AUTOMATED SHOPPING CART

2023/2024 ACADEMIC SESSION

DEPARTMENT OF MECHATRONIC ENGINEERING

UNIVERSITY OF BENIN

PIUS BENJAMIN CHUKWUEMEKA ENG1904904

UDOGARANYA ONYINYE DANIEL ENG1905682

OFFIA JEREMIAH UGBANA ENG1905720

OSESIAMHE GLORIA OCHUWA ENG1905738

SUPERVISED BY: ENGR. OMOZE J. UNUAREOKPA

CERTIFICATION

This is to certify the research, design and fabrication project titled “AUTOMATED SHOPPING CART”, under the supervision of Engr. Omoze J. Unuareokpa.

Project Supervisor

Project Coordinator 2022/2023 Academic session

Sign: …………………………

Date: …………………………

Sign: …………………………….

PROFESSOR GODWIN EJUVWEDIA SADJERE

Head of department

DEDICATION

Firstly, we want to dedicate this body of work to Almighty God for blessing us with the grace and strength to carry out this project.

To our families, whose support fueled our passion for learning during the course of our academic pursuit.

To the Faculty of Engineering for enriching us with knowledge, ability and the discipline to see this project through to completion.

ACKNOWLEDGEMENT

As a group, we wish to extend our deepest gratitude to the One who makes everything beautiful in His own time, Almighty God. Who has granted us the strength, grace, and wisdom to carry out this project.

We express our heartfelt gratitude to our supervisor, Engr. Omoze J. Unuareokpa for his steadfast guidance and expertise through the duration of this project. Your mentorship has been a corner stone throughout our design and implementation of this project.

We also want to appreciate the Faculty of Engineering, the Department of Mechatronics Engineering and the lecturers who spend their invaluable time imparting knowledge to us their students.

Additionally, we want to thank our families for the unwavering financial and emotional support during this time.

Lastly, we want to thank the pioneers, researchers and developers making advancements in our world of modern technology. We are the future.

ABSTRACT

Our project, the Automated Shopping Cart, is designed to improve inefficiencies in the retail industry. It aims to optimize the retail process by implementing modern technologies to ensure customers have a smoother shopping experience. Some of these technologies include an RFID sensor, Barcode scanners, Computer vision and AI, IOT and wireless communication etc. These working in conjunction with the software (website) enable an automated experience with item recognition, managing of lists and real time billing; all to ensure the customers efficient shopping experience and the retailers more effective management of operation.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

BACKGROUND TO THE STUDY

In recent years, the retail industry has undergone a remarkable transformation due to the introduction of new technologies designed to increase efficiency, enhance the customer experience, and provide greater economic benefits.

Retailers are increasing using digital technology, from consumer electronics to advanced analytics, to simplify operations and meet the needs of today's customers. But despite success in many areas, a major problem remains: inefficiencies in the supply process, especially at the checkout process. Customers often experience delays at billing counters, leading to dissatisfaction and frustration, while retailers face operational challenges such as human errors in billing and resource constraints.

Shopping carts, although commonly used in the retail industry, have remained largely unchanged for decades, serving as mere carriers for goods. The introduction of automation to shopping carts presents an opportunity to reinvent the shopping experience. Modern technologies such as Radio Frequency Identification (RFID), sensors, and the Internet of Things (IoT) can transform shopping carts into intelligent systems capable of automating important processes. The Automated Shopping Cart is a novel solution that integrates these technologies to make possible automatic item detection, real-time billing, and seamless integration with payment systems. This innovation not only addresses existing inefficiencies but also aligns with the global push towards automation and smart retailing.

PROBLEM STATEMENT

The traditional shopping experience, although proven to be functional to a proper degree, is fraught with inefficiencies, particularly at checkout counters. Customers regularly stand on long queues during peak shopping hours, which not only wastes time but also reduces satisfaction. Retailers, on the other hand, struggle with issues such as inaccurate billing, theft, and dependence on manual processes, which can lead to operational inefficiencies and financial losses.

Although automated checkout systems have been installed in some retail outlets, they still require a lot of user experience and do not prevent errors or misuse. In addition, small and medium-sized retailers often find the costs of these machines prohibitive. It is important to be efficient in implementing the purchasing process from product selection to payment, using effective solutions so that bottlenecks are eliminated, not obstructing traditional processes and improving overall performance.

AIM

The primary aim of this project is to design and develop an Automated Shopping Cart that makes use of modern technologies to provide a seamless and efficient shopping experience. The system will enable automatic item detection, real-time billing, and integration with digital payment platforms, reducing checkout times and enhancing customer satisfaction.

OBJECTIVES

1. To design a smart shopping cart equipped with advanced technologies such as RFID and sensors for automatic item detection and tracking.

2. To develop a software system capable of real-time computation of total costs as items are added or removed from the cart.

3. To create an intuitive interface for customers, displaying item details, prices, and the total bill in a user-friendly manner.

4. To assess the performance of the Automated Shopping Cart in reducing checkout times and errors compared to conventional methods.

5. To explore potential integration with existing retail systems, including mobile payment applications and inventory management platforms.

6. To evaluate customer satisfaction and operational efficiency through pilot testing in a simulated retail environment.

SCOPE

This study focuses on the development of a prototype Automated Shopping Cart tailored for medium to large-scale retail environments. The project encompasses both hardware and software development, including the integration of technologies for automatic item detection, real-time billing, and digital payment processing.

The study does not include large-scale implementation challenges such as cost analysis for mass production, compatibility with all retail management systems, or regulatory considerations for widespread adoption. Future research may explore these aspects for broader application.

RELEVANCE OF THE STUDY

The Automated Shopping Cart has immense potential to revolutionize the retail shopping experience by rectifying one of the most common challenges faced by customers and retailers alike: inefficiency at checkout. By automating item detection and billing, the system greatly reduces the time spent in queues, enhances the accuracy of transactions, and improves overall customer satisfaction.

For retailers, the Automated Shopping Cart allows for an opportunity to streamline operations, reduce dependency on manual processes, and minimize errors and losses. The project aligns with the global trend of adopting smart technologies in almost all aspects of human life including retail, contributing to the advancement of automation in the sector.

Additionally, the study provides a framework for integrating modern technologies into everyday processes, highlighting the role of IoT, sensors, and automation in creating intelligent systems. The insights gained from this research can serve as a foundation for further innovations in the retail industry, offering a roadmap for the development of cost-effective, scalable, and customer-centric solutions.

CHAPTER TWO

2.1 INTRODUCTION

Automated shopping carts have been an area of growing interest in the field of retail technology. Researchers have explored various aspects of these systems, ranging from their design and functionality to their impact on consumer behavior and store operations.

As customer preferences shift towards speed, convenience, and personalization, traditional retail operations are undergoing significant transformation. This chapter provides an in-depth review of the literature on automated shopping baskets, exploring the technologies, methodologies, advantages, challenges, and future directions in the context of retail automation. Here's an overview of previous research in the area of automated shopping carts:

2.2 HISTORY OF AUTOMATED SHOPPING CART

The First shopping cart was invented by Sylvan Goldman in June 4, 1937, along with his brother Fred. With the introduction of shopping carts shoppers were able to carry big items and a lot of items at once. This made shopping a lot easier and revolutionized the shopping industry.

In our busy life of retail, we have that silent friend called a shopping cart that assists us in collecting items while our search for things continues. Unbelievable as it sounds, this humble invention is an important milestone with more than a one-century-old history. Today’s shopping cart is a far cry from its simple wooden predecessor and has transformed the entire notion of shopping.

Therefore, in this exploration, we’re going to discuss the history of the shopping cart that took place from the late nineteenth century until the digital era.

Autonomous shopping carts are the most recent manifestation of the evolution of shopping carts in the 2020s. The automated, self-driving shopping carts that can follow a customer, scan items, and even help with bagging groceries are the best examples of such products. The innovation could further enhance shoppers' convenience and save them more time. Autonomous shopping carts make shopping for customers easier by acting almost like personal shopping assistants, following them around as they browse the store, keeping track of items, and streamlining the checkout process.

Using the most modern technology of computer vision and artificial intelligence, these self-guiding carts are aimed at radically changing a traditional in-store shopping process and providing easier access to the products to people with some physical limitations. It is a decade that has prepared a new generation of shopping cart innovation, which is still based on the use of technology in order to provide modern customer requirements.

2.3 REVIEW OF PAST TECHNICAL REPORT

In the 1930s, Sylvan Goldman, who owned a grocery store in Oklahoma, noticed that the traditional shopping devices were unable to satisfy the needs of the customers and retailers. It was Goldman's insights and innovative spirit that led him to invent the world's first true shopping cart, which has revolutionized how we shop today. It had a four-part, folding frame structure made of metal with the market cart hanging down off it.

Goldman's cart had a lot of storage facilities, which was not the case with older ones, making shopping much easier. At the outset, his sharp-witted idea was met with resistance by the customers, but soon he gained acceptability that birthed the modern shopping cart, which is now a fixture in almost every grocery store or supermarket, thus showcasing what an imaginative mind can do in influencing

Together with his brother Fred, Sylvan Goldman invented and implemented the world's first-ever trolley or shopping cart in 1937. They invented this four-wheeled, foldable carriage, which incorporated a basket-like structure attached to the metal framework along with tiny wheels.

