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SMART-Smart Mobile Autonomous Robotic Trolley

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Abstract: ***The traditional shopping experience in malls and complexes often entails time-consuming billing processes, leading to long queues at cashier counters, inefficiencies in analysing purchased items, and challenges in navigating vast product selections. In response to these issues, the proposed work focuses on developing a Smart Trolley system aimed at streamlining the shopping process, enhancing convenience for customers, reducing workload on both customers and salespeople, and facilitating easier product navigation within the premises. The Smart Trolley system utilizes an Espressif8266 (ESP8266) microcontroller integrated with various components, including a Espressif32 (ESP32) Cam (QR scanner) for item recognition, a webserver to access bill from mobile devices, and a GPS module for location tracking and navigation assistance. Through the integration of these technologies, customers can scan items as they place them in the trolley, view a real-time list of scanned items on the trolley's display screen, and complete the checkout process directly from the trolley interface, eliminating the need to visit traditional billing stations. Furthermore, GPS functionality enables personalized navigation assistance, guiding customers to specific products or locations within the store based on their preferences or shopping list. The development of the Smart Trolley system represents a significant step towards revolutionizing the shopping experience, offering increased efficiency, convenience, and security for both customers and salespeople. Through iterative design, integration, and testing, a robust and user-friendly solution poised to enhance the retail landscape and set new standards for shopping convenience in modern establishments was created***

Keywords: Smart Trolley, Autonomous Robotic Cart, QR Code Scanning, ESP8266, ESP32-CAM, IoT, Real-Time Billing, GPS Navigation, Web-Based Payment, LCD Display, DC Motor Control, Battery Management System, Remote Mobility, Retail Automation, Inventory Management.

I. INTRODUCTION

In today's fast-paced retail environment, customer satisfaction and efficiency are paramount. Traditional shopping involves manual billing at the checkout counters which can result in long queues leading to customer dissatisfaction, increased labor costs, etc. With the improvement in technology, there is a growing demand for innovative solutions that can improve customer experience and optimize the store operations at the same time. The concept of a "SMART Billing Trolley" emerges as a groundbreaking concept to address these challenges. This system integrates technologies like QR Code scanning, IoT(Internet of Things), GPS and real time data processing to automate the billing process inside the shopping cart. In an increasingly digital world, QR codes have emerged as an efficient and versatile tool to bridge the gap between digital and physical worlds at a pocket-friendly cost [14].In the proposed work, a system is designed to enable customers to scan the QR codes on items, providing them with the total bill amount and product details[4][6][9]. The system is designed to wirelessly transmit information about all purchased products to the supermarket's website, enabling customers to conveniently pay their bills through the website using their mobile phones.

II. LITERATURE REVIEW

Several smart trolley systems have been proposed in recent years to enhance the retail shopping experience. Mayur Sanap et al. developed a SMART autonomous trolley integrating RFID-based billing and ZigBee communication for low-power data transmission, along with mobility switches for easier navigation [1]. Sakshi Maurya et al. implemented an IoT-based smart trolley using NodeMCU, enabling real-time cloud-based billing and inventory tracking [2]. Tapan Kumar Das et al. utilized the ESP8266 Wi-Fi module to support web app integration for inventory management and e-bill generation [3]. Dipika D. Pradhan et al. introduced a Raspberry Pi-based system incorporating QR code scanning and LCD display for automated billing [4].

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Vidya Palve et al. proposed a "Smart Trolley in Mega Mall" using an AVR microcontroller and rechargeable battery for uninterrupted operation and coordinated control [5]. Mahesh Kumar et al. further extended the concept with an intelligent trolley using Raspberry Pi, integrating automated billing and real-time data management to reduce checkout times [7].

III. PROPOSED SYSTEM

A. *System Architecture*

As shown in Figure.1, the system consists of three important parts:

1) Trolley Control System: It is responsible for the movement and speed control of the trolley. It consists of components like GPS module, motors and motor driver IC[1]. It is shown in Figure 1 as TCS.

2) Shopping Control System: It is responsible for the scanning of items and bill generation. It consists of components like QR code scanner, LCD display and a webserver for billing. It is shown in Figure 1 as SCS.

3) Battery Management System: The trolley system uses 3.7V Li-ion batteries for motor control, while the shopping system runs on 6V AA batteries for the ESP32-CAM and LCD, both with independent power sources and on/off switches for efficiency. It is shown in Figure 1 as BMS.

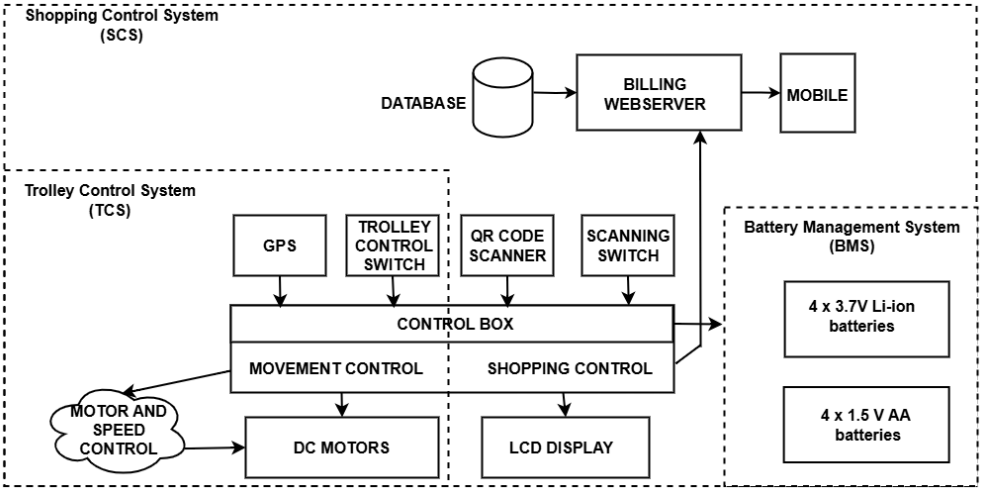


Figure 1: Block Diagram of System Architecture

B. *SystemMethodology*

The Smart Mobile Autonomous Robot Billing Trolley (SMART) is a blend of mechanical, software and hardware components consisting of two parts[1]:

1) Trolley Control System: This system controls the mobility of the trolley such as left, right, forward, backward and speed control. Hence, it includes parts like Motors, GPS, and an ESP-8266[1].

