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Smart Line Following Shopping Cart with Billing System using RFID

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Abstract:

Traditional checkout systems in supermarkets can cause long lines and delays for customers. To solve this problem, we've created a smart solution called the Smart Shopping Cart, which uses IoT technology to make the shopping experience more efficient. This system eliminates the need for standing in queues by allowing customers to scan products with an RFID system and place them in a smart cart. The cart, equipped with a Node MCU and an LCD screen, displays the total price of the items as they are added customers can also see their total bill on a web server, which helps them keep track of their purchases more easily. To improve the shopping experience even more, the smart cart is designed as a robot that can follow a set path in the store. Using infrared sensors, it moves on its own, making it capable of tasks like guiding customers, delivering items, or even helping with mall maintenance. The robot's system is designed to adapt to various obstacles, people, and changing routes in a mall environment, ensuring smooth and efficient movement. It uses algorithms for path tracking, obstacle avoidance, and speed control to navigate accurately. This project aims to improve mall operations, enhance customer experience, and reduce the need for human intervention. The robot's ability to work safely and independently in a busy environment shows its potential for future use in other public spaces.

Key components of the system include line-following sensors (like infrared or ultrasonic sensors), RFID reader and tags, and a microcontroller.

1. Introduction:

In today's fast-moving world, technology is advancing quickly. Most people are always connected to the digital world through their smartphones and laptops, thanks to fast internet, user-friendly apps, and personalized suggestions. This shift to digital has made everyday tasks much more convenient and efficient.

Technologies like social media have also expanded our access to information, allowing us to make more informed decisions about products.As cities grow more populated, the diversity of people's needs and preferences increases.

Many people go to malls and supermarkets to shop for a wide range of products. However, a big drawback is the crowded spaces, leading to long waits at checkout counters. Shoppers often spend a lot

of time scanning items and completing their purchases. Malls, which are popular for shopping, entertainment, and leisure, see many visitors daily. But with online shopping on the rise, physical stores face the challenge of keeping customers coming back. To address this, malls are exploring new ways to offer more personalized shopping experiences to attract and keep customers. One of these solutions is the introduction of smart shopping carts.

An automated smart shopping system leverages the Internet of Things (IoT) to connect all items within a store. Each product is embedded with an inexpensive RFID tag, which the shopping cart can automatically read. As items are placed into the cart, the product details are instantly captured, allowing the system to handle the billing process directly within the cart.

This eliminates the need for customers to stand in long queues at checkout. Additionally, if an item is not scanned properly, such as due to a tampered barcode, the system can identify it by checking the weight of the product. This also simplifies inventory management.This smart system benefits both customers and store employees by significantly reducing the time spent on manual billing, streamlining the shopping experience, and addressing the challenges faced by traditional brick-and-mortar stores.

2. Literature Review

In many retail stores, customers often spend more time waiting in line to pay than actually shopping, especially during busy times. The amount of time spent waiting can greatly affect their overall shopping experience and satisfaction with the service. Therefore, finding ways to reduce this waiting time is crucial, particularly in real- world settings.

One solution we suggest is a smart cart system that breaks up the long checkout lines into smaller, individual stations. With this system, customers don’t need to wait at the point of sale to scan and pay for their items.

The smart cart uses Radio Frequency Identification (RFID) technology to automatically scan products. Each item is tagged with a passive RFID sticker that holds details like the product's name and price. The cart itself is equipped with an RFID reader/writer that can detect these tags as items are added to the cart.

3. Methodology

3.1Requirement Analysis

Problem Identification: Shopping can be a simple and enjoyable task, but waiting in long billing queues can make it a tedious and time-consuming process. With crowded stores, customers often face delays while cashiers prepare their bills, leading to long lines. In the current pandemic situation, standing in queues at malls or shops is not ideal, as it increases the risk of virus transmission. This traditional billing process disrupts people's busy schedules and frustrates shoppers. To address these challenges, a line-following robot for shopping carts can offer a more personalized and efficient shopping experience. These robots allow customers to navigate the store without pushing their carts or worrying about losing them. Shoppers can focus on browsing and selecting products rather than spending time on the logistical aspects of their shopping.

Specification: The Smart Shopping Cart Line-Follower Robot is an autonomous system designed to enhance the shopping experience by making it more efficient. The cart uses infrared (IR) sensors to follow a set path and ultrasonic sensors to avoid obstacles while moving through the store. The system is powered by DC motors controlled by an Arduino, enabling the cart to move autonomously. Additionally, the cart is equipped with RFID scanning technology that automatically tracks the products placed in it. This allows for easy self-checkout via a mobile payment system, eliminating the need to wait in long checkout lines. The smart cart not only helps with navigation but also collects real-time data, provides personalized recommendations, and tracks inventory, further improving the shopping experience and reducing labor costs.