Sylvan Goldman Inventor of Shopping Cart

The introduction of this cart was a great relief for shoppers. They were able to carry bulkier items, and the process of shopping became easier for them. This gave birth to a retail revolution that has affected global consumers for centuries.

Initially, the shopping cart faced resistance owing to its practicality and convenience. The gadget was a new invention that people hesitated to accept. They used witty names for it, such as the "whisker biscuit" and "basket on wheels."

The playful nicknames mirrored one's doubt with that novelty shopper guide. As the initial resistance towards the product's usage, Sylvan Goldman tried a good trick. He recruited some people pretending to be "shoppers" who pushed trolleys through the store in order to create a feeling that he was accepted by society. This innovative marketing approach assisted clients to get over their fears and opened the door for the shopping cart, which is now popular in the world of business.

However, it became apparent that these shopping carts were convenient and useful during the 1940s, thus creating a market demand for the carts among retailers and customers as well. It was this age that would see the introduction of some crucial developments that made the shopping experience more fun. The retailers recognized that large storage capacity was desired, and the manufacturers provided them with shopping carts with expanded baskets.

Moreover, a child seat also became part of the design, which further enhanced shopping trip friendliness for parents, who could now easily move around with their children through shopping centers. These additional features, together with its original function of facilitating movement in grocery stores and supermarkets in the United States, made it an essential tool. Shopping carts ceased to be an innovation and became a part of modern stores where the convenience of shoppers takes the first priority.

The 1950s marked a major revolution in the development of shopping cart features that we are familiar with today. In this period of time, manufacturers reacted to the need of buyers to improve toughness, bigger storage space, and better movement. Thus, shopping carts were built using strong metal frames, making them durable and hardy, vital attributes needed for daily usage purposes.

In response, extra large storage compartments were added where customers could comfortably carry different types of commodities that they wanted to buy. Smooth-rolling wheels were also introduced, leading to improved mobility within stores, therefore making shopping easier and quicker. However, the contemporary shopping cart still largely adopts the same framework that was instituted during the 1950s; hence, this ingenious invention is a successful and functional one.

This led to continual development and adaptation of shopping carts since they became more and more prominent in the whole shopping process. Shopping carts have undergone several transformations in response to shifting customer and retail business expectations. This was to enhance convenience, durability, and the overall shopping experience, demonstrating the retail industry's efforts to remain relevant to its consumers.

In the 1970s, there were serious modifications in the way shopping carts were constructed, which replaced old-fashioned metal carts with plastic grocery carts. The plastic carts had numerous benefits that addressed the major issues. Firstly, they were light, thus easy to move around by the buyers and shop attendants. Additionally, plastic carts were easy to clean and maintain, which was vital in consideration of hygienic conditions at that time.

They also did not get rusted as easily as the previous ones, which further increased their life span and lowered the cost of maintenance. Moreover, this helped to keep their appearance clean and new. Plastic shopping carts were also cheap and affordable to most retailers. The move to plastic as the new industry standard can be considered a very reasonable and intelligent response to the increasing needs of both retailers and buyers, which has resulted in a continuous evolution of the shopping cart to better meet the requirements of the users.

It is notable that in the 1980s, there was a remarkable innovation that led to the adoption of swivel wheels for the world of shopping carts. Prior to this development, traditional carts were only wheeled, and this made the traditional carts difficult to maneuver through the busy aisles of the stores. The swivel wheels enabled better navigation in narrow areas and within the store arrangement.

This improvement greatly enriched the customers' shopping experience as it minimized the irritation caused by walking down congested aisles. The introduction of swivel wheels made the shopping cart more convenient to use but increased sales for retailers and efficiency of store layouts. Adaptations of this device in the 1980s showed the continuation of efforts to create the perfect tool for changing the retail world.

Supermarkets also noticed the need to serve family shoppers and made significant changes in the design of shopping carts in the 1990s. The adaptations were made specifically for family shopping. Significantly, shopping carts with child seats were among some of the additions. In a nutshell, this made it possible for parents to safely and easily move around with their small kids as they went about buying. More convenience in shopping was provided to parents since through cup holders, drinks and snacks could be easily accessible when required.

These innovations not only made shopping enjoyable among families but also encouraged parents with young children to frequently visit the supermarket, showing that grocery stores are accommodating places for the family. There was a lot of evolution involved in the design of shopping carts in the 1990s as it aimed at enhancing user experience and meeting the needs of different users.

The start of the century marked a chapter, in the evolution of shopping carts as technology advanced and opened up new possibilities. Retailers and tech companies saw the potential, for using solutions to improve the shopping experience. As a result smart shopping carts emerged as a game changer integrating technology to make shopping more convenient, efficient and engaging.

This has resulted in the creation of shopping carts, which have the potential to completely transform the shopping experience more. These advanced carts, incorporating technology strive to enhance convenience, efficiency and interactivity during the shopping process.

In the 2000s, the retail underwent a rapid transformation by introducing self-checkout kiosks and scan-able carts. The innovations were based on bar-code scanning and enabled customers to scan and pay while shopping. Such made the checkout shorter, thereby eliminating long queues at traditional registers.

Customers could even scan their own items, checkout, and pay with nothing more than their phones. The adoption of self-checkout technology enhanced efficiency in shopping processes as well as providing convenience for those tech-savvy shoppers. In the 2000s, technology transformed the traditional shopping at the store into a fast and autonomic way to pay, thus altering their experience.

2.4 TYPES OF AUTOMATED SHOPPING CART

Automated shopping carts are tools that enhance the online shopping experience by simplifying and automating various tasks, improving the overall efficiency of the purchasing process. Here are some common types of automated shopping carts:

1. Abandoned cart recovery carts
2. One-click checkout carts
3. AI-powered personalized carts
4. Subscription carts
5. Cart abandonment analytics carts
6. Smart cart with price comparison
7. Multi-channel carts
8. Carts with automatic discounts and offers

1. **ABANDONED CART RECOVERY CARTS**

These systems automatically remind customers about items left in their cart. They may send emails, text messages, or push notifications to encourage the shopper to complete their purchase.

2. **ONE-CLICK CHECKOUT CARTS**

Simplifying the checkout process, these carts automatically fill in a shopper's saved details (like payment information and shipping address), allowing them to complete purchases with a single click.

3. **AI-POWERED PERSONALIZED CARTS**

Leveraging artificial intelligence, these carts analyze user data and behavior to recommend products, apply personalized discounts, and tailor the shopping experience based on past actions.

4. **SUBSCRIPTION CARTS**

These carts enable users to set up recurring payments for products they purchase regularly. The system automatically processes the order at scheduled intervals, making it ideal for subscription-based businesses.

5. **CART ABANDONMENT ANALYTICS CARTS**

Some systems focus on providing insights into cart abandonment behavior, helping merchants identify patterns in lost sales and offering automated solutions to improve conversion rates.

6. **SMART CART WITH PRICE COMPARISON**

These carts automatically compare prices across different online platforms and suggest the best deal to customers. They might also offer automatic coupon application at checkout.

7. **MULTI-CHANNEL CARTS**

These carts sync across different sales channels, like online stores, social media platforms, or mobile apps, allowing users to add items to their cart across multiple devices or platforms and check out seamlessly.

8. **CART WITH AUTOMATIC DISCOUNTS AND OFFERS**

This type of cart applies discounts, promo codes, or offers automatically, based on the user's preferences, cart content, or special promotions running in the store.

These types of carts can be found in e-commerce systems and platforms like Shopify, WooCommerce, or other specialized e-commerce tools, each offering different levels of automation to improve the customer experience.

2.5 TECHNOLOGICAL ADVANCEMENTS IN AUTOMATED CARTS

- Sensor Technologies: Research has explored the use of various sensors (e.g., RFID, weight sensors, and computer vision) to enable carts to track items being added and update the total

  ]

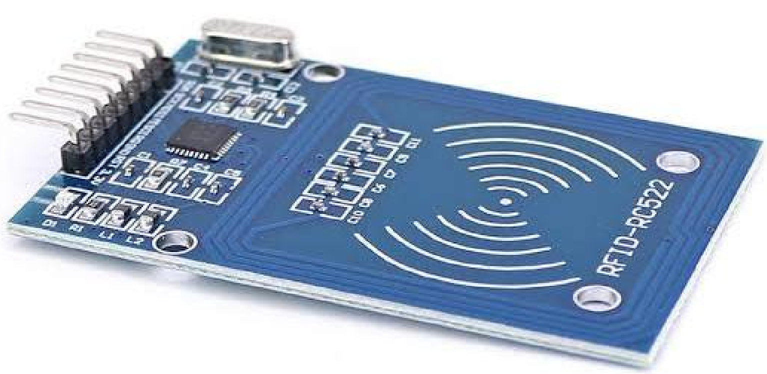


Fig 2.1 RFID Sensor

- AI and Machine Learning: AI has been implemented for object recognition, user behavior prediction, and optimizing the shopping process. Machine learning algorithms can enhance customer experiences by personalizing offers or promotions.
- Robotic Systems: Some studies have examined fully automated robotic carts that can autonomously navigate a store, pick up items, or assist in retrieving products based on the shopper's needs.

