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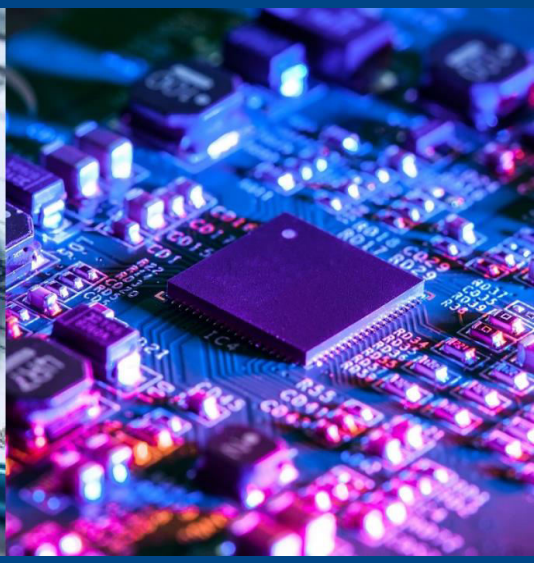

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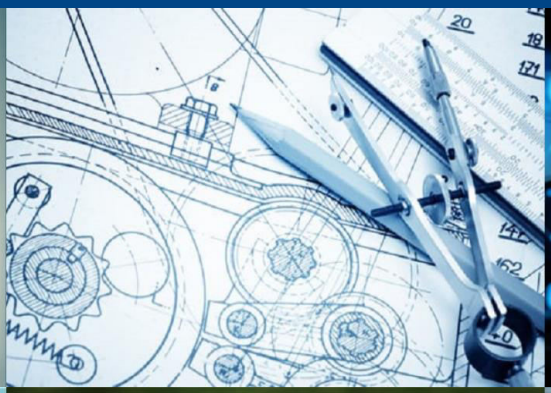

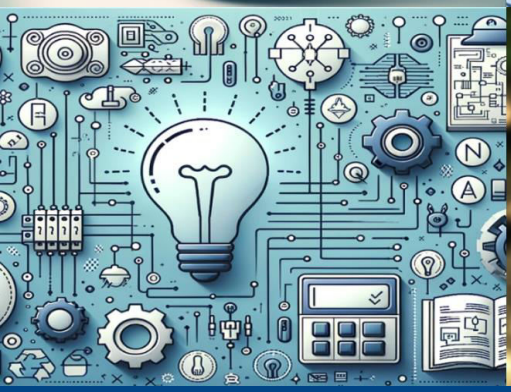

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Autonomous Human-Following Smart Trolley with RFID Billing

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ABSTRACT: The retail industry continues to face operational inefficiencies due to long billing queues, manual trolley handling, and time-consuming checkout procedures. This paper presents the design and implementation of an Autonomous Human-Following Smart Trolley integrated with an RFID-based automatic billing system. The proposed system utilizes sensor fusion technology combining Ultrasonic and Infrared sensors to achieve real-time human tracking and collision avoidance. An Arduino UNO microcontroller serves as the core processing unit, while the L298N motor driver controls differential drive locomotion. RFID technology enables offline automatic billing without dependency on cloud infrastructure or Wi-Fi connectivity. The trolley autonomously follows the user while maintaining a predefined safe distance and dynamically updates the billing information on an I2C LCD display. Experimental validation demonstrates improved shopping convenience, reduced checkout delays, and enhanced accessibility for elderly and physically challenged users. The proposed architecture provides a low-cost, scalable, and energy-efficient solution suitable for modern smart retail environments.

KEYWORDS: RFID Billing, Smart Retail, Human-Following Robot, Autonomous Navigation, Edge Computing.

I. INTRODUCTION

Retail systems still depend on manual trolley handling and barcode billing, causing long queues and customer inconvenience. Barcode scanners require line-of-sight alignment and increase billing latency. Elderly and physically challenged users also face difficulty in handling conventional trolleys. The proposed smart trolley integrates autonomous navigation and RFID billing to provide hands-free movement and queue-less checkout. The trolley follows the user using ultrasonic and infrared sensors while RFID tags automatically update the bill in real time. Unlike cloud-based systems, the proposed architecture works completely offline using embedded edge computing.