2) Shopping Control System: This system controls the entire billing process by calculating the total amount, checking the expiry date, payment gateway, and generating the bill. Hence, it includes parts like QR code scanner, LCD display, a website for the trolley (or supermarket) and a database[3].

IV. TROLLEY CONTROLLING SYSTEM

A. *Mechanical Structure*

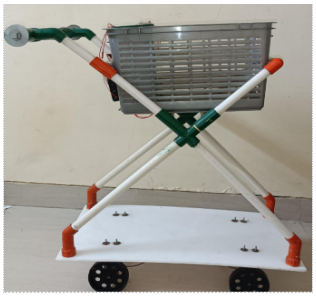


Figure 2: Trolley Mechanical Design [1]

In mechanical structure there are three parts: The first part is the acrylic sheet which is used in making the base of trolley and the control box. The second part is the polyvinyl chloride pipes and joints which are used in making the structure of the trolley. The third important part is the basket which is used to store the products[1].

B. Motor Control

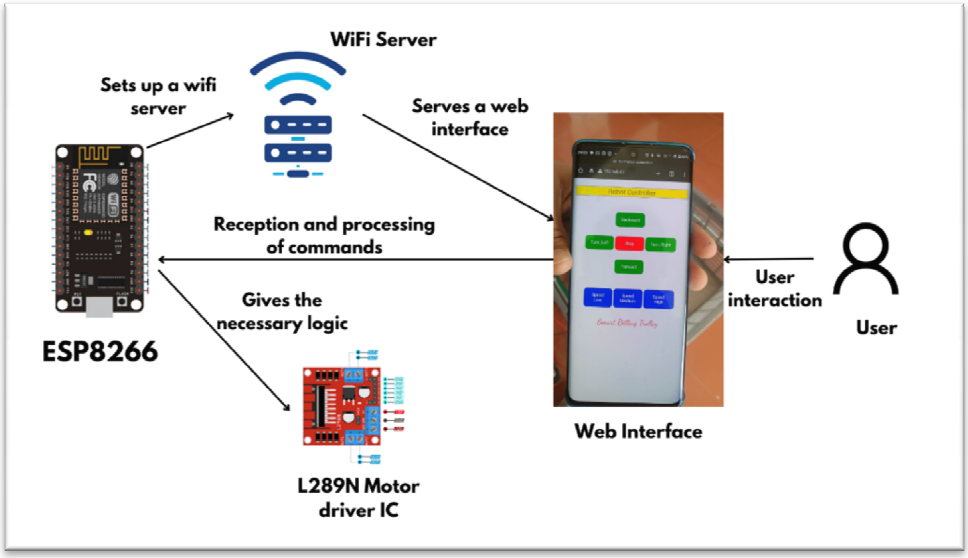


Figure 3: Motor Control via Webserver

1) Motor Control via Webserver: This system implements wireless motor control using ESP8266 microcontroller, an L289N motor driver and a web-based interface. The ESP8266 (NodeMCU) functions as both a Wi-Fi Access Point (AP) and a Web server, allowing remote control of the motors via a browser[19][20]. The L289N motor driver interfaces with the motors, providing control over their direction and speed[12]. The Web interface features buttons for various commands, including movement controls (forward, backward, turn left, turn right, and stop) and speed settings (low, medium, and high)[22]. Real-time communication is facilitated through WebSocket technology, enabling low latency command transmission for seamless motor operation[22][23].

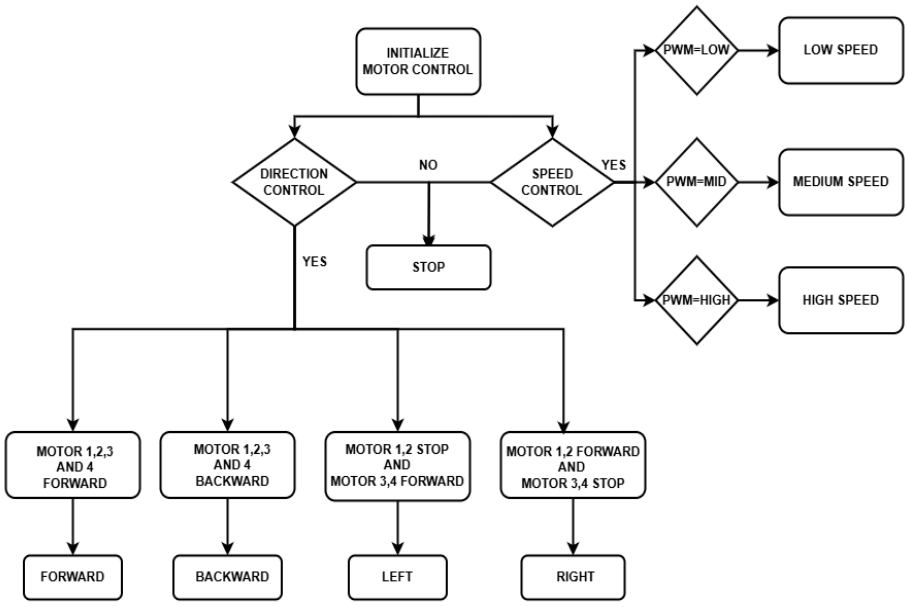


Figure 4: DC Motor Speed and Direction Control

2) DC Motors: The Figure.4 shows the algorithm used for speed and direction control of the motors. The trolley is installed with four 60 RPM, 12V DC motors. For controlling the direction of motors, a L289N motor driver IC is used[10][12]. The motors are installed at four corners of the base at a particular distance below the base so that the wheels do not touch with the base ceiling. In order to avoid this the motors are installed on a wooden block connected to the base[1].

C. Control Box:

It consists of 3 major components as shown in the Figure 5

1) ESP8266 Microcontroller: The ESP8266 is a low-cost Wi-Fi microcontroller designed for IoT applications, featuring a 32-bit RISC processor (Tensilica L106) running at up to 80 MHz It includes 64 KB of instruction RAM, 96 KB of data RAM, and built-in Wi-Fi (802.11 b/g/n) supporting station and access point modes. With up to 17 GPIO pins, it enables digital I/O, PWM, UART, SPI, and I2C communication. The ESP8266 supports a two-stage boot process, real-time operating systems (RTOS), and multiple power-saving modes, making it ideal for battery-operated and standalone Wi-Fi applications[21].