2.6 CONSUMER EXPERIENCE AND BEHAVIOR

- Convenience: A key benefit identified in studies is the convenience of automated shopping carts, particularly in reducing time spent in checkout lines. Research suggests that the more efficient the cart, the more likely customers are to adopt it.
- Usability: Many studies have focused on the ease of use of automated carts. Issues like user interfaces, ease of setup, and interaction design have been pivotal. The effectiveness of these carts depends on how well they integrate with existing shopping behavior.
- Privacy Concerns: As some systems track the consumer's movements and purchasing choices, research has examined the privacy concerns related to data collection, especially in light of new data protection laws.

2.7 RETAIL IMPLICATIONS

- Store Operations: Researchers have assessed how automated shopping carts can impact store layout, inventory management, and employee roles. For example, when carts are equipped with sensors, real-time inventory tracking becomes possible, helping retailers streamline stock management.

- Cost-Benefit Analysis: Some studies have focused on the financial viability of automated carts. While the upfront investment in technology can be high, the potential for reducing labor costs and improving the shopping experience may offer long-term savings.

2.8 IMPACT ON CHECKOUT PROCESS

- Seamless Transactions: Automated carts that enable frictionless payment, such as the ability to automatically charge a customer's account upon leaving the store, have been widely researched. This technology can potentially eliminate the need for traditional checkout lines.

- Self-Scanning: Integration with self-scanning systems (such as barcode scanning or RFID) allows customers to scan and track items as they shop, minimizing the chances of errors and speeding up the overall process.

2.9: ROBOTIC ASSISTANCE AND NAVIGATION

- Autonomous Cart Movement: Some studies have focused on how autonomous carts can navigate through stores using sensors and navigation algorithms. These carts can either follow customers or move independently, helping customers find specific items or carry products for them.

- Customer Interaction: Research on human-robot interaction (HRI) in retail settings is growing, focusing on how customers respond to autonomous carts and robots. A major consideration is how consumers trust these systems and whether they feel comfortable with robots assisting them.

2.10: CHALLENGES AND LIMITATIONS

- Technological Limitations: Issues such as system reliability, sensor accuracy, and connectivity have been addressed. Challenges include ensuring carts can navigate complex store layouts, detect misplaced or removed items, and handle various environmental conditions.

- Costs and ROI: The financial costs of implementing automated carts have been a point of debate, especially for small retailers. The research has shown that for the technology to be profitable, it needs to offer significant reductions in labor costs and increase customer satisfaction.

- Consumer Trust: Gaining consumer trust in automated systems is another barrier. Some studies suggest that consumers may be reluctant to use the technology due to concerns about errors in item tracking, data security, or lack of human interaction.

2.11: FUTURE TRENDS

- Integration with E-Commerce: A growing area of interest is integrating automated carts with online shopping systems, allowing for hybrid shopping experiences. These carts could be part of a larger, omnichannel shopping strategy.

- Environmental Impact: There is an increasing focus on sustainability, where automated carts are designed to optimize energy use and reduce waste, such as minimizing packaging or promoting eco-friendly purchases.

2.12: TECHNOLOGIES AND ALGORITHM THAT ARE TYPICALLY USED

Automated shopping carts, also known as "smart carts," utilize a combination of technologies and algorithms to enhance the shopping experience, streamline the checkout process, and optimize customer interactions. Here are some key technologies and algorithms commonly used:

1. Computer Vision

Technology: Computer vision algorithms are used to detect and track products placed in the cart. Cameras and sensors (e.g., weight sensors, RFID) track product movements and update the cart in real-time.

Example: Amazon Go stores use computer vision and machine learning to automatically detect items taken off the shelf and add them to the cart.

2. Radio Frequency Identification (RFID)

Technology: RFID tags are placed on products, allowing the cart to automatically detect the items added or removed. This reduces the need for manual scanning.

Example: In-store automated systems that scan RFID tags to update the shopping cart seamlessly.

3. Sensor Fusion

Technology: A combination of sensors (such as weight sensors, motion sensors, and infrared sensors) work together to detect the presence of items in the cart and the shopper’s interactions with it.

Example: Weight sensors embedded in the cart can track item removals or additions based on changes in weight. Proximity sensor

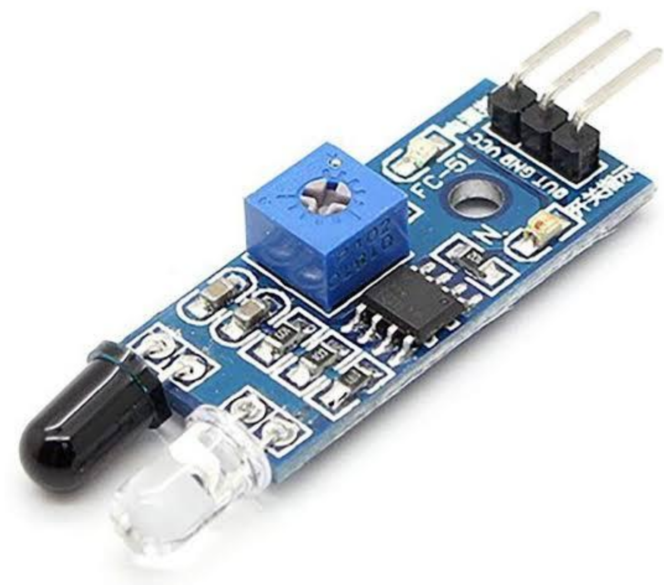


Fig 2.2 Proximity sensor

4. Machine Learning and AI Algorithms

Technology: Machine learning algorithms process the data from various sensors (camera, RFID, etc.) to identify patterns in shopper behavior, product selection, and inventory. AI can also recommend products and optimize the shopping experience.

Example: Personalized product recommendations and dynamic pricing based on shopping history.

5. Neural Networks

Technology: Convolutional Neural Networks (CNNs) are often used for object recognition in computer vision tasks. They help identify and classify products placed in the cart in real-time.

Example: Image processing algorithms that identify different products through cameras mounted on the cart.

6. Wireless Communication (Bluetooth, NFC)

Technology: Bluetooth or Near-Field Communication (NFC) technology is often used to connect the smart cart to a store's centralized system or the customer's mobile app. This allows for seamless transaction updates and real-time inventory management.

Example: NFC-enabled smart carts allowing customers to track their cart total and receive promotions directly to their phone.

7. Mobile Integration

Technology: Mobile apps connected to the smart cart help with inventory, payments, and personalized suggestions. Mobile phones with QR codes or Bluetooth can sync with the cart to streamline the experience.

Example: A customer's phone is paired with the cart to automatically calculate the total cost and push notifications for discounts or sales.

8. Dynamic Pricing Algorithms

Technology: These algorithms adjust the prices of items in real-time based on factors such as demand, stock levels, and customer preferences. This helps the store optimize revenue.

Example: Real-time discounts offered based on customer shopping behavior or loyalty.

9. Cloud Computing and Data Analytics

Technology: Cloud-based systems collect and analyze vast amounts of data, enabling real-time inventory tracking, order processing, and customer analytics.

Example: Centralized data systems that track each customer's cart, provide personalized recommendations, and ensure stock levels are updated instantly.

10. Predictive Analytics

Technology: Predictive algorithms use historical data, such as a customer's past shopping behavior, to suggest products or even automate the shopping list creation.

Example: Shopping carts that predict items the customer might want to buy based on their past purchases or seasonal trends.

11. Blockchain (Optional for Payment and Security)

Technology: In some cases, blockchain technology is integrated to provide secure transactions, traceable inventory, and fraud prevention during automated payments.

Example: Smart contracts for payment processing and ensuring product authenticity.

12. Autonomous Cart Navigation (Robotic Carts)

Technology: In more advanced systems, automated carts can navigate the store independently to assist customers. These carts use path finding algorithms and sensors to avoid obstacles.

Example: Autonomous robots that guide customers to product locations within the store, providing an interactive shopping experience.

