



Faculty of Engineering & Information Technology
Computer Engineering Department
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Design and Development of a Vending Machine

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Dedication

Firstly, Thank God for everything we have done in this project, we would dedicate this work to our parents. Whom gave us all things to reach this stage in our life, which with their supports we can stand here today, we will never finish to thank our parents for all the opportunities that they have offer, for all the teachings that they have told us and for every advice that come out of their mouth. We hope that we can make you proud as we proud of you.

To our brothers, teachers, doctors special our supervisor Dr. Hanal Abuzant and our colleges we dedicate this research.

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We are indebted to our families and friends for their unwavering encouragement and understanding during this journey.

Disclaimer Statement

This project was done by Muath Saed and Hamza Nayef at the Computer Engineering Department, Faculty of Engineering, An-Najah National University. It has not been altered or corrected, other than editorial corrections. As a result of the assessment, it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of the students. An-Najah National University accepts no responsibility or liability for the consequences of this report when being used for a purpose other than the purpose for which it was commissioned.

Abstract

The significance of this project lies in its focus on the development and implementation of a vending machine system. Vending machines play a vital role in our daily lives, providing convenient access to a wide range of products. This project aims to enhance the functionality, efficiency, and user experience of vending machines through the application of modern technologies and innovative features.

In this project, several important aspects will be covered. Firstly, the design and engineering of a robust and user-friendly vending machine system will be explored. This includes the development of hardware components, such as the machine structure, payment systems, and product dispensing mechanisms. Additionally, software aspects such as inventory management and user interface will be considered to optimize the overall performance of the vending machine.

The main objective of the project is to create a reliable and efficient vending machine that offers a seamless user experience. This involves ensuring that the machine accurately dispenses products, accepts various payment methods, and provides real-time inventory updates. Also, it aims to enhance the vending machine's capabilities by incorporating advanced features such as cashless payments and remote monitoring.

The development process will consist of several stages. Initially, thorough research and analysis of existing vending machine systems will be conducted to identify areas for improvement and innovation. Then, the hardware and software components will be designed and developed accordingly. Testing and validation will be carried out to ensure the system's reliability and performance.

While vending machines have been widely used, this project aims to introduce novel features and improvements to existing systems. Although there may be similar applications available today, the specific combination of features and functionalities proposed in this project may offer unique advantages and capabilities not found in current vending machine solutions. By addressing the limitations of traditional vending machines and incorporating cutting-edge technologies, this project strives to contribute to the evolution of vending machine systems.

NOMENCLATURE/symbols

V: Volt.

DC: Direct Current.

IR: Infrared.

UI: User Interface.

RFID: Radio Frequency Identification.

LCD: Liquid Crystal Display.

LED: Light-Emitting Diode.

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Chapter One: Introduction

Vending machines are widely used for dispensing products or services in various settings such as schools, offices, and public spaces. However, commercially available vending machines can be expensive and lack customization options. The goal of this project was to design and construct a vending machine that overcomes these limitations by using affordable components and providing flexibility for customization.

1.1 Objectives

The primary objectives of this project include:

- Developing a robust vending machine system with improved functionality.
- Enhancing user experience through modern technologies and innovative design.
- Optimizing the performance of the vending machine system through hardware and software advancements.

1.2 Significance

Vending machines offer convenience, accessibility, and revenue generation opportunities for businesses. They have a cultural significance as symbols of modern life and consumer culture, and their continued evolution and adaptation to new technologies make them an integral part of contemporary society.

1.3 Organization of the Report

This report is structured as follows. Chapter 2 provides an overview of the theoretical background and previous work related to vending machines. Chapter 3 details the methodology used in designing and implementing the enhanced vending machine system. Chapter 4 presents the results of performance testing and analysis. Chapter 5 discusses the implications of the findings and their alignment with the project objectives. Finally, Chapter 6 summarizes the conclusions drawn from the project and provides recommendations for future enhancements.

Chapter Two: Theoretical Background and Previous Work

2.1 Theoretical Background

Vending machines have long been a staple in the retail industry, offering consumers a convenient way to purchase goods without the need for direct human interaction. The theoretical foundation of vending machines encompasses principles from various fields, including mechanical engineering, electronics, user interface design, and supply chain management. These machines rely on mechanical components for product dispensing, sensors for detecting customer interactions, and payment systems for transaction processing.

