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Smart Shopping Trolley Robot

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ABSTRACT-

The Smart Shopping Trolley Robot is an intelligent, automated system designed to enhance the retail shopping experience by combining robotics, sensor technologies, and user-centric features. This robotic trolley autonomously follows the shopper, identifies and scans items in real-time using RFID or barcode scanning, and maintains a digital bill, minimizing the need for manual checkout processes. Equipped with obstacle detection sensors, it ensures smooth navigation within crowded store environments while maintaining user safety. Integration with a mobile application allows shoppers to view their cart contents, receive product suggestions, and make seamless digital payments. The system aims to reduce checkout queues, improve inventory tracking, and offer a modern, convenient shopping experience, thereby benefiting both customers and retailers through increased efficiency and personalization.

Keywords- Smart Trolley, RFID, Autonomous Robot, Esp32 cam, Obstacle Avoidance, stm module.

1. Introduction

In today's fast-paced world, consumers seek convenience, speed, and efficiency in every aspect of life including shopping. Traditional retail shopping often involves long queues, time-consuming billing processes, and difficulty in managing carts, especially in crowded stores. To address these challenges, the concept of a Smart Shopping Trolley Robot has emerged as an innovative solution aimed at transforming the in-store shopping experience.

The Smart Shopping Trolley Robot is an intelligent, sensor-driven system designed to follow customers autonomously while helping them track their selected items in real-time. By integrating technologies such as RFID/barcode scanning, microcontrollers, obstacle detection sensors, and mobile applications, this system offers an automated alternative to manual shopping and checkout. It allows customers to monitor their purchases, view real-time billing, and even complete payments without standing in line.

This project not only enhances user convenience but also benefits store management by improving inventory control and reducing staffing requirements at checkout points. With the increasing demand for smart retail and automation, the Smart Shopping Trolley Robot represents a step forward in the evolution of the modern shopping experience.

2. Literature Survey

Over the past decade, several researchers and developers to address common problems like long billing queues, inefficient item tracking, and poor customer experience in traditional stores have explored the concept of a Smart Shopping Trolley or automated cart.

Several researchers have contributed towards developing intelligent and automated shopping systems using RFID, mobile apps, and autonomous trolleys.

In [1], Chadha et al. designed a smart trolley with RFID tags, an ESP8266 Wi-Fi module, and a mobile application to perform real-time billing and reduce human effort during checkout. The system connects to Firebase for database synchronization and supports mobile-based payment, reducing queues and making shopping efficient.

Hanooja et al. [2] introduced a human-following trolley powered by Raspberry Pi and Pi Cam, which detects a customer's colour tag and follows them through the store. Billing is automated using RFID tags, and the total cost is updated on an LCD screen, eliminating the need to stand in long queues.

In [3], Tharindu et al. presented a low-cost passive UHF RFID-based smart trolley that uses circular polarized antennas to improve tag readability and scanning speed. This system addresses common retail issues such as shoplifting, stock mismanagement, and barcode limitations.

Sanap et al. [4] proposed an autonomous robotic trolley using an ATmega16 microcontroller, EM-18 RFID reader, and ZigBee communication for wireless billing. The system also includes obstacle detection and a motion control algorithm to ease customer effort.

Naveenprabu et al. [5] developed an IoT-based smart trolley integrated with Bluetooth, RFID, and obstacle avoidance. The movement of the trolley is controlled through a mobile app, and the bill is sent to both the customer and admin via the Internet.

In [6], Das et al. designed a smart shopping system that sends e-bills to customers' email, eliminating the need for physical receipts. The system includes an Arduino, RFID reader, and ESP8266 module, interacting with an online database and a dedicated web interface.

Wankhede et al. [7] proposed a barcode-based electronic trolley system integrated with an Android application. Customers scan product barcodes using their smartphones, which are automatically added to their virtual cart. The app supports online payments and generates the final bill on the user's device.

Kowshika et al. [8] implemented a smart shopping cart combining RFID, Raspberry Pi, and a mobile app. The trolley displays real-time product information, helps budget control, and supports app-based payments.