Proposed System: The proposed system introduces the Internet of Things (IoT) to create an automated smart shopping experience. Each product in the store is tagged with a low-cost RFID tag. When a customer places an item in the smart cart, the RFID reader embedded in the cart automatically detects the product, registering details such as price and weight. The cart's robot system is equipped with IR sensors, ultrasonic sensors, and motor drivers, all controlled by an Atmega 328 microcontroller to ensure smooth operation. The cart is mounted on a steel It features four DC motors with wheels for easy movement in any direction, and the microcontroller uses motor drivers to control the motors effectively.

Hardware Required: The hardware for the Smart Shopping Cart Line-Follower includes a microcontroller like Arduino or Embedded C, which processes data. The cart uses DC motors and motor drivers (e.g., L298N) for movement, along with IR sensors for line-following and ultrasonic sensors for obstacle avoidance. The system is powered by Li-Ion batteries. On the software side, line-following algorithms, obstacle detection logic, and integration with mobile apps are used to enable product scanning (via RFID), user control, and self-checkout. The system also provides real-time product tracking, recommendations, and seamless mobile payment capabilities via NFC or mobile payment systems.

Flow: The Smart Shopping Cart Line-Follower follows a pre- programmed path within the store, using IR sensors to detect lines on the floor and ultrasonic sensors to avoid obstacles in its way. As it moves, the cart scans the products with its RFID reader, sending real-time updates to a connected system. The cart's movement is adjusted based on sensor feedback, ensuring it navigates smoothly. The system also includes automatic product tracking, personalized recommendations for the shopper, and a self-checkout mobile payment system to complete the shopping process efficiently.

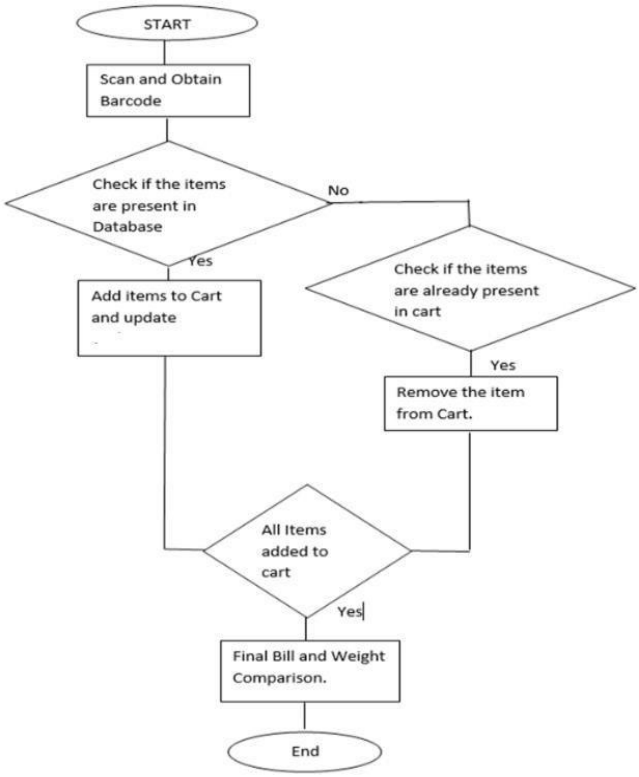

Fig no .1

frame with a mesh-based trolley, allowing it to carry products like a traditional shopping cart.

3.2System Design

Mechanical Design: The mechanical design of the Smart Shopping Cart involves creating a sturdy framework that can support all the cart's components, such as the motors, wheels, and sensors. The wheels are made of rubber for good grip and smooth movement on store floors. The motor mounts and sensor brackets are custom-built to securely hold the components in the best positions for efficient navigation. The cart is lightweight yet strong enough to handle the necessary hardware, including the RFID system, battery, and control system, while ensuring stability and ease of movement within the store aisles

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Control System Architecture: The Smart Shopping Cart features a line-following system, using IR (infrared) or ultrasonic sensors to automatically guide the cart along a predetermined path in the store. An RFID reader scans the items placed in the cart by reading the RFID tags on them. The reader links each item to its price, which is stored in a database.

The cart uses a microcontroller to process all the data, calculate the total cost of the items, and display the total on an LCD screen. At checkout, the system helps with payment processing and can generate a receipt. This automated system makes the shopping experience smoother by improving navigation, item tracking, and billing.

