SMART TROLLEY: A MORE ENHANCED SHOPPING EXPERIENCE

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***Abstract*—Retail automation is transforming the shopping process through billing automation, product recognition, and customer support. In this paper, we suggest a smart shopping trolley that employs RFID technology, Arduino controller, and human following ability to enhance shop navigation and customer satisfaction. The system comprises an Arduino Uno, RFID reader, LCD display, IR sensors, and ultrasonic sensor. Experimental results demonstrate that the system not only provides efficient billing and product tracking with low latency and high precision but also keeps pace with the user constantly, thus enhancing physical convenience during shopping. Directions for future efforts will include database scalability, sensor incorporation, and enhanced security mechanisms.**

***Keywords*—RFID, Arduino, Smart Trolley, Automated Billing, Human Following, Ultrasonic Sensors**

I. INTRODUCTION

Retail automation is also changing customer experience by reducing checkout times, eliminating human mistakes, and enhancing in-store assistance. RFID technology, combined with low-cost microcontrollers such as the Arduino Uno, has made new retail innovations possible. This paper introduces a smart shopping trolley that, besides auto-detecting and charging products, includes sophisticated product navigation and human following functions.

The system employs a user-friendly touch-screen interface for guiding products through the store to simplify the customers' ability to locate products within the store. The trolley makes use of real-time information extracted from a central database for guiding consumers towards the precise locations of the product being sought out, thus facilitating the entire process. The trolley is also supported with ultrasonic sensors to establish human following functions to enable the trolley to dynamically pursue and follow the consumer and reduce human effort in addition to maximizing ergonomic comfort.

The principal contributions of this research are:

- System Integration: An integrated hardware–software system that includes RFID sensing, wireless connectivity, interactive touchscreen interface, and integrated navigation and human following capabilities.
- Automated Product Location and Billing: An automated system that tracks products, maintains real-time billing information, and guides customers to product locations on the sales floor.
- Human Following: A new technology that allows the trolley to follow the shopper safely and efficiently based on ultrasonic sensor data and motor control.

The system is developed with user convenience as a high priority:

- Automated Processes: RFID-based product recognition and automatic billing reduce manual intervention, lessening user workload.
- Guided Navigation: Real-time product location guidance enables users to quickly locate products in the store.
- Effortless Mobility: The human following feature makes the trolley automatically follow the shopper, reducing the physical effort needed.

II. LITERATURE SURVEY

The integration of technology into shopping spaces has resulted in the creation of intelligent systems to promote customer convenience and operational effectiveness. This literature survey discusses some of the innovations in smart shopping carts and automated trolleys in terms of their design, functionality, and user experiences.

Roja and Senthil Kumaran, in the article 'Automatic Movable and Secure Trolley Using RFID'[1], (2017) presented an automatic, movable trolley system with the use of Radio Frequency Identification (RFID) technology to aid airport passengers. The system uses RFID readers and tags to recognize human movement, so that the trolley would automatically follow the passenger. Obstacle sensors are incorporated to prevent collisions, and force sensors ensure luggage security by triggering an alarm if unauthorized access is detected. This design aims to reduce manual effort and enhance the safety of luggage handling in airport environments. Narula, Shah, and Rokde in the paper 'Smart Shopping Cart Using a Product Navigation System'[2], (2014) created a smart shopping cart with a touch-screen-based graphical user interface to help customers find products in a supermarket.

The system offers item information and their locations, utilizing an indoor positioning system based on passive RFID tags and readers. This arrangement places the product and user locations on the screen at the same time, making the process of shopping faster by saving time and effort. Shabina, Mahek, Alone, Mohite, and Borate in paper 'Smart shopping trolley using Arduino UNO'[3],2024 paper suggests a smart trolley system based on Arduino UNO, which would save checkout time and improve the customer shopping experience. It applies RFID technology for automatic billing, minimizing manual scanning work. The system is user-friendly and cost-effective and hence viable for mass retail deployment. Kodape, Kinare, Mangrulkar, Kasar, Bhatlawande in the article 'Smart trolley System'[4],2023 delves into an intelligent trolley system using IoT and RFID to make shopping hassle-free. It targets real-time identification, automated billing, and minimizing human intervention at the billing counter. The system tries to make shopping more convenient for customers and minimize long queues at supermarkets.

III. METHODOLOGY

The three major modules constituting the system architecture are Self-Billing, In-Store Navigation, and Human Following Mechanism. The controller is an Arduino Uno manages input from other modules and provides smooth execution.