3. System Model

The Smart Shopping Trolley Robot is designed as an intelligent embedded system that integrates hardware and software components to assist customers during in store shopping. The system follows the user autonomously, identifies and scans products using RFID or barcode technology, displays item and billing information in real time.

1. System Architecture Overview

The system model is divided into the following major modules:

A. Sensing and Detection Module

- Ultrasonic/IR Sensors: Used for obstacle detection and distance measurement to avoid collisions. • User Tracking Sensor (e.g., Bluetooth, IR beacon, or camera based): Ensures the trolley follows the user accurately

B. Product Identification Module

- RFID Reader / Barcode Scanner: Scans products as they are placed in the trolley. Each item is recognized and registered in the billing system. • Microcontroller (e.g., Arduino / Raspberry Pi): Acts as the central processing unit to control and manage data from the sensors and scanners.

C. Billing and Display Module

- LCD / OLED Display: Shows real-time item names, quantities, and total cost.
- Buzzer / Voice Feedback (optional): Provides audio confirmation for actions like item addition or error notifications

D. Mobility and Navigation Module

- DC Motors with Motor Driver (e.g., L298N): Enables autonomous movement.
- Obstacle Avoidance System: Sensors guide the trolley to navigate safely around obstacles.

E. User Interaction Module

- Mobile Application (via Bluetooth or Wi-Fi):
  - Displays cart summary
  - Provides payment gateway integration
  - Sends notifications (e.g., item Limit alert, special offers)
  - Enables user login and session management

F. Power Supply

- Rechargeable Battery Pack: Powers the entire system.
- Voltage Regulator: Ensures safe and stable power delivery to all component

2. Functional Flow

1. User Authentication store card.
2. Trolley Follows the User using IR or image based tracking.
3. Items is scanned through RFID/barcode as they are added to the cart.
4. Item Details Displayed on the on-board screen.

5. Obstacle Detection System ensures safe navigation in aisles.
6. At Checkout, user confirms purchase.
7. Payment Processed, and a digital receipt is generated.

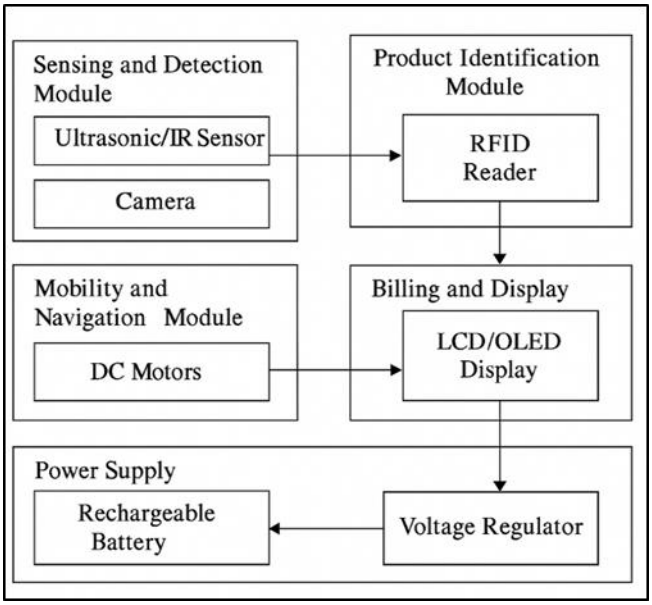

Figure 1 Block diagram of the Smart Shopping Trolley

4. Proposed Mechanism Description

The Smart Shopping Trolley Robot is design to automate the shopping experience by combining autonomous movement, product recognition, and digital billing into a single, user-friendly system. The proposed mechanism integrates several hardware modules controlled by a central microcontroller, supported by a mobile application for enhanced user interaction.

1. User Tracking and Movement

- The trolley uses IR sensors, Bluetooth beacons, or ultrasonic sensors to detect and follow the customer.
- Based on proximity data, the microcontroller sends signals to the motor driver, which controls the DC motors to move the trolley forward or stop when needed.
- Obstacle detection sensors ensure that the trolley avoids collisions with shelves or other customers.