2) NEO-M6 GPS Module: By integrating the NeoM6 GPS module with the ESP8266, the system enables precise tracking of the device's geographical coordinates in real-time[10]. Through a user-friendly interface accessible via smartphones, tablets or computers users can remotely interact with the trolley to retrieve its location. The system uses Google Maps API to display the trolley's location in real-time and is thus reliable and accurate.

3) L289N Motor Driver IC: SMART is installed with four 60 RPM 12V DC motors and for controlling the direction and speed of motors the L289N motor driver IC is used[10].

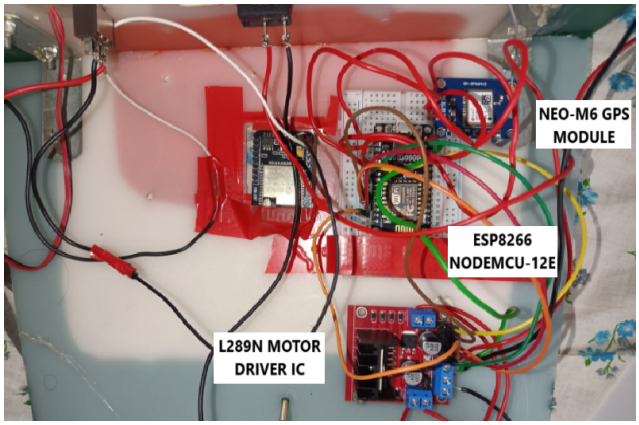


Figure 5: Control Box Circuitry

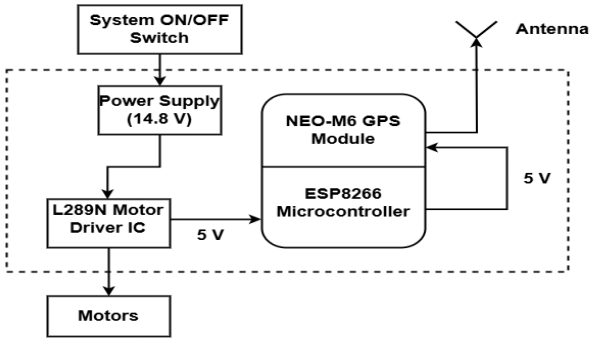


Figure 6: Control Circuit Block Diagram

D. Control Panel

The Control Panel consists of all physical switches and a 16x2 LCD display. System ON/OFF switch is used to disable or enable supply from all circuit connected in SMART trolley[1]. The QR code scanner ON/OFF switch is used to enable or disable the power supply to the ESP-32 cam module to save power consumption and avoid heating. The LCD display is used to display the item details.

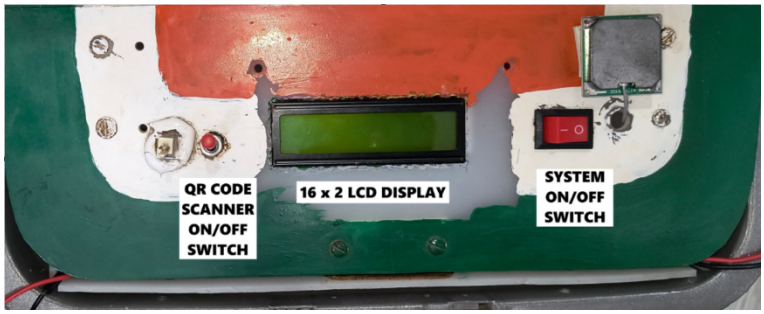


Figure 7: Control Panel

V. SHOPPING CONTROL SYSTEM

The SMART shopping trolley has several features to give the customers more autonomy in the shopping experience. The Shopping Control System is divided into 3 parts as shown in Figure. 8

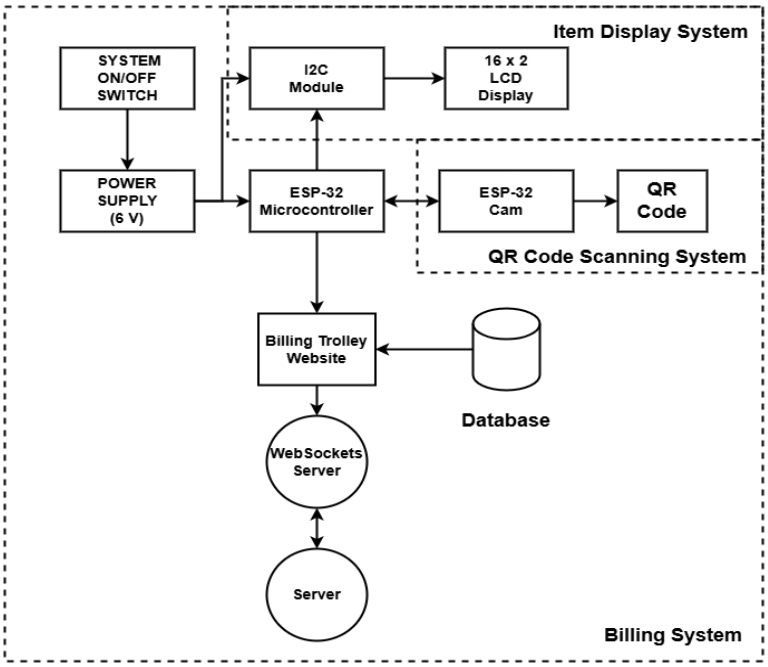


Figure8: Shopping Control System

A. QR Code Scanning System

In this proposed system, an ESP32-CAM module was integrated to perform QR code scanning, leveraging its onboard camera for image capture and the ESP32QRCodeReader library for efficient QR code detection and decoding [8][16][17]. This setup enables the system to scan and decode QR codes containing essential product information such as name, weight, price, and expiry date. The QR code data follows a structured format (name:weight:price:expiryDate) for easy parsing and validation[4][6][9].