II. LITERATURE SURVEY

Researchers have proposed cloud-based RFID billing systems, LiDAR-based robots, Bluetooth tracking systems, and dual-controller architectures for smart retail applications. Cloud-based systems suffer from network latency, while LiDAR increases system cost and power consumption. Bluetooth localization becomes inaccurate in crowded environments. The proposed system overcomes these limitations through low-cost sensors, simplified embedded architecture, and offline RFID billing.

III. EXISTING SYSTEM AND LIMITATIONS

Existing retail systems mainly depend on manual shopping carts, barcode scanners, cloud-based smart trolleys, and line-following AGVs. Manual trolleys require physical effort, barcode billing increases waiting time, and cloud-based systems depend on stable internet connectivity. Line-following AGVs cannot adapt to dynamic human movement. These drawbacks create the need for a decentralized autonomous trolley system.

IV. PROPOSED SYSTEM

The proposed system consists of sensing, processing, and actuation layers. The sensing layer includes HC-SR04 ultrasonic sensors, infrared sensors, and the EM-18 RFID reader. Arduino UNO processes sensor inputs and executes navigation and billing algorithms. L298N motor driver controls DC motors using differential drive locomotion. The

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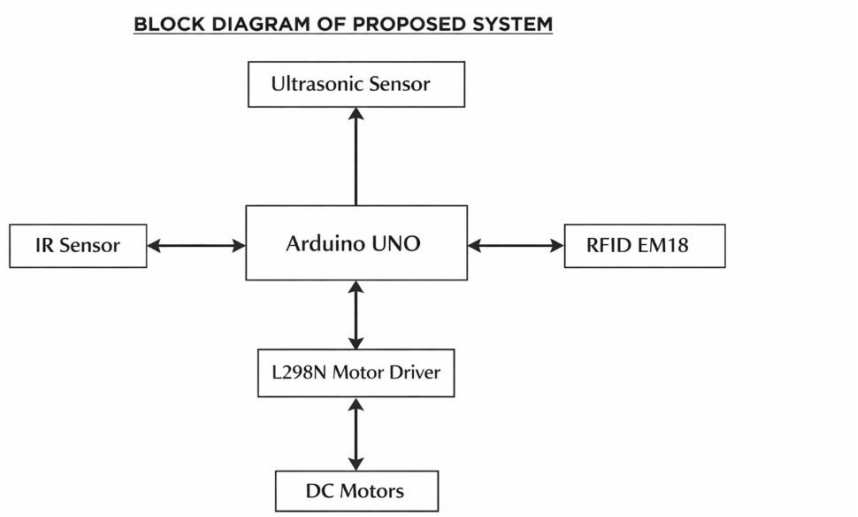
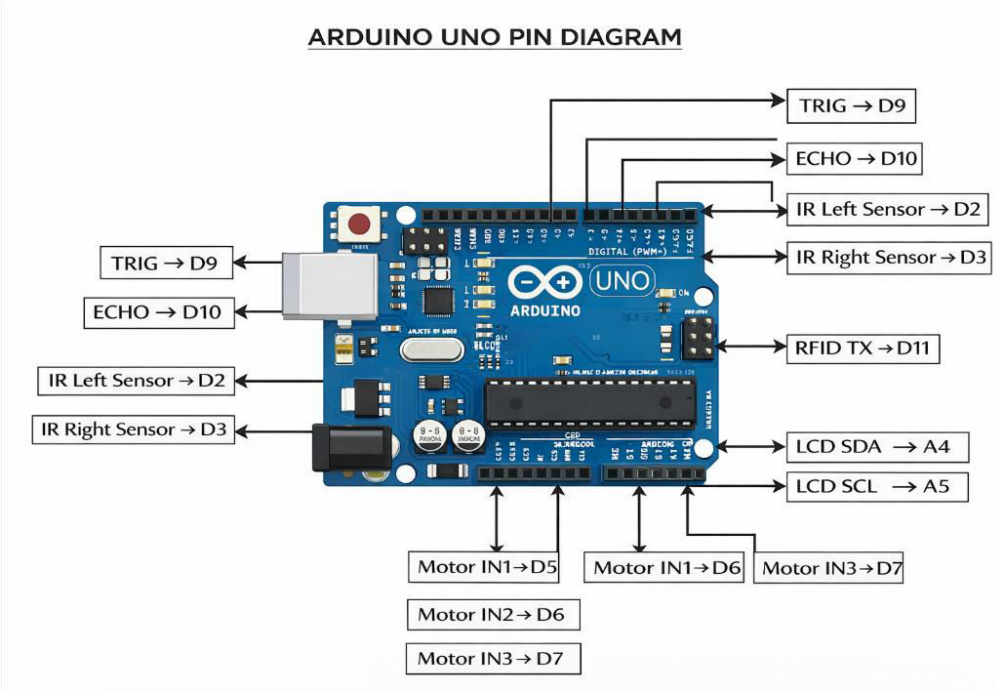
trolley continuously measures the user distance. If the user moves away, the trolley follows automatically; if the user stops, the trolley also stops. RFID tags attached to products are scanned and added to the local billing database displayed on the LCD.