A. Self-Billing Module

The self-billing system automatically checks out by identifying products in real-time and displaying billing details:

RFID Module and Tags:

Product information is retrieved from product RFID tags by the RFID module (e.g., EM-18).

RFID Tag Detection Time:

$$Td = D / S \qquad (1)$$

where:

Td = Detection time
D = RFID reader and tag distance
S = Signal speed

Arduino Uno:

Used as the system controller, which manages the product data and operations of the system. The Arduino Uno is an open-source microcontroller board with a high degree of adoption that is built on the ATmega328P. It has 14 digital I/O pins, 6 analog inputs, a 16 MHz quartz crystal, and various communication interfaces like UART, SPI, and I2C, making it apt for embedded projects. It runs at 5V and can be powered through USB or an external power source (7-12V).

Figure 1: Arduino Uno Microcontroller

LCD Display:

The LCD (Liquid Crystal Display) module is one of the most common output devices in embedded systems for visually representing information. A 16x2 LCD (16 characters on a line, 2 lines) is utilized to display real-time product information, billing details, and navigation instructions in this project. The display uses the Hitachi HD44780 controller, allowing it to be easily communicated with by microcontrollers such as Arduino Uno through a 4-bit or 8-bit data interface. Its low power consumption, affordability, and reliability make it a vital element in smart systems.

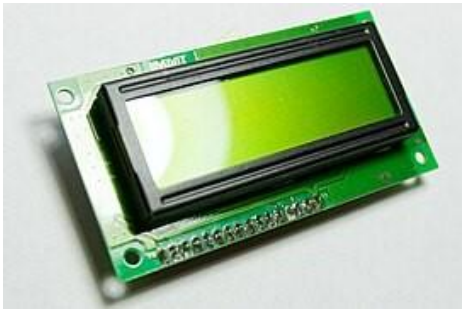

Figure 2: 16x2 LCD Module

B. In-Store Navigation Module

The in-store route guidance system assists consumers in finding products effectively through a software interface on a laptop.

Steps:

- User Input through Software Interface: The client inputs the product name or chooses a category through a graphical user interface (GUI) on a laptop.
- Product Location Retrieval: The software asks the system to look into a central database of products for the product's location. With an available ESP8266 Wi-Fi module, it's possible to receive real-time updates of location via an online stock.
- Navigation Display on Laptop: The found location of the product is displayed within the software screen, informing the user which aisle or shelf the product is.

Arduino Uno:
For processing user inputs and fetching product location data.

Wi-Fi Module (ESP8266) (Optional):

The ESP8266 Wi-Fi module is an affordable, high-performance wireless communication module with which microcontrollers such as Arduino Uno can access the internet. It provides support for TCP/IP protocols, which support real-time data exchange between remote databases and cloud services. The module works at 2.4 GHz and can be set to Station (STA) mode, Access Point (AP) mode, or both. In this project, the ESP8266 provides real-time product location and wireless billing update to improve the shopping experience.

Figure 4: ESP8266 Wi-Fi Module

C. Human Following Mechanism

In order to minimize physical effort, the trolley comes with human-following based on sensor and motor control:

Ultrasonic Sensors (e.g., HC-SR04):

HC-SR04 ultrasonic sensor is a very common distance-sensing sensor based on the ultrasonic wave reflection principle. It is composed of a high-frequency sound wave emitting transmitter and a receiving antenna for the reflected waves. By determining the transmission to reception time difference, the sensor measures the object distance with very high accuracy.

Ultrasonic sensors in this project are applied for the smart trolley's human-following system. The sensor is always detecting the user position and controls the trolley's motion in correspondence with the position to ensure efficient and autonomous motion

Figure 5: HC-SR04 Ultrasonic Sensor

Ultrasonic Sensor Distance Calculation:

$$d = (t * v)/2 \quad (2)$$

Where:

d = Measured distance

t = Time taken by the sound wave to return

v = Speed of sound in air (~343 m/s)

IR Sensor:

The Infrared (IR) sensor is an electronic component which detects objects and calculates distances using infrared radiation. It has an IR LED (transmitter) which gives off infrared light and a photodiode (detector) that senses the reflected infrared light off surrounding objects. The level of reflected IR light indicates the proximity of an object.

In this project, the IR sensor is employed in the human-following mechanism to distinguish between the user and obstacles. It assists the trolley in following human movement and preventing unnecessary stops or collisions.