2.2 Previous Work

Historically, research and development endeavors in the field of vending machines predominantly focused on enhancing mechanical reliability and diversifying product offerings. Nevertheless, the evolution of technology has ushered in new possibilities that extend beyond these conventional faces. There is a burgeoning interest in elevating user experiences, streamlining inventory management, and integrating intelligent technologies.

Chapter Three: Methodology

3.1 Standards and Specifications (Codes)

The development of the vending machine system adhered to relevant engineering standards and specifications to ensure the design met requirements. The following standards and specifications played a significant role in guiding the project:

- 1. Arduino Coding Standards:** The project adhered to established coding standards for Arduino programming. These standards encompassed naming conventions, code structure, and best practices for readability and maintainability.
- 2. Arduino Libraries:** Relevant Arduino libraries and packages were utilized to expedite development and ensure compatibility with hardware components. These libraries followed standard coding practices and interfaces.
- 3. IEEE 802.11 (Wi-Fi Standard):** The project utilized the IEEE 802.11 standard for wireless communication via the ESP8266 module. This standard ensured compatibility with common Wi-Fi networks and protocols, enabling seamless communication between the vending machine and the mobile app.

3.2 Constraints

3.2.1 Time Constraint

The project required an uninterrupted span of two months for its construction and testing, commencing with the design and fabrication of the physical structure, progressing to the development and integration of features, and ultimately culminating in the assembly of all components. This collective timeline posed a considerable challenge to overcome.

3.2.2 Sensitivity of Electrical Components

Navigating the intricacies of small electrical components such as drivers and microchips proved challenging, given their heightened sensitivity to voltage, current, and even environmental fluctuations. Furthermore, some of these delicate chips incurred damage during the machine's development phase.

3.3 Design and Engineering of Hardware Components

The development of the enhanced vending machine system involves the design and engineering of critical hardware components. This includes the machine's physical structure, product dispensing mechanisms, and payment systems. The structural design aims to ensure durability, ease of maintenance, and aesthetic appeal. The product dispensing mechanisms are optimized for accurate and reliable product delivery.

3.3.1 Mechanical Parts

3.3.1.1 Timing Belt and Timing Pulley 5mm

These mechanical components work in unison to provide synchronized movement for the collecting box within the vending machine system.



Figure 1: Timing Belt and Timing Pulley 5mm

3.3.1.2 V-Slot 20×20

The V-Slot 20×20 aluminum provides structural support, stability, and precise linear motion for collecting box.



Figure 2: V-Slot 20×20

3.3.1.3 Helical Spring

The helical spring is integrated into the vending machine's mechanism and connected to a servo motor. It is used to provide controlled force for dropping items during the dispensing process, ensuring reliability and precision in item delivery.

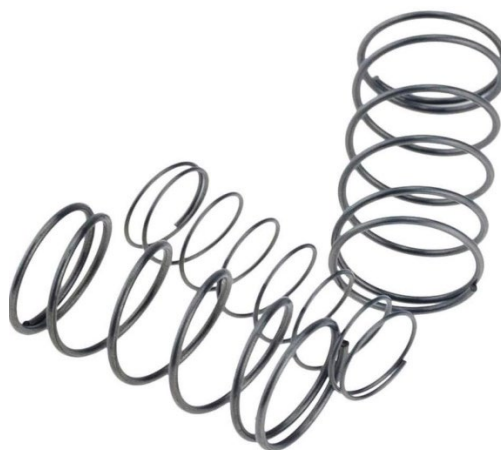


Figure 3: Helical Spring

3.3.1.4 Gantry Plate 4-Wheels

The gantry plate, equipped with four wheels, plays a crucial role in guiding and supporting the movement of the collecting box. It ensures smooth and controlled motion along the V-Slot, contributing to the accuracy of product delivery.



Figure 4: Gantry Plate 4-Wheels

3.3.2 Electrical Parts

3.3.2.1 Arduino Mega 2560

The Arduino Mega microcontroller coordinates the operation of various components and executes programmed instructions (Arduino, n.d.).