To prevent duplication, the system maintains an in-memory list of scanned items and cross-references each scanned QR code with this list. If an item has been scanned previously, it is skipped; otherwise, the data is processed for further actions. This method ensures accurate tracking of unique items and prevents redundant entries.

The system is also designed to communicate with a remote web server over Wi-Fi. Upon successfully decoding a QR code, the extracted information is sent to the server for remote storage and monitoring[16]. The HTTPClient library is used to create a POST request containing the QR code data, serialized in JSON format[3]. This server communication allows the system to update records in real-time, making it suitable for applications like inventory management or product tracking[2].

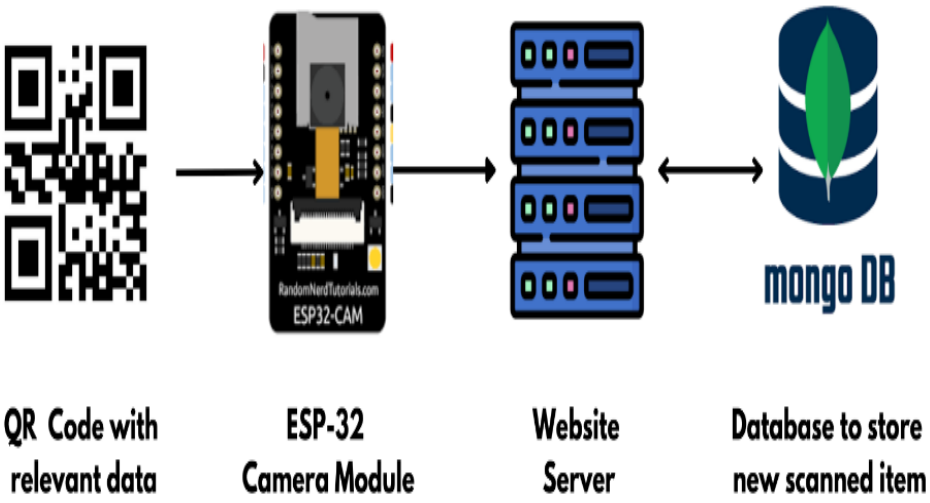


Figure 9: QR Code Scanning

B. Item Display System

The item display system uses a 16x2 LCD to show scanned item details. After scanning a QR code, the system parses the payload for item information, including name, price, weight, and expiration date. For a successful scan, the item's name and price are displayed briefly on the LCD[1] [4]. Additionally, the screen provides status messages, such as "Item Scanned!" or prompts such as "Place QR Code" when waiting for input, as shown in Figure. 11 [4]. The LCD ensures real-time feedback, enhancing user interaction with clear and concise information.



Figure 10: Status Message: "Place QR Code"

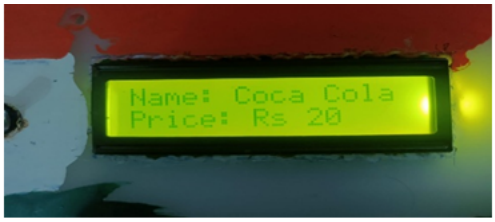


Figure 11: Individual Scanned Item

C. Billing System

The Billing System is divided into 5 steps:

Step 1: Transfer of Trolley ID and Items to the website

Step 2: Item Quantity Updating and Expiry Date Detection

Step 3: Calculation of Total Amount

Step 4: Payment Gateway and Bill Generation

Step 5: Database Cleaning and Logging of Transactions

1) Transfer of Trolley ID and Items to the website: Each trolley is uniquely identified by the MAC address of the ESP-32 CAM module, which serves as the trolley ID. This ID is used during the customer login process, along with their name and phone number[4][18]. The system looks for all the scanned items in the database which have this trolley ID associated with them and populates the cart. When a new item is scanned, a WebSocket event labelled" ITEM ADDED" is emitted to notify all connected clients in real time[23]. This ensures efficient and instantaneous synchronization of the cart contents across all devices, facilitating seamless management and monitoring of the shopping experience.

