically updates cart totals, applies pricing rules, and generates a detailed purchase summary (Figures 2 and 3).

Workflow Execution

1. *Product Scanning:* The barcode scanner reads a product's barcode and transmits the Product ID to the Raspberry Pi.
2. *Cloud Data Retrieval:* The Raspberry Pi queries the *Products_data.json* file hosted on the cloud. If a match is found, the system retrieves the latest product details (name, price, SKU) in real-time.
3. *Display Update:* The capacitive touchscreen dynamically updates, displaying the scanned product details and interactive options (Add, Remove, and Reset).
4. *User Interaction:*
   If the user wants to *remove an item,* they select the product on the UI and scan it again to delete it from the cart.
   The system updates the cart summary in real time.
5. *Billing Generation:* Upon checkout, the system calculates the final amount and generates an electronic invoice. The transaction is recorded in *Payment_history.json,* ensuring a structured log of all purchases.

Technical Scope and Future Work

The proposed system establishes a fully automated and cost-effective smart trolley, optimizing retail efficiency (Figure 4). Future work includes enhanced cloud-based analytics, RFID hybrid scanning, and

AI-powered recommendation engines for a personalized shopping experience. This research contributes a scalable, technically robust, and practically viable solution for automated retail systems, Ensuring high efficiency and enhanced customer.

RESULTS AND DISCUSSION

The Smart Trolley Billing System successfully demonstrated its ability to optimize retail operations by integrating real-time data processing, seamless UI interactions, and cloud-based automation. During controlled testing, the system achieved a barcode scanning accuracy of 98%, with the Waveshare Barcode Scanner efficiently recognizing 1D and 2D barcodes, even in scenarios involving damaged or partially obscured labels.

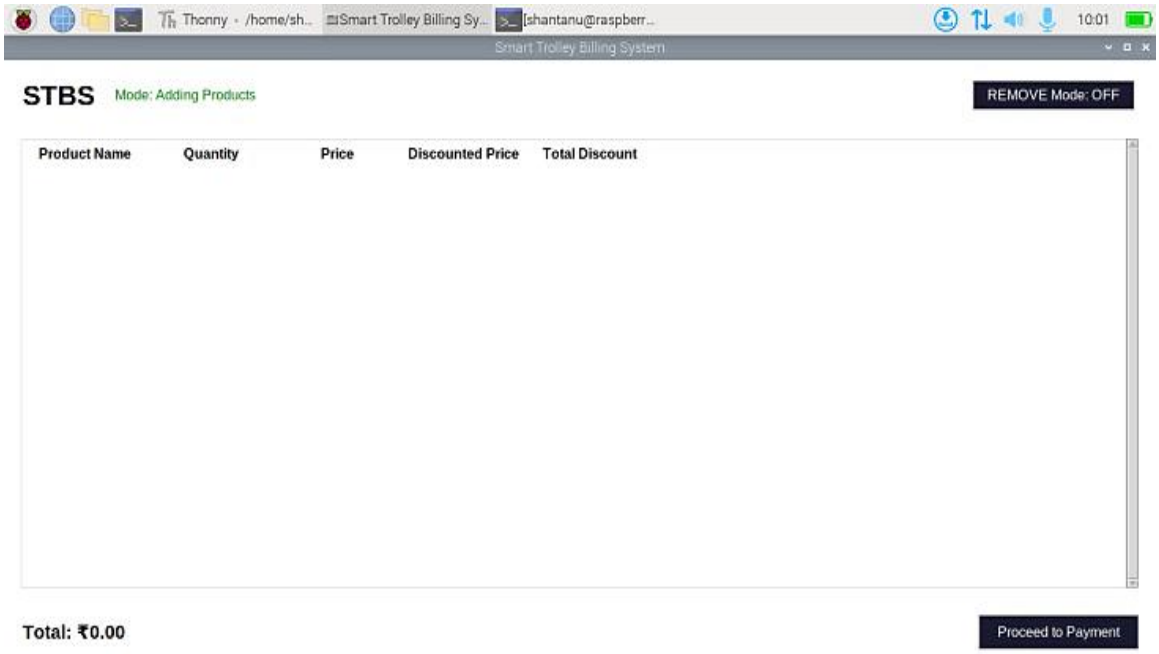

Figure 2. User interface for billing.