CHAPTER THREE

DESIGN AND ANALYSIS

3.1 BLOCK DIAGRAM OF THE SYSTEM

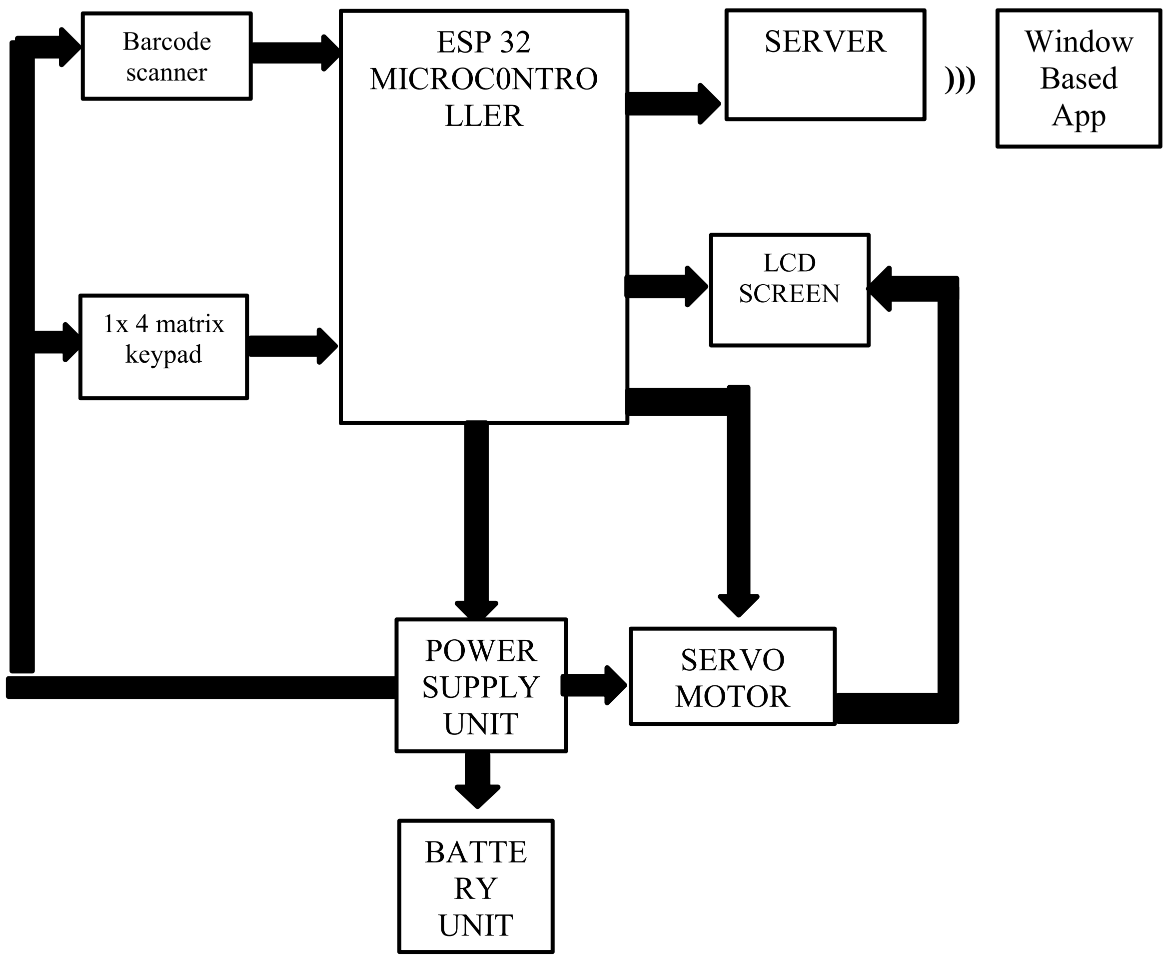


Figure 3.1: Block Diagram of the System

3.1.1 MICROCONTROLLER UNIT (ESP 32)

This microcontroller was chosen because of its wide range of applications. This functionality is enabled by the presence of the Bluetooth and Wi-Fi modules. The Wi-Fi module ensures a wider physical connection while the Bluetooth module ensures mobile connection to a phone.

The operating condition of this microcontroller is convenient for the design of the automated shopping cart.. The standard operating conditions for the ESP 32 Microcontroller are given in the table below.

TABLE 3.1 Standard Operating Conditions for the ESP 32microcpntroller

SYMBOL	PARAMETER	MIN	TYPICAL	MAX	UNIT
VDD33	Power supply voltage	3.0	3.3	3.6	V
I_{VDD}	Current delivered by external power supply	0.5	-	-	A
T	Operating ambient temperature	-40	-	85	^0C

3.1.2. DISPLAY UNIT (LMO16L)

This unit consists of the 16 by 2 LCD screen. LCD stands for liquid crystal display. It serves as the channel which shows real time data generated by the system. One reason for which it was chosen is because of its effectiveness in displaying information.

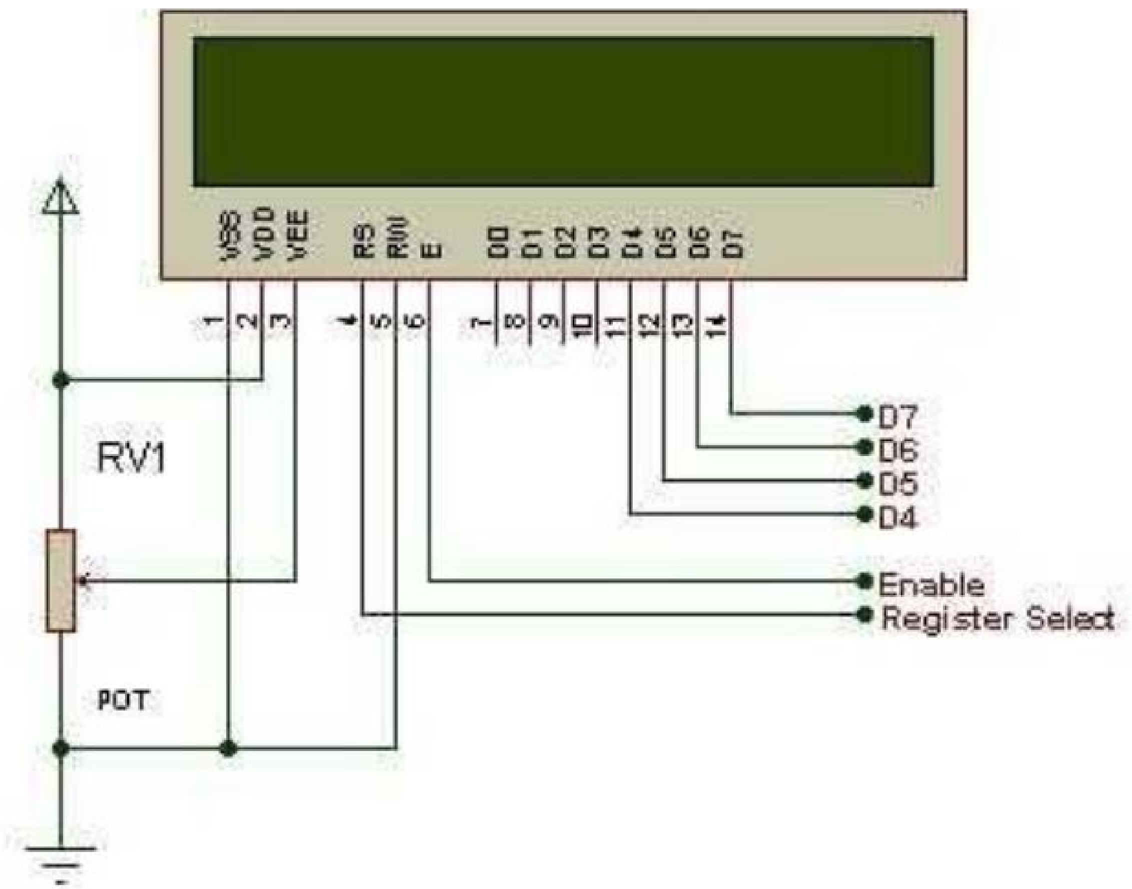


FIG 3.1.1: THE LMO16L LCD SREEN AND ITS PIN CONNECTIONS

3.1.3 BARCODE SCANNING UNIT (GM805 SERIES UART)

The barcode scanning unit consists of a bar code scanner. The barcode scanner used here is the GM805 Series UART. The GM 805 Series barcode scanner module is a high-performance device capable of effortlessly reading both 1D and 2D codes with precision. This barcode scanner operates on 5v. Below is a table which gives the technical specification of the Gm805 Series UART scanner.

Table 3.2 Specifications of the GM 805 series UART Scanner

Parameter	Performance
Sensor	
Scan mode	
Indicator Light	
Lighting	White LED
Read Code Type	
GM 805-S Reading Distance	1D: EAN-13, EAN-8, UPC-A, UPC-E, ISSN, ISBN, CodaBar, Code128, Code 93, ITF-14, ITF-6, GS1 Composite, GS1 Databar (RSS), Matrix 2 of 5
GM 805-S Reading Distance	5–30cm
GM 805-L Reading Distance	7-50cm
Contrast	> 25%
Scan Angle	Roll: 360º Pitch: 65 Yaw: 65º
Viewing Angle	67 (Horizontal) 53 (Vertical)

3.1.4. INPUT UNIT

The input unit is made up of the input keypad. The keypad used in the design of this system is the 1 by 4 matrix keypad. This 4-button keypad offers a practical human interface for this project. Its adhesive backing allows for easy mounting in various applications thus making it convenient for use. To connect it to the ESP 32 microcontroller, a female 5-pin berg connector is needed.