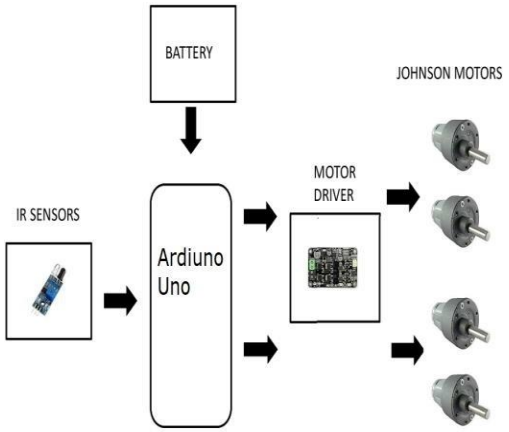

Fig no .2

3.3 Hardware Assembly

Microcontroller: The microcontroller is the brain of the system, controlling everything, from sensor inputs and motor movements to RFID data processing and billing.

IR/Ultrasonic Sensors (Line Following): Positioned beneath the cart, these sensors help the cart follow a line on the floor to stay on track.

DC Motors and Motor Driver: The DC motors move the cart, while the motor driver controls their speed and direction based on signals from the microcontroller.

RFID Reader: This device scans the RFID tags on the products in the cart, sending the product's details to the microcontroller for billing.

LCD Display: The cart uses an LCD or LED screen to show the total cost of the items in the cart, product names, and navigation status.

RFID Tags: Each product is tagged with an RFID tag that stores its unique ID. The RFID reader scans these tags to retrieve the product information.

Battery: A rechargeable battery powers the cart's operations, ensuring continuous use.

Payment Module: A system for contactless payment, such as NFC or a QR code scanner, is integrated to allow quick, easy payments at checkout.

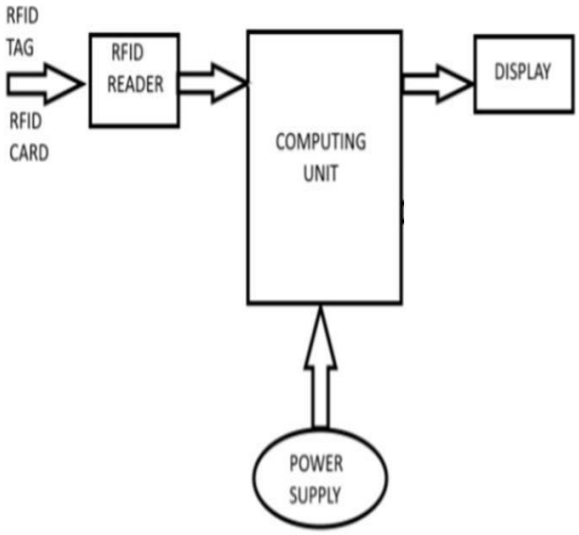

Fig no .3

3.4 Software Required:

- **Arduino IDE:** The software used to program the microcontroller.
- **Embedded C:** The programming language used to write the code for the system.

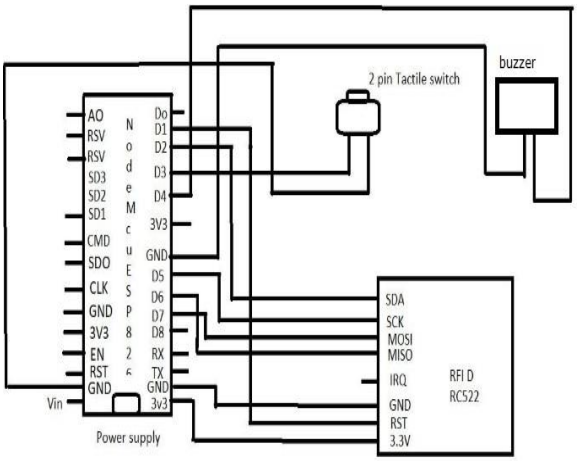

Fig no. 4 successful implementation of Smart Line Following Shopping Cart with Billing System using RFID.

3.5Testing and Optimization

Functional Testing: The first step is to ensure that the cart accurately follows the designated path in the store. This includes testing the cart's ability to navigate and respond to its environment.

Straight Line Navigation: We will test the cart to see if it can follow a straight line. The IR or ultrasonic sensors need to detect the line correctly, and the motors should adjust to keep the cart on track.

Turns and Curves: The cart's ability to navigate turns and curves will be tested to ensure it can stay within the path, even when going around corners or making sharp turns.