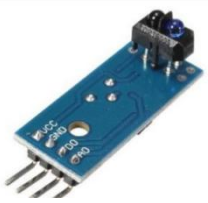

Figure 6: Infrared (IR) Sensor

Motor Driver (L298N):

L298N motor driver is a dual H-bridge motor driver module for speed and direction control of DC motors. It

enables bidirectional control of two separate motors with Pulse Width Modulation (PWM) signals. The module is a 5V logic level and can support motor voltages between 5V and 35V, with a continuous current rating of up to 2A per channel. The L298N motor driver, in this project, is responsible for the management of the trolley's motion, making sure that it travels smoothly and exactly as required. The driver takes its control signal from the Arduino Nano, altering the speed and direction of the trolley accordingly, depending on the feedback of the ultrasonic and IR sensors.

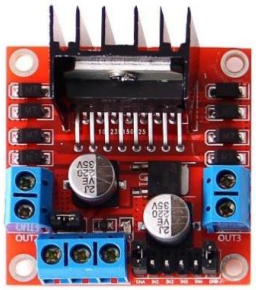

Figure 7: L298N Motor Driver

Speed of Trolley Movement:

□ = □ □ □ (3)

where:

v = trolley's linear speed

r = wheel radius

ω= angular velocity of the wheels

Adding these modules to the intelligent trolley, its shopping convenience is improved because it provides automated billing, real-time direction, and minimized human interaction.

TABLE I. COMPONENTS AND SPECIFICATION

Components	***Specification***	***Function***
RFID Module	EM-18	Reads product tags
Microcontroller	Arduino UNO	Controls all operations
LCD Display	16x2 or 20x4	Displays billing details
IR Sensors	TCRT5000	Detects movement and obstacles
Ultrasonic Sensor	HC-SR04	Measures distance for human following
Motor Driver	L298N	Controls trolley movement

IV. IMPLEMENTATION AND RESULTS

The intelligent shopping trolley is achieved through the utilization of low-cost devices, thus providing a low-cost retail automation solution. RFID provides accurate and efficient product identification, while the in-store navigation system eliminates considerable search time. The human-tracking feature provides convenient mobility by allowing the customers to move freely without having to push the trolley manually.

A. Experimental Setup

The prototype utilized Arduino UNO, EM-18 RFID module, sensors, and was evaluated in an imitation retail environment to see improvements in efficiency.

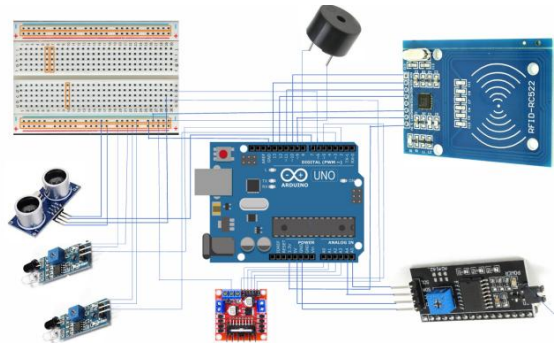

Figure 8: Circuit Diagram

B. *Results and Discussion*

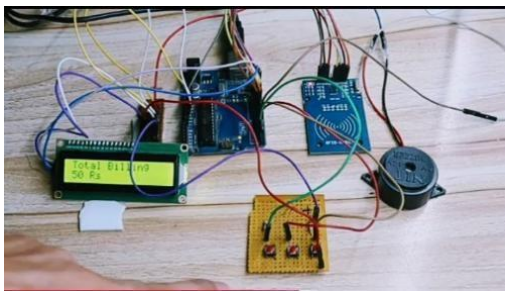

Figure 9: Prototype Implementation of the Smart Shopping Trolley

V. COMPARISON WITH EXISTING SYSTEMS

TABLE II. COMPARISON TABLE

Feature	***Existing Smart Trolleys***	***Proposed system***
Billing method	RFID- Based auto billing	RFID Based autpo billing
Navigation Assistance	Limited(Basic store mapping)	Real time instore navigation with location tracking

Feature	***Existing Smart Trolleys***	***Proposed system***
Human Following	Absent in most designs	Implemented using ultrasonic and IR sensors
Checkout Time Reduction	Partial improvement	Significant reduction by eliminating queues

VI. CONCLUSION

This work introduces a novel concept of retailing through an integration of RFID-based auto billing, real-time product guidance, and an intelligent human-tracking system. All these features are embedded in such a manner that the intelligent shopping trolley becomes easier, labour-free, and more efficient. Product suggestions through AI-based methods and voice prompts may be introduced as additional user interactions in further enhancements.

Future Scope:

The system can be expanded with the following capabilities:

•AI-Powered Product Recommendations: Browsing behaviour analysis for personalized recommendations.

•Voice Commands: Support for voice product search.

•Cloud Integration: Storage of shopping data for analytics

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