4.1 Block Diagram of Proposed System



4.2 ARDUINO UNO PIN DIAGRAM



The proposed system integrates autonomous navigation and RFID billing into a single embedded platform.

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4.1 SYSTEM ARCHITECTURE

The architecture consists of three major layers:

1. Sensing Layer

- HC-SR04 Ultrasonic Sensor
- Infrared Sensors
- EM-18 RFID Reader

2. Processing Layer

- Arduino UNO (ATmega328P)
- Embedded C++ firmware

3. Actuation Layer

- L298N Motor Driver
- DC Gear Motors
- LCD Display

V. HARDWARE COMPONENTS

- Arduino UNO serves as the central controller with ATmega328P microcontroller, 16 MHz clock frequency, and UART communication support.
- HC-SR04 ultrasonic sensor measures distance using acoustic time-of-flight. Infrared sensors provide directional guidance and obstacle detection.
- EM-18 RFID reader scans passive RFID tags for product identification and billing. L298N motor driver controls the speed and direction of DC motors.

VI. WORKING PRINCIPLE

- The system initializes all sensors, motors, and LCD display. The ultrasonic sensor continuously measures the distance between the user and trolley.
- If the distance exceeds the threshold, the trolley moves forward; if the distance becomes too small, the trolley stops automatically.
- IR sensors detect left and right movement for steering control. The RFID reader scans product tags and compares them with the local database.
- Boolean logic prevents duplicate entries, and rescanning removes the item from the bill.

VII. CIRCUIT AND SOFTWARE DESIGN

- The circuit contains two sections: billing and navigation. The billing section includes RFID reader, LCD display, push buttons, and Arduino UNO.
- The navigation section contains ultrasonic sensors, IR sensors, L298N motor driver, DC motors, and battery supply.
- The firmware is developed using Embedded C++ in Arduino IDE with PWM motor control, non-blocking finite state machine design, real-time RFID parsing, and safe-zone monitoring algorithms.

VIII. RESULTS AND DISCUSSION

- The prototype was tested in a supermarket-like environment. The trolley maintained a safe distance between 10 cm and 30 cm with stable tracking performance.
- Collision-free navigation and quick stopping response were achieved. RFID billing accurately detected tags within 5–7 cm and updated the bill instantly without internet dependency.
- The 11.1V Li-ion battery provided stable operation with reduced voltage fluctuations and efficient power management.

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IX. ADVANTAGES OF PROPOSED SYSTEM

- Eliminates checkout queues
- Reduces physical effort
- Provides autonomous navigation
- Supports offline billing
- Low-cost implementation
- Scalable architecture
- Energy-efficient design
- Improved shopping convenience

X. APPLICATIONS

The proposed system can be deployed in:

- Supermarkets
- Hypermarkets
- Airports
- Hospitals
- Warehouses
- Smart malls
- Retail automation systems

XI. FUTURE SCOPE

Future improvements may include:

- AI camera integration
- Cloud inventory synchronization
- Mobile payment gateway
- Voice assistant support
- LiDAR-based navigation
- Smart battery management systems
- Mobile application integration
- IoT-enabled analytics

XII. CONCLUSION

The Autonomous Human-Following Smart Trolley with RFID Billing successfully demonstrates a low-cost and efficient solution for modern retail automation. The integration of ultrasonic and infrared sensor fusion enables reliable autonomous navigation, while RFID-based offline billing eliminates checkout delays and network dependency.

The proposed architecture significantly improves shopping convenience by reducing physical effort and automating the billing process. Experimental validation confirms the reliability of the embedded edge-computing framework and the effectiveness of the differential drive navigation system.

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