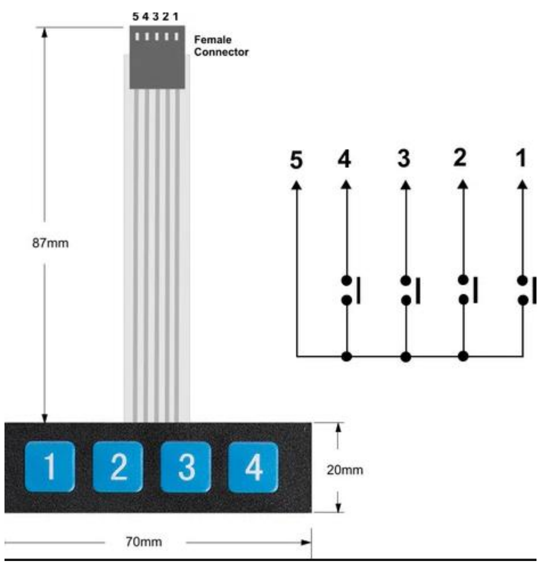


Figure 3.1.2: Layout of the 1 by4 keypad

3.1.5. POWER SUPPLY UNIT

The power supply unit consists of a dc buck voltage converter and lithium ion batteries. The buck voltage converter decreases voltage while increasing voltage from input to output. The lithium ion battery is a rechargeable battery that uses lithium ions to store battery.

3.2 DESIGN CONSIDERATIONS

The following considerations and assumptions were made during the design of this system:

1. In designing this system, the Esp 32 microcontroller was preferred to other microcontrollers because of its in built Wi-Fi capability.

2. In choosing the microcontroller, the Esp 32 was preferred because it has inbuilt components like crystal oscillators thus ensuring no need for external connection of such components.

3.3 DESIGN COMPONENTS

The components assembled together to give the system are:

1. Power Supply (DC Buck Voltage Converter)

2. Microcontroller

3. Servo motor

4. Lcd screen

3.3.1 POWER SOURCE (DC BUCK VOLTAGE CONVERTER)

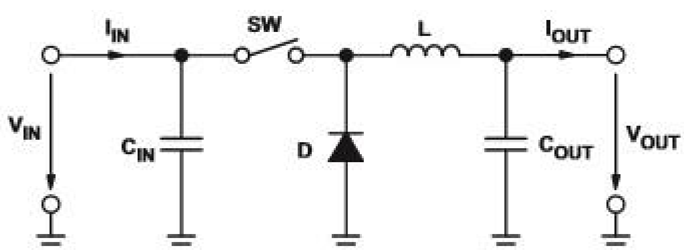


Fig 3.3.1 Buck Converter Power Stage

3.3.1.1 MAXIMUM SWITCH CURRENT OF THE BUCK VOLTAGE CONVERTER

1. The first step is to calculate the maximum duty circle.

Maximum Duty Circle,

$$D = \frac{vout}{vin} \times \eta \ldots \ldots \ldots . \ldots \ldots (1)$$

NOTE: n represents the efficiency of the converter

$V_{IN\ (max)}$ represents the maximum input voltage

2. The second step is to calculate the Inductor Ripple Current

$$= (V_{IN(max)} - V_{OUT}) \times \frac{D}{fs} \times L \ldots \ldots . . (2)$$

Where:

f_s = minimum switching frequency of the converter

L = selected inductor value

D = duty circle calculated in equation 1

From this, the maximum switch current can be gotten if the maximum output current is below the calculated value.

Therefore,

$$Maximum\ Switch\ Current = \frac{\boldsymbol{\Delta / L + IOUT(MAX)}}{\mathbf{2}}$$

3.3.2 DESIGN AND SPECIFICATIONS OF THE SERVO MOTOR

The servo motor is located in the servo motor block. This block consists of a servo motor MG 966R. The circuit diagram of a simple servo motor is shown in figure 3.3.2 below. The servo motor can be applied to the system in multiple ways. It can be used to control the steering of the cart, it can be used to position the item for automated scanning etc.

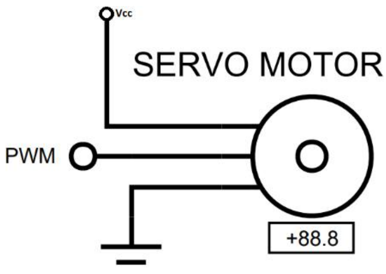


Figure 3.3.2.1 A Servo Motor Circuit Diagram

This servo has a running current of 500mA and a stall current of 2.5 A. It also has an operating voltage range of 4.8v to 7.2v. For the purpose of this project, the MG 996R servo motor is interfaced with the ESP 32 microcontroller.

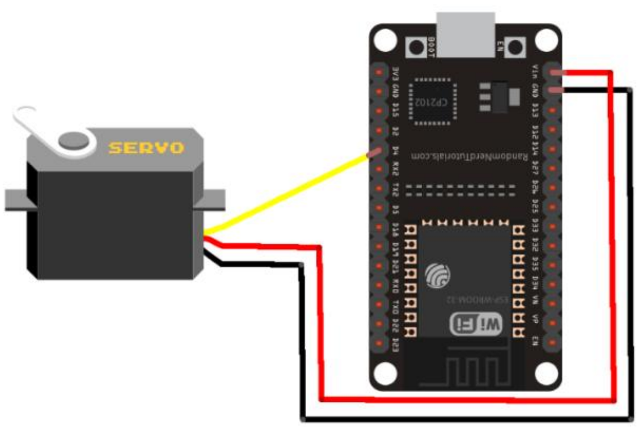
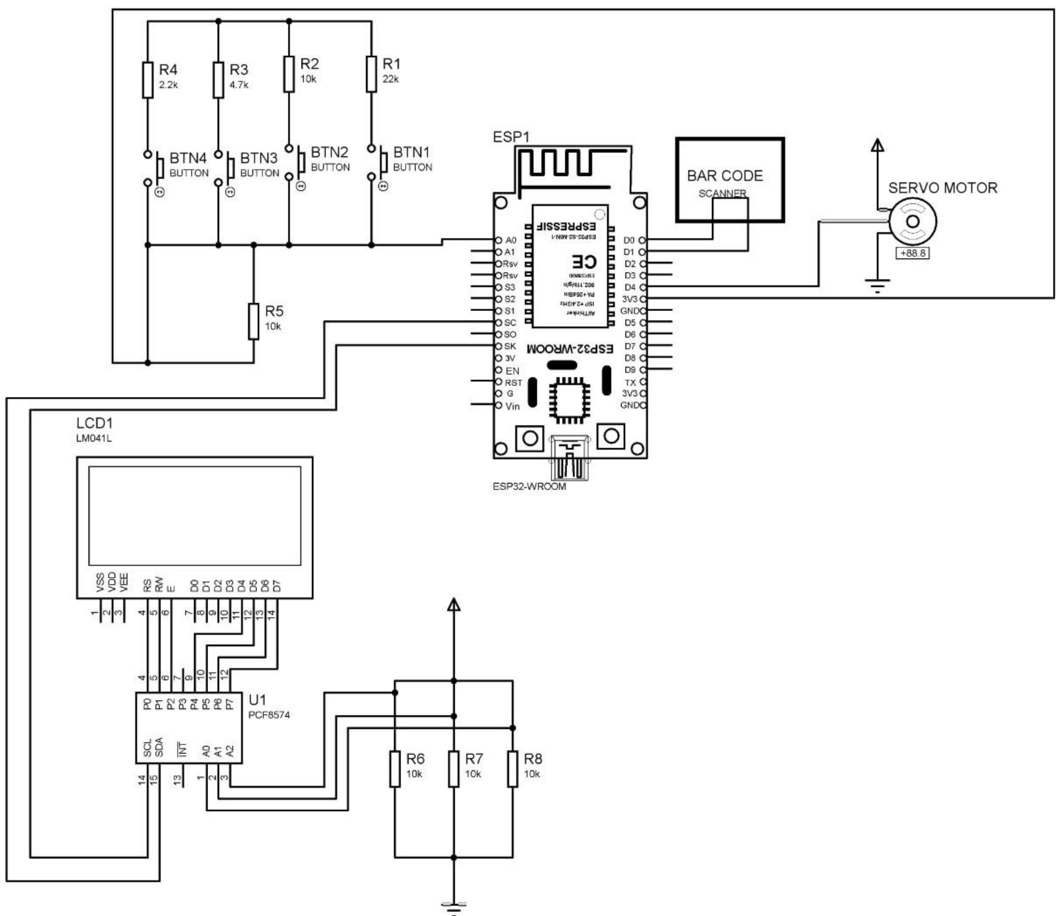
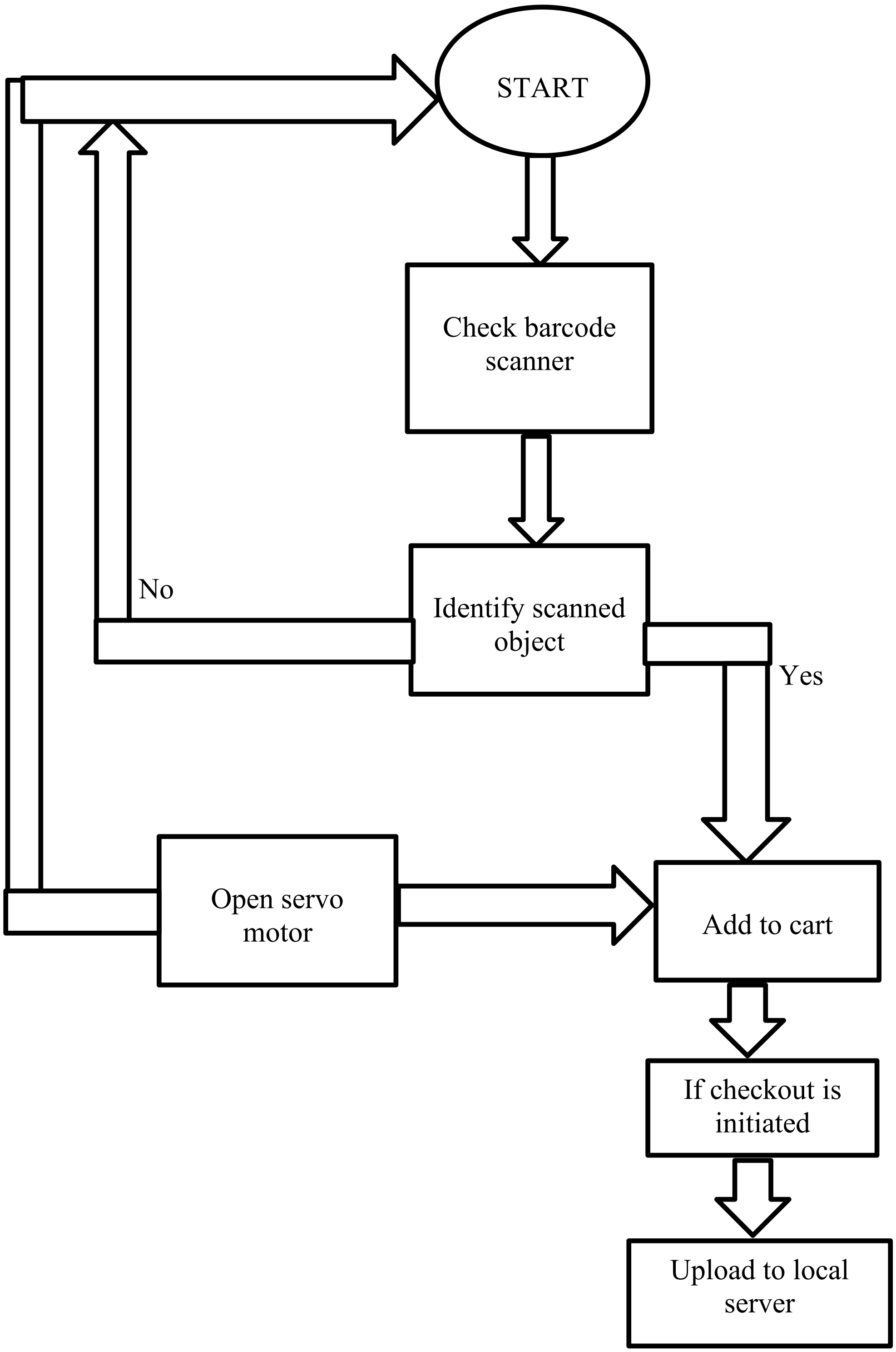