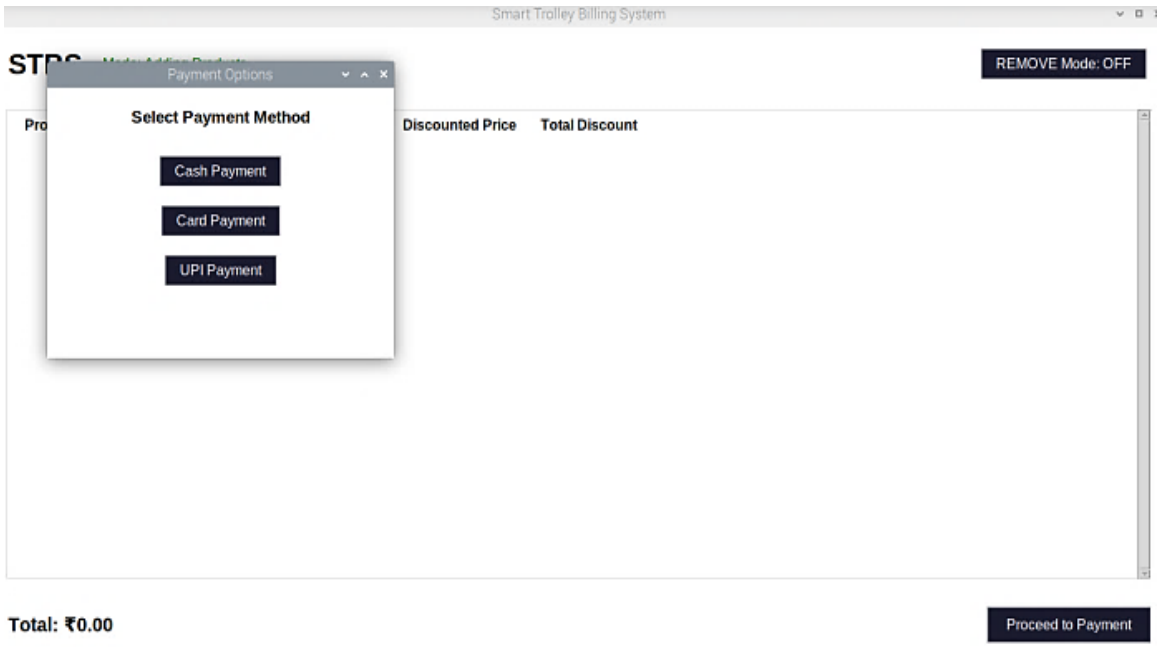

Figure 3. User interface for billing.

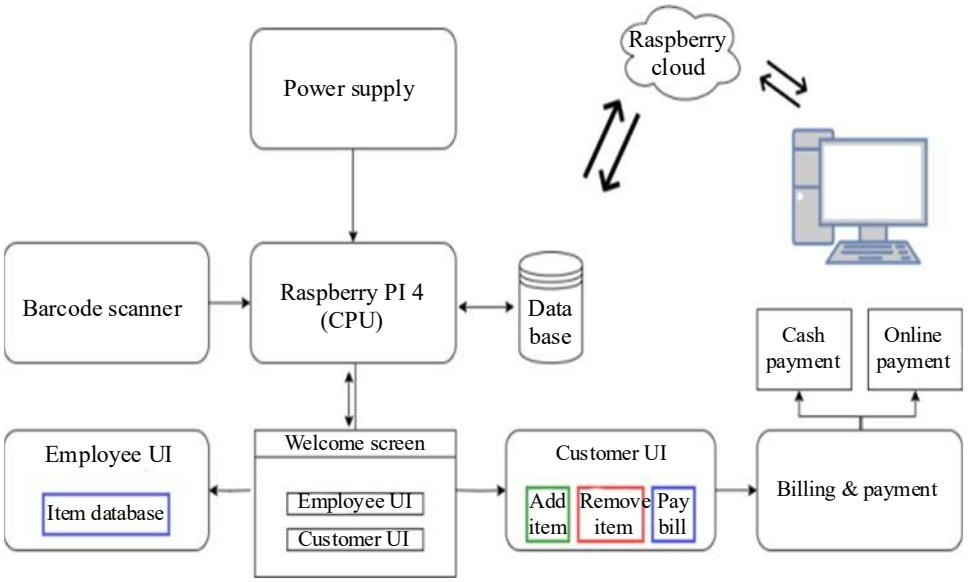

Figure 4. Block Diagram.