Obstacle Detection: If an obstacle appears in the cart's path, we need to confirm that the cart can either stop, avoid, or automatically reroute itself without issue.

Performance Metrics:

Billing System Response Time: The system should update the total price and display it on the screen within 200-500 milliseconds.

Line Following Response Time: The cart's response time for line following should be quick—within a few milliseconds to a couple of hundred milliseconds—so that it can navigate smoothly with minimal delay.

Load Capacity: The cart should be able to carry a range of 5-20 kg (10-45 lbs), depending on the motor specifications. This ensures it can hold a reasonable amount of shopping items.

3.6 Final Deployment

Prototype Demonstration: The Smart Line Following Shopping Cart with its RFID billing system should be demonstrated in a real-world setting to show how it works in action. This helps to showcase its functionality and ease of use.

Documentation: A user guide will be provided, explaining how to use the system, along with technical documentation that outlines the design and operation of the cart.

3.7Accuracy Metrics for the Entire System

Navigation Accuracy: The cart should stay on the predefined path with minimal deviation. During a typical shopping experience, the cart should remain within 5-10 cm of the path at all times, even when navigating turns, avoiding obstacles, or carrying a load.

RFID Billing Accuracy: The cart should accurately scan and add the prices of items to the total bill. The final total displayed should be 99% accurate, matching the sum of the individual item prices.

Overall System Accuracy: The overall error rate for the entire system—covering line-following, RFID scanning, and billing—should be very low. Ideally, the error rate should be less than 1-2%, meaning only a tiny fraction of the cart's movements or scans should result in errors.

4. Results

When a customer adds a product to the smart shopping cart, the RFID tag attached to the product is automatically scanned. The system retrieves the product's details, and these are sent to the microcontroller. Based on the pre-programmed code, the microcontroller generates a bill with all the required information.

As each product is added to the cart, the bill is updated instantly. The updated bill is displayed both on the cart's LCD screen and on a web server. This feature allows customers to view and check the details of the items they've added, ensuring they can easily keep track of their purchases.

Customers can also remove items from their cart if needed. To do this, they simply press a button and scan the item they want to remove, and the system will adjust the bill accordingly.

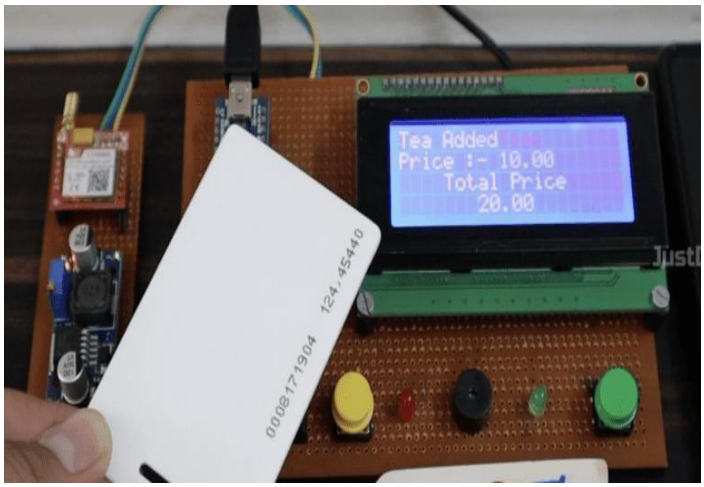

Fig no. 5

5. Conclusion

The main goal of this smart shopping cart is to make the shopping experience easier and more convenient, particularly in busy cities with crowded stores. The cart allows customers to scan and bill their products directly at the cart, eliminating the need to stand in long checkout lines.

The system, powered by a microcontroller (NodeMCU) and RFID technology, is designed to scan products, generate a bill, display it on the LCD screen, and upload the same information to a web server. This enables customers to view and manage their bill from their own devices, enhancing their shopping experience.

6. Future Scope:

The Smart Line Following Shopping Cart with RFID Billing System has a lot of potential for future upgrades. It could be integrated with mobile apps to allow real-time tracking and offer personalized shopping experiences. Using AI, the cart could navigate more effectively and suggest products based on the shopper's preferences. Additionally, it could offer a completely cashless and autonomous checkout process.

Augmented reality (AR) could enhance in-store navigation, making it easier for customers to find what they're looking for. The system could also use IoT technology for smarter inventory management and data sharing between stores. Future versions might focus on using eco-friendly materials and energy-efficient designs. Moreover, this technology could be rolled out across global retail chains, providing a consistent and automated shopping experience in stores everywhere.

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