Figure 3.3.2.2: interfacing the MG996R servo motor with the ESP 32 microcontroller.

3.4 OVERALL CIRCUIT DIAGRAM



3.5 SYSTEM FLOWCHART



3.6 WORKING PRINCIPLE OF THE SYSTEM

The smart shopping cart system is designed to automate the checkout process, keep track of the products added to the cart, and manage user input for various functionalities. The user will scan items via a barcode scanner, input information via a keypad, and interact with the system through an interface hosted on a server. The servo motor can be used to physically lock or unlock the cart, or to activate some parts of the cart (e.g., a compartment).

In this system, the ESP32 will act as the central controller of the entire system, managing communication between all components (barcode scanner, keypad, servo motor, and the server). The microcontroller will also be responsible for sending data to the server for processing (such as the list of scanned items, user inputs, etc.), and receiving commands (like activating the servo motor or triggering alerts). The barcode scanner then reads the barcode of products being added to the shopping cart. The scanned barcode will be transmitted to the ESP32, which will then relay the data to the server for identification and pricing. The server will use a database of products to match the barcode and retrieve product details (name, price, stock, etc.). The server will then store product data and perform processing such as validating the barcode, calculating the total price, applying discounts, and generating a final receipt The keypad inputs additional commands or information. For example, the user can input quantities, discounts, or verify the items in the cart.

Alternatively, the keypad can be used for user authentication (e.g., PIN entry) or to control certain aspects of the cart (locking/unlocking the cart). The servo motor interacts with other physical components of the cart, such as locking/unlocking a compartment or triggering an alarm.

The servo motor can be used for locking or unlocking a section of the cart or activating a mechanism to prevent theft.

Upon starting the cart, the ESP32 initializes all components and establishes communication with the window-based server via Wi-Fi or another wireless protocol. The ESP32 checks for any user input (via the keypad or barcode scanner) to start the shopping session. As the user scans a product's barcode, the scanner transmits the barcode data to the ESP32.The ESP32 forwards this information to the window-based server where it is cross-referenced with the product database. The server retrieves the product details (name, price, stock, etc.) and sends this information back to the ESP32 for display on the cart interface or further processing. The user may enter additional commands using the 4x1 keypad. For instance, the user could input a specific quantity, apply a discount, or make any other selections.This data is sent to the ESP32 and communicated to the server for validation or processing. If needed (e.g., during checkout), the ESP32 may activate the servo motor based on specific conditions such as: locking or unlocking compartments of the cart to secure high-value items and deactivating the cart or controlling access to the items based on user interactions or a final checkout command.

As items are added, the ESP32 continually updates the list of products in the cart, calculating the total price, taxes, and any discounts. Upon checkout, the ESP32 will send a command to the window-based server to process the payment or finalize the transaction. The server may also notify the ESP32 to lock or unlock the cart once payment is completed. The ESP32 communicates with the window-based server in real-time to keep the cart's database updated and to ensure that product information is correct. The server can provide information about promotions, product availability, or other updates to the ESP32, which will be displayed to the user.

By integrating these components and processes, the smart shopping cart system can effectively manage the shopping experience, track items, and provide a seamless, secure checkout process.

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULTS

4.1 CONSTRUCTION

A model of a smart shopping cart was constructed. Construction involved both hardware and software design as the hardware functionality is not independent of the software. Construction of hardware involved the use of several locally made materials to attain the desired structure. Some of the materials brought together to attain the desired structure include;

1) Acrylic glass

2) Plastic T and L joints.

3) Tyre base

4) PVC pipes

Fig 4.1 Side view of the smart shopping cart

Fig 4.1.2 Top view of the smart shopping cart

Fig 4.1.3 Back view of the smart shopping cart

Steps involved in designing this system include;

1. Buying of materials and components.

2. Simulation

3. Soldering of electronic components on the Vero board.

4. System programming (microcontroller, led screen, barcode scanner)

5. Testing and packaging.

4.2 SIMULATION

Software design involved designing a circuit containing the sensors and other necessary components on Proteus. The desired circuit was designed using the Proteus 8 professional. This was then programmed and simulated successfully on Proteus before code was transferred to the microcontroller. The figure below shows the designed circuit using the Proteus software.