2. Product Identification and Billing

- As the user places items into the trolley, each product is identified either by:
  - An RFID reader detecting the RFID tag on the item.
  - Or a barcode scanner scanning the product's barcode.
- Upon successful identification, the microcontroller updates:
  - The LCD/OLED display on the trolley with item name and price.
  - The mobile app with cart contents and total bill using Bluetooth or Wi-Fi.

3. Billing System

- The system maintains a dynamic list of items and their prices.
- It continuously updates the total cost and displays it on both the screen and the app.
- The user can view, remove, or change item quantities via the mobile app interface.
- At the end of the shopping process, the user can proceed to payment:

4. System Control Flow

1. Initialization: System boots up; sensors and modules are activated.
2. Tracking: Trolley begins following the customer.
3. Item Detection: RFID/barcode module scans each added item.
4. Cart Update: Billing module updates cart and displays information.
5. Navigation: Sensors detect and avoid obstacles during movement.
6. Final Billing: User confirms cart and proceeds with payment.
7. Checkout: Payment processed; a digital receipt is generated.

5. Additional Features (Optional Enhancements)

- Voice Feedback: Provides audio confirmation for actions.
- Weight Sensor: Confirms that an item has actually been placed in the trolley.
- Product Recommendation: The app can suggest items based on purchase history.
- Inventory Sync: Communicates with the store's central server to update stock in real time.

This proposed mechanism offers a seamless shopping experience, reducing the need for staff intervention, speeding up checkout, and improving customer satisfaction all while keeping costs manageable by using commonly available components like Arduino, sensors, and wireless modules.

5. Performance Evaluation

The performance of the Smart Shopping Trolley Robot was evaluated based on a series of functional and non-functional parameters. Testing conducted in a controlled retail like environment to simulate real-world usage scenarios. The evaluation focuses on the following core areas:

1. Product Detection Accuracy:

Feature	**RFID-Based System**	**Barcode-Based System**
Detection Accuracy	~98% (for properly tagged items)	~95% (manual alignment needed)
Scan Time per Item	~1 second	2–3 seconds
Interference Issues	Minor (if multiple tags overlap)	Moderate (depends on line-of-sight)

- **Observation**: RFID is seamless but requires infrastructure; barcode systems are cheaper but need user assistance.

2. Navigation and Obstacle Avoidance

Parameter	**Result**
User Following Accuracy	90–95% (Bluetooth/IR tracking range ~1–2m)
Obstacle Detection Accuracy	~95% (with ultrasonic sensors)
Response Time	~0.5–1sec

• **Observation**: The trolley reliably follows the user in open and semi crowded spaces but may require tuning for dynamic, high-traffic areas.

3. Billing and User Interface

Parameter	**Result**
Real	Time Yes (delay < 1 second) Billing Update
Display	Clear and responsive
Readability	LCD/OLED screen

• **Observation**: The billing system is smooth and sresponsive. Mobile app integration enhances usability, especially for tech-savvy users.

4. Power Efficiency and Runtime

Component	Power Usage	Battery Life
Motors + Sensors	Medium	~3–4 hours continuous use
Display+ Microcontroller	Low	-

• **Observation**: Battery backup is sufficient for regular shopping trips but may need charging between long sessions or during peak hours.

5. User Experience & Usability

Criteria	Rating (1–5)
Ease of Use	4.5
Setup Time	4.0
System Reliability 4.2	4.2
Overall Satisfaction 4.5	4.5

• **Observation:** Users appreciated the convenience and novelty of the system. Minor issues reported during navigation in very tight spaces.

5. Conclusion and Future Work

The Smart Shopping Trolley Robot presents a modern, tech-driven solution to common problems faced in traditional retail environments, such as long billing queues, inefficient item tracking, and customer inconvenience. By integrating components like RFID/barcode scanners, autonomous navigation using sensors, real-time billing, and mobile application support, the system streamlines the shopping process and enhances the overall user experience.

The robot successfully automates item detection, billing, and navigation while maintaining a user-friendly interface. Performance evaluation shows that the system is accurate, reliable, and efficient for practical retail scenarios. The project demonstrates the potential for smart technologies to transform conventional shopping into a seamless, automated, and enjoyable experience.

While the current prototype achieves its core objectives, there is significant scope for enhancement and scaling. Future improvements may include:

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