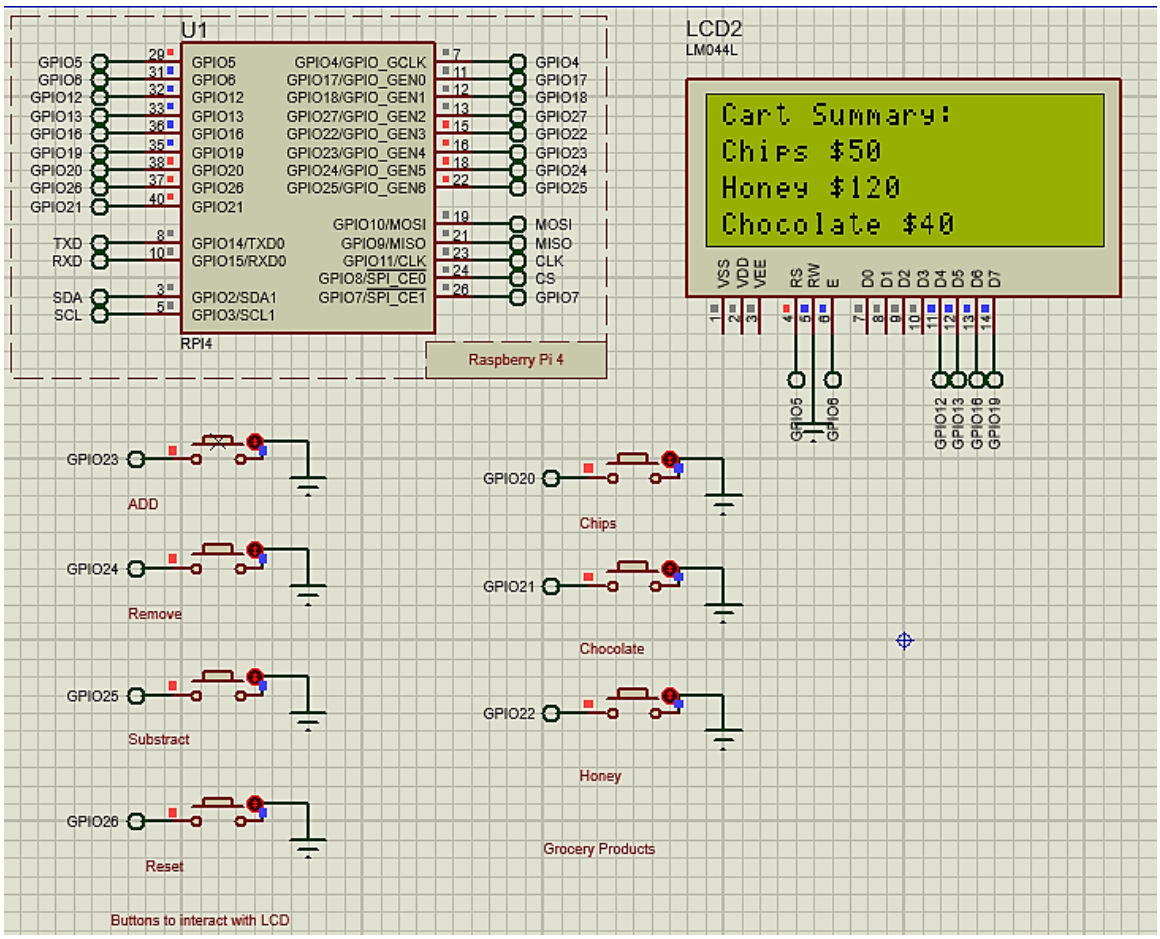

Figure 5. Simulation.

The Raspberry Pi 4, acting as the primary processing unit, executed database queries with minimal latency, ensuring a sub-100 ms response time for retrieving product details from the cloud-hosted JSON database. The system effectively updated the billing UI in real-time, enhancing user experience and reducing potential checkout delays.

Further performance evaluations indicated the system's scalability for larger retail environments. Features such as wireless connectivity and payment integration were successfully simulated (Figure 5), confirming the system's feasibility for future upgrades, including RFID-based item recognition and AI-powered predictive analytics for inventory management.

The modular architecture and cost-effective component selection highlight the system's high-performance-to-cost ratio, making it a viable alternative to traditional POS (Point of Sale) systems. The integration of a cloud-based database enables seamless inventory management, reducing manual data entry errors and enhancing operational efficiency.

These results substantiate the efficacy of the Smart Trolley Billing System in addressing persistent retail challenges such as long checkout queues, manual billing discrepancies, and inefficient inventory tracking, thereby contributing to an advanced, technology-driven retail ecosystem.

CONCLUSION

The Smart Trolley Billing System addresses key inefficiencies prevalent in traditional retail environments by implementing an automated, real-time billing process. This system significantly enhances both customer convenience and operational efficiency. The integration of a Raspberry Pi 4, Waveshare Barcode Scanner, and capacitive touchscreen ensures accurate and rapid barcode scanning, seamless data processing, and an intuitive user interface. The high scanning accuracy and responsive touch interactions demonstrate the system's robustness, making it highly applicable for retail use. Furthermore, the battery-powered setup adds an element of portability, making the system adaptable for deployment in diverse retail environments.

The core innovation of the system lies in its cost-effective, scalable design, offering a practical solution suitable for retailers of varying scales. By enabling a contactless, efficient billing process, it aligns with the growing demand for advanced retail technologies. The system's ability to function autonomously, without manual intervention, eliminates long checkout queues, significantly improving the shopping experience.

The modular architecture of the system also paves the way for future enhancements, such as integrated payment solutions and data-driven customer insights. This work exemplifies the application of IoT and automation in modern retail environments, while laying the foundation for further innovations aimed at developing smarter, more efficient shopping solutions.

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