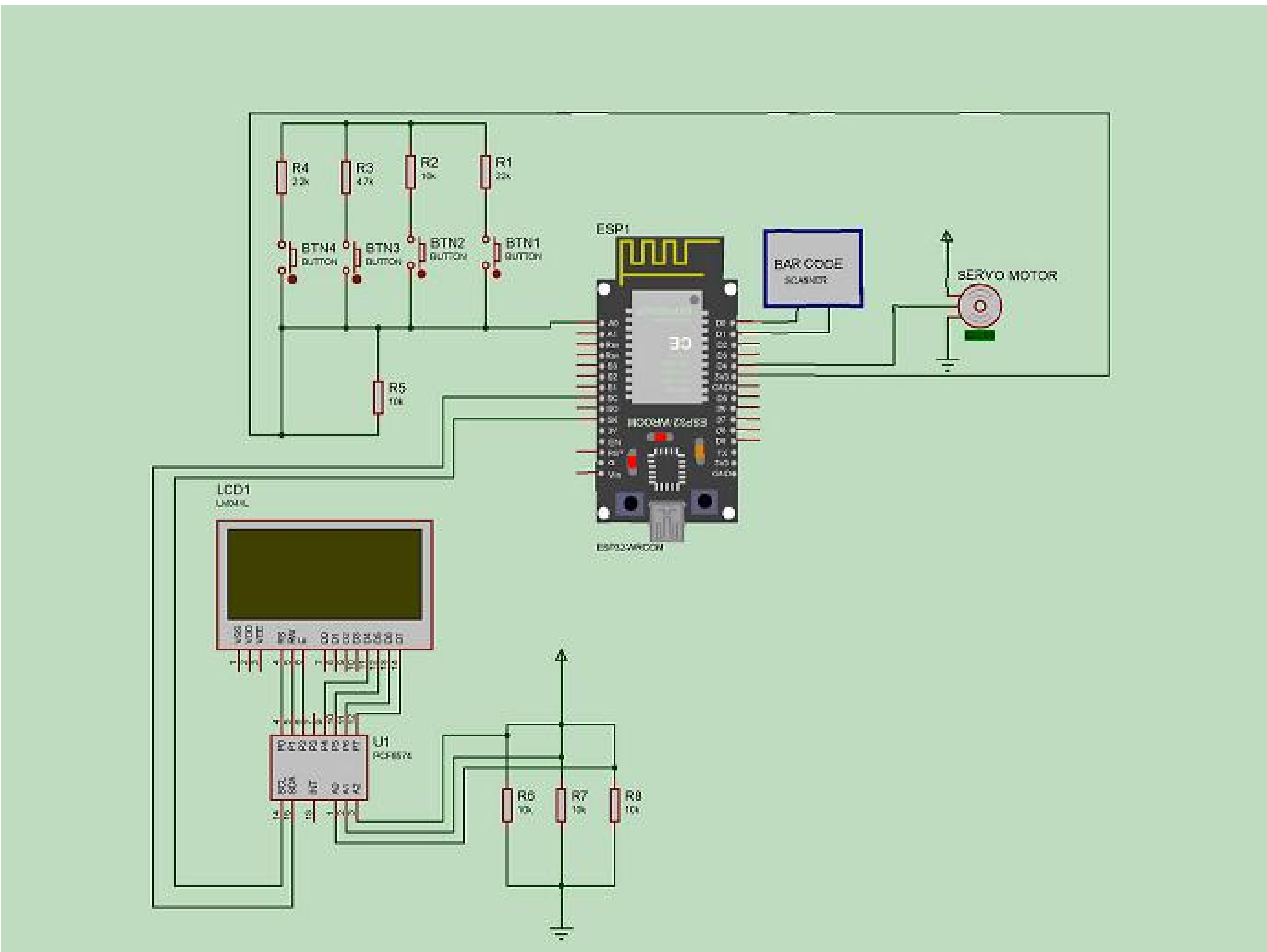


Fig 4.2 Circuit Diagram designed on Proteus

The demonstration of simulation requires that a model be produced. The model should contain the key qualities, practices and element, of the chosen physical or conceptual frame work or process. The model if done properly, should represent the operation of the frame work in real time.

4.3 SYSTEM PROGRAMMING INVOLVING THE USE OF LIBRARIES

First of all, the ESP 32 was programmed using the Arduino Ide. The libraries were software serial. H, liquid crystal I2c.H, Wire.H and Wi-Fi.H. To enable storage of system information, the library EEPROM.H was used. For creation of the webpage, an html, css and javasript code was written in the Ardino Ide. For communication between the system and webpage, a Javascript code was used.

The Wi-Fi library connects the ESP to the internet. It also triggers the communication between the Esp 32 microcontroller and the webpage. The EEPROM.H library was used to save system information. The Software Serial.H library enables the reading of the scanned QR code.

4.3.1 LCD SCREEN PROGRAMMING

The programming of the LCD screen involved the use of two libraries. They are the Liquid Crystal I2C library and the Wire.H library. The liquid crystal library enabled the display of the text on the LCD screen. The Wire.Hlibraray determines the connection of the liquid crystal I2C device. This library defines the pin and the various ports to connect it.

Below is the adjusted code used to get system response.

Corrected Code:

```cpp
#include <Wire.h>

#include <EEPROM.h>

#include <LiquidCrystal_I2C.h>

#include <SoftwareSerial.h>

#include <WiFi.h>


// Define LCD and GM805 pins (adjust if needed)

LiquidCrystal_I2C lcd(0x27, 20, 4);

#define GM805_RX_PIN 18

#define GM805_TX_PIN 19

SoftwareSerialgm805Serial(GM805_RX_PIN, GM805_TX_PIN);


// WiFi credentials (REPLACE WITH YOUR CREDENTIALS)

Const char* ssid = “Galaxy A12580F”; // Replace with your WiFi SSID
```

```
Const char* password = “isreal12”;   // Replace with your WiFi password

WiFiServerserver(80);



// Define button pin

ConstintconfirmButtonPin = 2; // Example pin, change as needed



// Variables

String items[5];

Intprices[5];

IntitemCount = 0;

InttotalPrice = 0;

IntscrollOffset = 0;

Char qrCodeData[100];



Void setup() {

Serial.begin(115200);

Gm805Serial.begin(9600);

Wire.begin();
```

```
Lcd.init();

Lcd.backlight();


  // Initialize button pin

pinMode(confirmButtonPin, INPUT_PULLUP);


displayWelcomeMessage();

loadItemsFromEEPROM();

displaySavedItems();


WiFi.begin(ssid, password);

Serial.print("Connecting to WiFi");

  While (WiFi.status() != WL_CONNECTED) {

Delay(500);

Serial.print(".");

  }

Serial.println("\nConnected!");

Serial.print("IP address: ");
```

```
Serial.println(WiFi.localIP());


Server.begin();

}


Void loop() {

readQRCode();

handleButtonInputs();

handleWebRequests();

delay(300);

}


Void displayWelcomeMessage() {

Lcd.print("Welcome to Smart");

Lcd.setCursor(0, 1);

Lcd.print("Shopping");

Delay(2000);

Lcd.clear();
```

```
}


Void loadItemsFromEEPROM() {
  For (int I = 0; I < 5; i++) {
Int address = I * 20;
    Char buffer[20];
    For (int j = 0; j < 20; j++) {
      Buffer[j] = EEPROM.read(address + j);
    }
    String itemData = String(buffer);
itemData.trim();


if (itemData.length() > 0) {
intspaceIndex = itemData.indexOf(' ');
if (spaceIndex != -1) {
items[itemCount] = itemData.substring(0, spaceIndex);
prices[itemCount] = itemData.substring(spaceIndex + 1).toInt();
itemCount++;
```

```
      }
    }
  }
}

Void displaySavedItems() {
Lcd.clear();
  For (int I = 0; I <itemCount; i++) {
Int row = I – scrollOffset;
    If (row >= 0 && row < 4) {
Lcd.setCursor(0, row);
Lcd.print(items[i]);
Lcd.print(“ “);
Lcd.print(prices[i]);
    }
  }
  If (itemCount == 0) {
Lcd.setCursor(0, 0);
```

```
Lcd.print("Scan QR to add");

Lcd.setCursor(0, 1);

Lcd.print("items");

  }

}


Void readQRCode() {

  If (gm805Serial.available() > 0) {

IntbytesRead = gm805Serial.readBytesUntil('\n', qrCodeData, 99);

qrCodeData[bytesRead] = '\0';

    String qrDataString = String(qrCodeData);

qrDataString.trim();


if (qrDataString.length() > 0) {

Serial.print("QR Code Data: ");

Serial.println(qrDataString);

parseQRCodeData(qrDataString);

displaySavedItems();
```

```
    }
  }
}

Void parseQRCodeData(String qrData) {
IntstartIndex = 0;
  While (startIndex<qrData.length()) {
IntcommaIndex = qrData.indexOf(',', startIndex);
    If (commaIndex == -1) {
commaIndex = qrData.length();
    }

    String itemPricePair = qrData.substring(startIndex, commaIndex);
IntspaceIndex = itemPricePair.indexOf(' ');

    If (spaceIndex != -1) {
      String itemName = itemPricePair.substring(0, spaceIndex);
      String priceStr = itemPricePair.substring(spaceIndex + 1);
```

```
Int price = priceStr.toInt();


      If (itemCount< 5) {
Items[itemCount] = itemName;
Prices[itemCount] = price;
saveItemToEEPROM(itemCount);
itemCount++;
      } else {
displayMaxItemsReached();
break;
      }
    }
startIndex = commaIndex + 1;
  }
}


Void saveItemToEEPROM(int index) {
Int address = index * 20;
```

```
  String itemData = items[index] + " " + String(prices[index]);
itemData.toCharArray(qrCodeData, itemData.length() + 1);
for (int I = 0; I <itemData.length(); i++) {
EEPROM.write(address + I, qrCodeData[i]);
  }
EEPROM.write(address + itemData.length(), 0);
EEPROM.commit(); // Commit changes
}


Void handleButtonInputs() {
IntanalogValue = analogRead(34);
  Float voltage = (analogValue / 4095.0) * 3.3;


  If (voltage >= 0.8 && voltage <= 1.5) { // QR Code Scan
Delay(200);
readQRCode();
  } else if (voltage >= 0.4 && voltage <= 0.6) { // Clear All
Delay(200);
```

```
clearAllItems();

  } else if (voltage >= 0.25 && voltage <= 0.3) { // Send to Webpage

Delay(200);

sendDataToWebpage();

  } else if (voltage >= 0 && voltage <= 0.20) { // Scroll Up

Delay(200);

scrollOffset--;

if (scrollOffset< 0) {

scrollOffset = 0;

    }

displaySavedItems();

  }

}



Void clearAllItems() {

itemCount = 0;

for (int I = 0; I < 5 * 20; i++) {

EEPROM.write(I, 0);
```

```
  }
EEPROM.commit(); // Commit changes
displaySavedItems();
}

Void sendDataToWebpage() {
calculateTotalPrice();
displayTotalPrice();
}

Void calculateTotalPrice() {
totalPrice = 0;
for (int I = 0; I <itemCount; i++) {
totalPrice += prices[i];
  }
}

Void displayTotalPrice() {
```

```
Lcd.clear();

Lcd.print("Total: ");

Lcd.print(totalPrice);

Delay(2000);

displaySavedItems();

}



Void displayMaxItemsReached() {

Lcd.clear();

Lcd.print("Max 5 items!");

Lcd.setCursor(0, 1);

Lcd.print("Clear or Send");

Delay(2000);

displaySavedItems();

}



Void handleWebRequests() {

WiFiClient client = server.available();
```

```
  If (client) {
Serial.println(“New client.”);
    String request = client.readStringUntil(‘\r’);
Client.flush();


Client.println(“HTTP/1.1 200 OK”);
Client.println(“Content-Type: text/html”);
Client.println();


Client.println(“<!DOCTYPE html><html><head><title>Shopping List</title></head>”);
Client.println(“<body><h1>Shopping List</h1>”);
Client.println(“<table border=’1’><tr><th>Item</th><th>Price</th></tr>”);


    For (int I = 0; I <itemCount; i++) {
Client.printf(“<tr><td>%s</td><td>%d</td></tr>”, items[i].c_str(), prices[i]);
    }
Client.printf(“<tr><td><b>Total:</b></td><td>%d</td></tr>”, totalPrice);
Client.println(“</table>”);
```

```
Client.println("<button onclick=\"window.location.href='/confirm'\">Confirm Payment</button>");

    If (request.indexOf("/confirm") != -1) {
displayPaymentConfirmed();
    }
Client.println("</body></html>");
Client.stop();
  }
}

Void displayPaymentConfirmed() {
Lcd.clear();
Lcd.print("Payment");
Lcd.setCursor(0, 1);
Lcd.print("Confirmed!");
Delay(2000);
displaySavedItems();
}
```

```

### Summary of Changes:

- **Button Pin Initialization**: Corrected to `INPUT_PULLUP`.

- **Function Redundancy**: Combined `displayMaxItemsReached()` and `displayLimit()` into one function.

- **EEPROM Commit**: Added `EEPROM.commit()` after writing to EEPROM.

- **Button Debounce**: Added a delay to handle button inputs more reliably.

- **HTTP Response Logic**: Moved the confirmation logic to the correct place in the HTML response

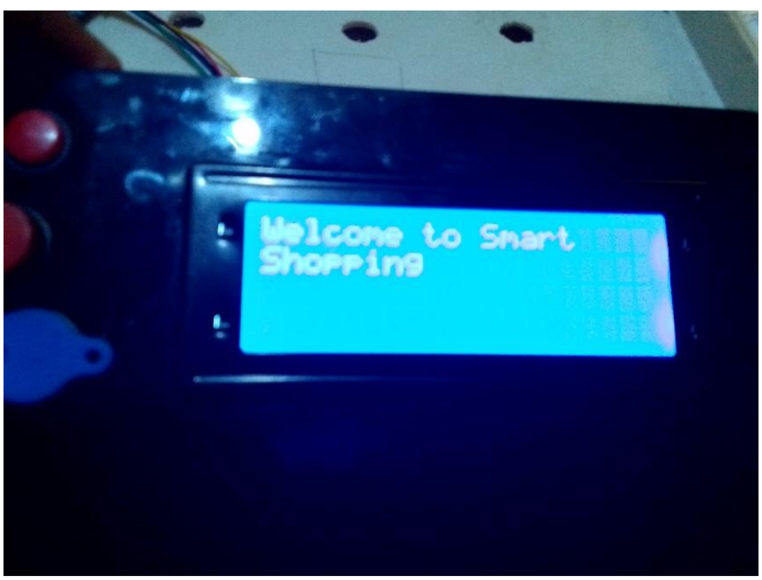



Fig 4.3.1 Display of LCD screen
```