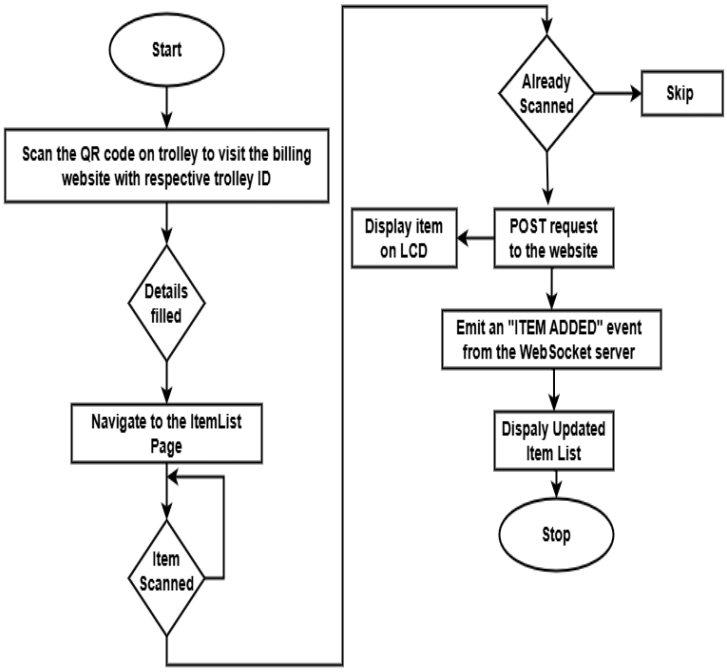


Figure 12: Item and Trolley ID Transfer Algorithm

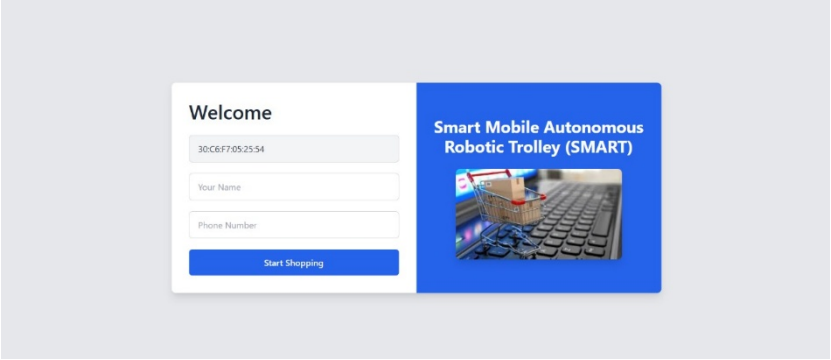


Figure 13: Website Login

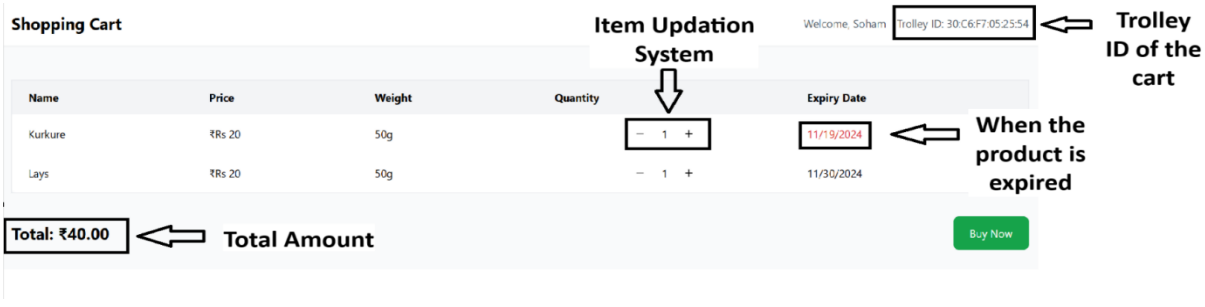


Figure 14: Billing Panel

2) Item Quantity Updating and Expiry Date Detection: The Item Quantity updating is handled in real time using WebSocket, when a quantity is updated on the website an"ITEM UPDATED" event is emitted which is received by all the connected clients and the quantity is updated in the database as well as on the website in real-time[18][23]. The Expiry Date Detection system checks the expiry date of the product against a threshold date i.e. the current date and if the expiry date of the product is less than equal to the current date the product is flagged as expired and displayed in red on the website[1].

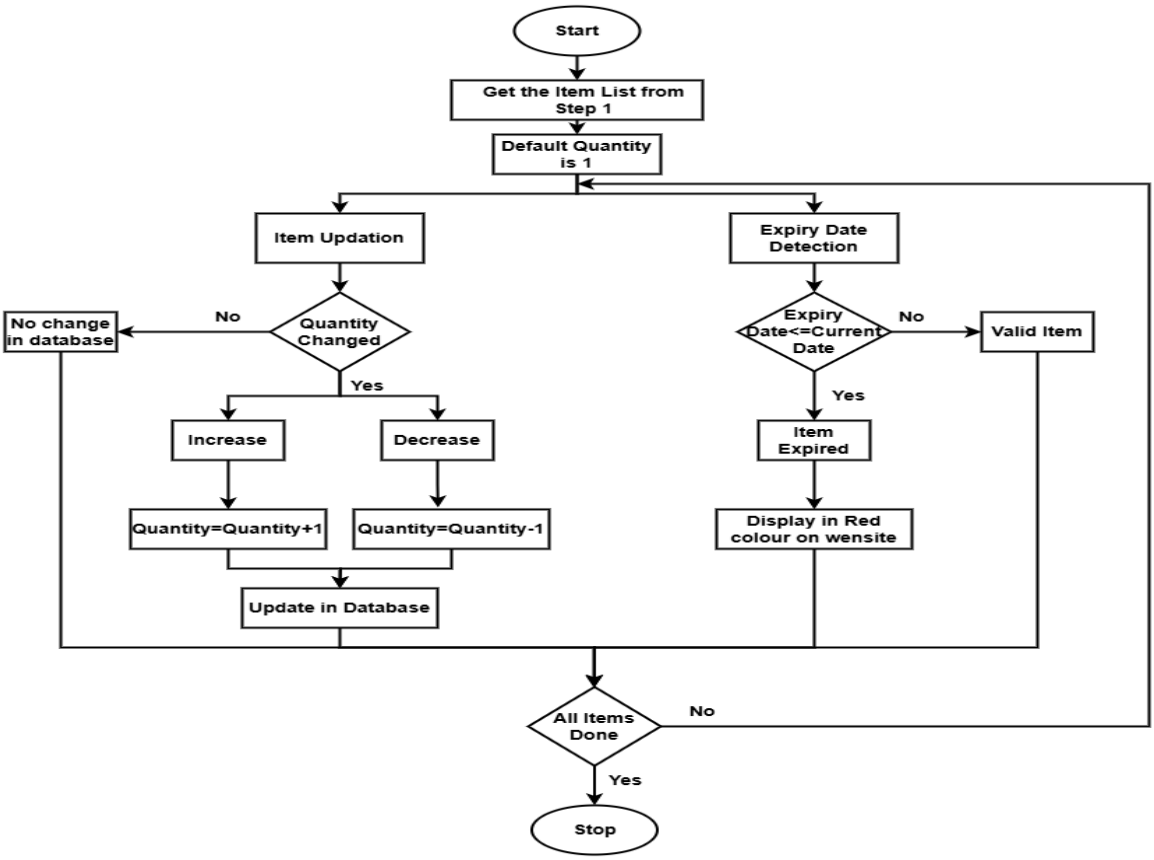


Figure 15: Item Updating and Expiry Date Detection Algorithm

3) Calculation of Total Amount: For this step, the Item Quantity is received from the step 2 and based on whether thequantity is increased or decreased, the total amount is calculated based on the algorithm shown in figure 16.