Fig 4.3.2 Communication between Lcd screen and button

4.4 TESTING AND RESULT ANALYSIS

Various tests had to be carried out on the smart shopping cart to determine its efficiency. The various test include:

1. Functionality test.

2, Performance test

3. Usability test

4.4.1 FUNCTIONALITY TEST

This is done to ensure that the barcode scanner reads different barcode types accurately. This test was also carried out with barcodes with good printed quality and those with faded printed quality. Below is a table showing the systems response.

Quality of barcode	System Response
Good	Accepted
Fairly good (faded)	Accepted
Bad	Rejected

Table 4.1 Result of functionality test

As seen from the results, this system shows optimal functional capacity. However, bad barcodes are not to be used on the system as it automatically rejects them.

4.4.2 PERFORMANCE TEST

This test was carried to measure the response time of the system in detecting items and showing price list and item name.

ITEM	ITEM DETECTION TIME (mS)	Price in naira
A pack of sugar	200	2000
A pack of cornflakes	200	2000

A bottle of water	200	2000

Table 4.2 Result of Performance test

4.4.3 USABILITY TEST

This test was done to verify the systems ability to operate for long periods. It was discovered that the systems operational time frame for use is based on power supply and power stored in the battery. The battery is an alternate source of power for the system.

Smart system	Power supply (on)	Power supply (off)	Battery (on)	Battery (off)
Shopping cart	In operation	In operation	In operation	No operation

Table 4.3.1 Result of Usability test based on power supply conditions.

CHAPTER 5

LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

LIMITATIONS

1. High Initial Cost: Developing and deploying automated shopping carts, including the necessary hardware, software, and integration, can be expensive for retailers.

2. Maintenance: Automated systems require ongoing maintenance, including hardware repair, software updates, and ensuring they function optimally.

3. Security Risks: There may be vulnerabilities in the system related to user data privacy, payment processing, and cyber attacks.

4. Customer Resistance: Some customers may be unfamiliar or uncomfortable with technology, leading to reluctance in adopting automated shopping carts.

5. Limited Flexibility: Automated carts may struggle with handling unusual or complex purchases that require human judgment, like bulk items or items in irregular shapes.

6. Technical Failures: The technology can fail due to issues like sensor malfunctions, software glitches, or connectivity problems, leading to disruptions in service.

7. Space Constraints: For physical carts, size limitations may restrict the variety and volume of items that can be carried, especially for larger purchases.

8. Limited Customization: Some automated carts may not offer personalization or flexibility in terms of product suggestions, product variations, or discounts.

RECOMMENDATIONS

1. Improve User Interface: Simplify the interface and provide clear instructions to make the technology accessible to a broader customer base, including those less familiar with tech.

2. Enhanced Security Features: Invest in robust encryption, secure payment systems, and customer authentication to protect against cyber threats.

3. Ongoing Monitoring & Support: Establish systems for continuous monitoring and offer customer support to help users resolve any issues that arise while using automated carts.

4. Flexible Design: Ensure carts are adaptable to various types of products, including those with odd shapes or bulkier items, to ensure broad usability.

5. Customer Feedback Integration: Implement mechanisms for customers to provide feedback on their experience with the automated cart, allowing for future improvements.

6. Affordable Solutions: Start with cost-effective solutions, especially for smaller retailers, and gradually scale as demand increases, focusing on ROI and long-term savings.

7. Employee Assistance: Provide assistance for customers who may need help with the automated carts, ensuring a hybrid model that combines human assistance and automation.

8. Comprehensive Testing: Regularly test the systems for bugs, malfunctions, and technical issues to ensure the reliability of the carts and smooth operation.

CONCLUSIONS:

Automated shopping carts represent a significant step toward enhancing the shopping experience through convenience, efficiency, and personalization. However, for successful implementation, challenges such as cost, technical complexity, and customer adoption must be addressed. By investing in user-friendly interfaces, robust security measures, and offering reliable customer support, retailers can maximize the potential of automated carts. Moreover, continuous innovation and responsiveness to customer needs are essential to keep pace with advancements in automation technology and ensure that the shopping experience is not only automated but also seamless and enjoyable.

REFERENCES

1. Kim et al. (2018) - "SLAM-based Navigation for Autonomous Shopping Cart"

2. Lee et al. (2020) - "Sensor Fusion for Obstacle Detection in Autonomous Shopping Carts"

3. Chen et al. (2019) - "Computer Vision-based Product Recognition for Autonomous Shopping Carts"

4. Wang et al. (2020) - "Deep Learning-based Product Classification for Autonomous Shopping Carts"

5. Patel et al. (2019) - "User Interface Design for Autonomous Shopping Carts"

6. Kim et al. (2020) - "Gesture Recognition for Human-Robot Interaction in Autonomous Shopping Carts"

7. Lee et al. (2019) - "Collision Avoidance System for Autonomous Shopping Carts"

8. Chen et al. (2020) - "Secure Payment Systems for Autonomous Shopping Carts"

9. Kim et al. (2019) - "Autonomous Shopping Cart: A Study on Efficiency and User Experience"

10. Patel et al. (2020) - "Enhancing Shopping Experience with Autonomous Shopping Carts"