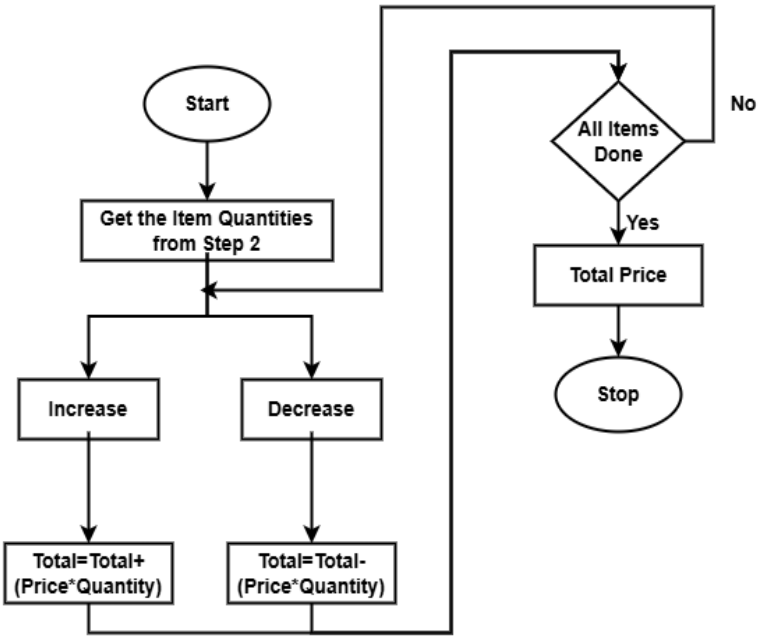


Figure 16: Algorithm for Calculating Total Amount

4) Payment Gateway and Bill Generation: The payment gateway and bill generation process, as outlined in the figure 18 is designed to ensure a user-friendly experience for online transactions. The process begins by calculating the total amount payable dynamically fetched from the system. Users are presented with a decision point where they can either proceed to payment by selecting the"Buy Now" option or return to continue shopping. If the user chooses to proceed, the system redirects them to a payment gateway. Here, users input their payment details, such as card information[4]. In case of an unsuccessful transaction, the system loops back, allowing users to re-enter their details. Upon successful payment confirmation, the system generates a detailed bill dynamically incorporating the user details and the cart details which is downloaded to the user's device [15].

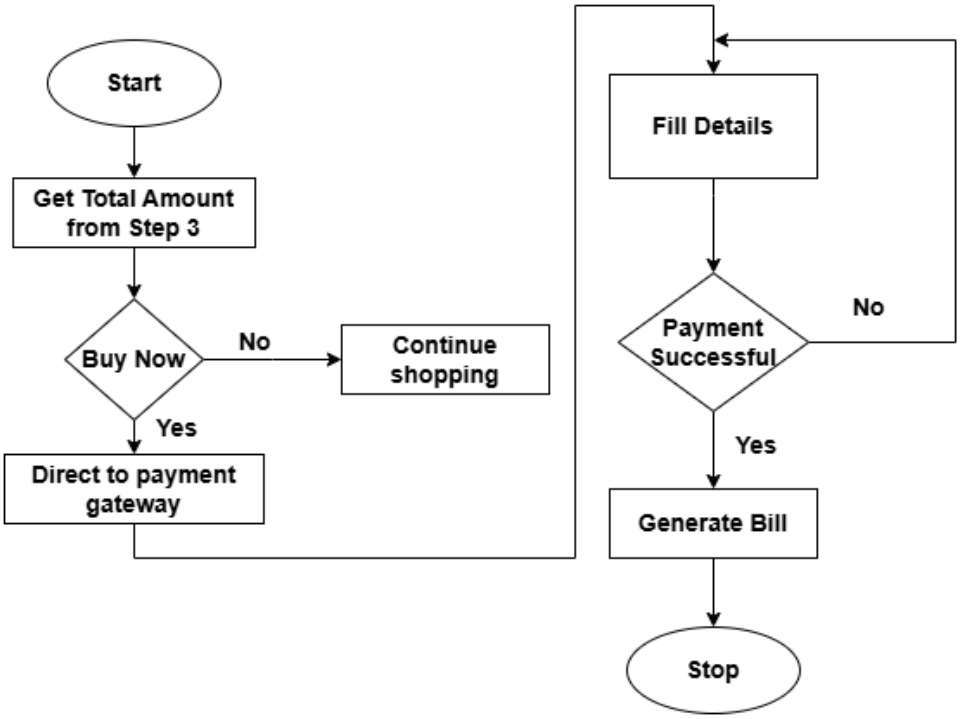


Figure 17: Bill Generation

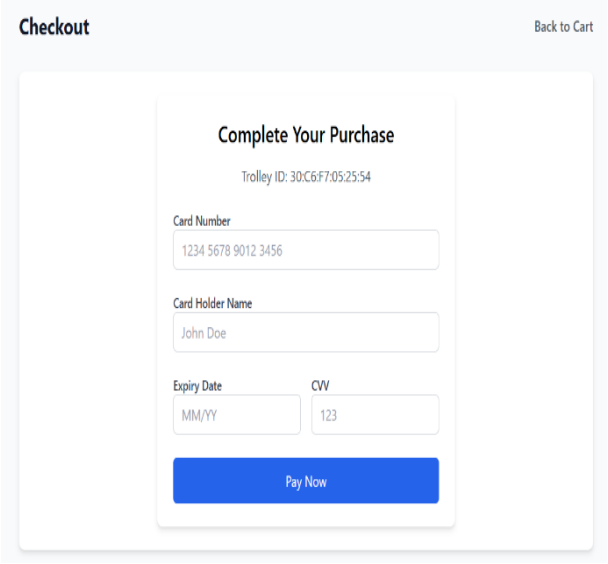
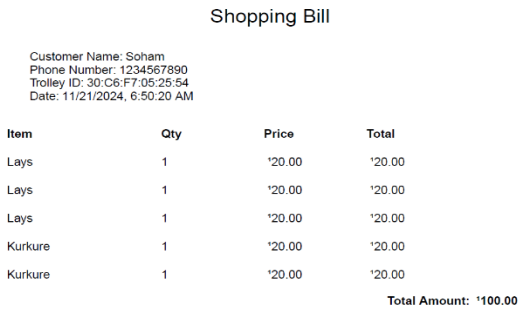


Figure 18: Payment Gateway



Shopping Bill

Customer Name: Soham
Phone Number: 1234567890
Trolley ID: 30:C6:F7:05:25:54
Date: 11/21/2024, 6:50:20 AM

Item	Qty	Price	Total
Lays	1	₹20.00	₹20.00
Lays	1	₹20.00	₹20.00
Lays	1	₹20.00	₹20.00
Kurkure	1	₹20.00	₹20.00
Kurkure	1	₹20.00	₹20.00

Total Amount: ₹100.00

Figure 19: Generated Bill

5) Database Cleaning and Logging of Transactions: Upon successful payment, the records associated with the trolley ID in the primary database are removed, ensuring the database remains optimized[1]. Simultaneously, the item details, along with customer and payment information, are transferred to a dedicated analytics database[15]. This approach minimizes data redundancy, enhances system efficiency, and ensures the security and immutability of transactional data for future analytical use.

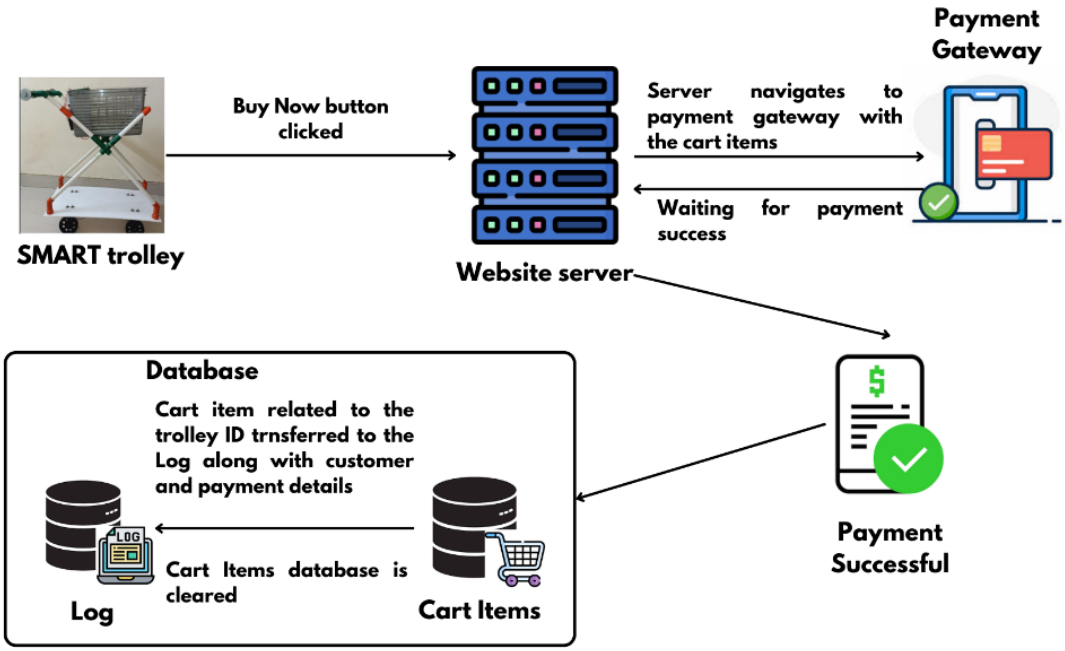


Figure 20: Database Cleaning and Transaction Logging

VI. BATTERY MANAGEMENT SYSTEM

The battery management system for the trolley controlling and shopping systems is designed to ensure efficient power delivery and minimize energy consumption. The trolley controlling system is powered by four 3.7V Li-ion rechargeable batteries connected in series, supplying sufficient voltage to an L298N motor driver IC. This motor driver not only powers the motors but also provides a stable 5V output for the ESP8266 module. To optimize energy use, the system includes a dedicated on/off switch, allowing manual control of the power supply when the system is idle. The shopping system operates independently, using four 1.5V AA batteries connected in series to provide a 6V power supply. This voltage powers the ESP32-CAM module, which serves as the central controller for the system. The ESP32-CAM module also supplies power to the I2C LCD display. Similar to the trolley system, the shopping system features its own on/off switch to conserve battery life when not in use. This dual- system approach, with separate power sources and independent control, ensures reliability and energy efficiency. The inclusion of manual switches in both systems reduces unnecessary power consumption and extends battery life.

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Figure 21: Battery Management System

VII. RESULTS

A. Final Implementation- Hardware

This section details the final hardware implementation of the SMART system. Figure 22 showcases the prototype of the shopping trolley, which is constructed using polyvinyl chloride (PVC) and acrylic materials. Both materials are chosen for their rigidity and lightweight properties. The trolley's framework is built using 1-inch diameter PVC pipes and joints, while the base and control box are made from acrylic sheets. Additionally, a plastic basket is incorporated to hold the products[1].


Figure 22: Trolley Side and Front View

The QR Code Scanner is placed in such a way that itcan focus on scanning of the items irrespective of the itemsorientation as long as the QR code is visible as shown in figure23. The figure 23 shows the output of LCD display at differentstages of shopping.



Figure 23: QR Code Scanner and LCD Display

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B. Final Implementation- Software

The user interface of the billing station is shown in figure 24. A user interface having Customer details trolley details, total shopping amount, product details and expire product indication[1][3]. MongoDB, a NoSQL database, is used as a database for storing data regarding the billing. In the database the trolley ID, items, customer details, date, time and total amount is store[6]. In this prototype the main database containing the scanned items data is cleaned after every customer checkout and the billing data is logged into a separate database to ensure there is no redundancy.

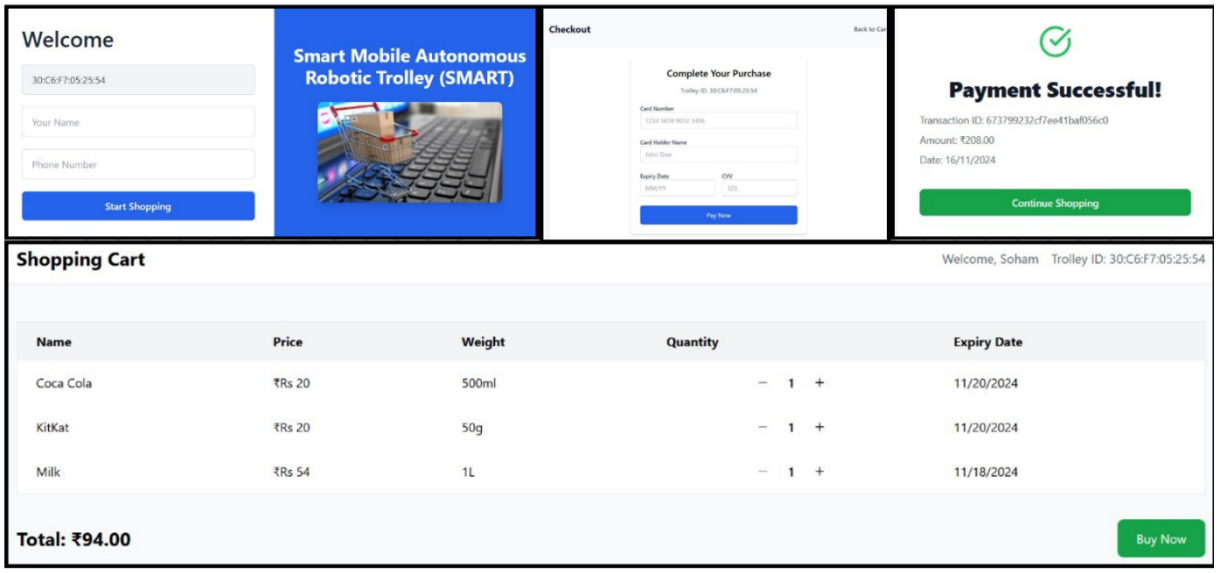


Figure 24: Website User Interface

VIII. CONCLUSION

This paper demonstrates a mechanical framework that can be utilized in trolleys at shopping centres that can carry a weight of 15 kg and an electronic system that can control the SMART Billing Trolley efficiently for more than 4 hours. With the integration of technologies like QR Code scanning, remote mobility control and web-based billing systems, this system shows the potential for seamless automation and enhanced customer convenience. The system's modular design, integrating a Trolley Control System for mobility and a Shopping Control System for item scanning and billing, ensures functionality across mechanical. software and hardware domains. Key features like real-time item tracking, automated billing, and remote payment gateways improve efficiency and reduce workload for customers and sales personnel alike.

IX. FUTURE WORK

The SMART Billing Trolley has successfully demonstrated its potential to revolutionize the retail shopping experience through automation and customer-centric design. there are a few aspects that can be included to make it more robust and economical.

A weight sensor could be added to detect discrepancies between actual weight of items in the trolley and total billing weight for anti-theft measures.[7] Artificial Intelligence could be incorporated to analyse customer shopping habits and provide personalized product recommendations. The logged transaction data can be used for gathering insights on shopping trends, inventory optimization and customer behaviour thus helping the owner operate the supermarket more efficiently[6].

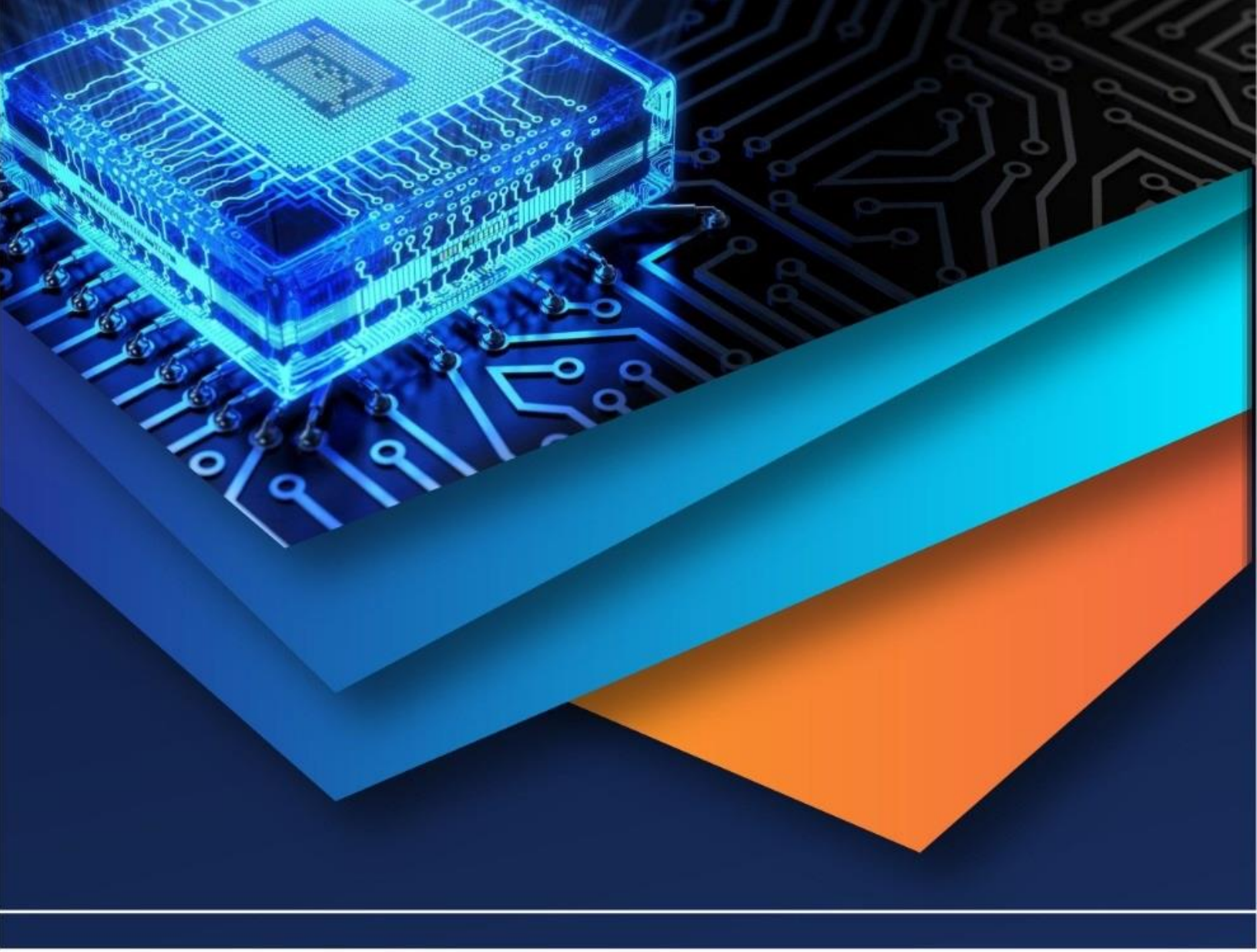
X. ACKNOWLEDGMENT

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