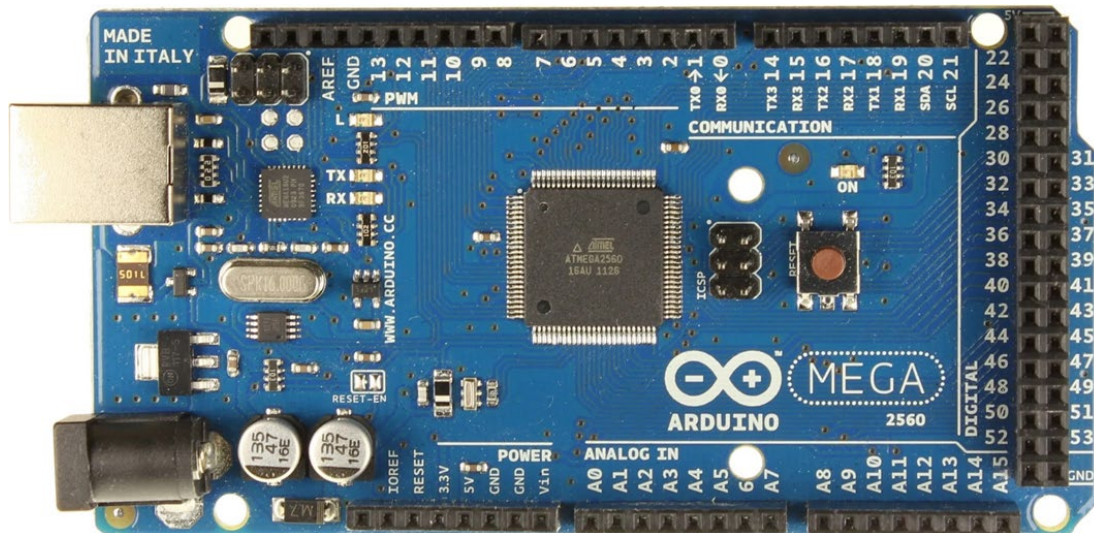


Figure 5: Arduino Mega 2560

3.3.2.2 LCD Display 16x2

The LCD display provides essential information to users, such as purchasing instructions and transaction details.



Figure 6: LCD Display 16x2

3.3.2.3 Coin Acceptor

The coin acceptor validates and processes currency, enabling cash-based transactions (Ehardware Siang, 2018).



Figure 7: Coin Acceptor

3.3.2.4 Momentary Push Buttons 7mm

The momentary push button with a 7mm form factor is strategically placed to serve as a user interface element for product selection. Users can press this button to select their desired product.



Figure 8: Momentary Push Button 7mm

3.3.2.5 4-Servo Motors

Servo motors enable controlled movement of the helical spring used for item dispensing. They enhance the precision of actions.



Figure 9: Servo Motor

3.3.2.6 Stepper Motor Nema-17

The Nema-17 stepper motor is a core component of the vending machine's collecting box's movement, ensuring accurate and controlled product delivery (Maximous, 2017).



Figure 10: Stepper Motor Nema-17

3.3.2.7 A4988 Stepper Motor Driver With Heatsink

The A4988 stepper motor driver, along with the attached heatsink, enables precise control of the stepper motor responsible for product delivery.

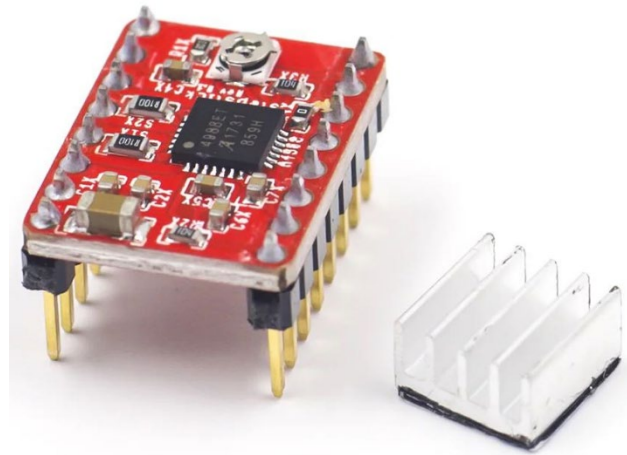


Figure 11: A4988 Stepper Motor Driver With Heatsink

3.3.2.8 LM2596 DC-DC Converter Step Down With Heatsink

This DC-DC converter efficiently steps down the input voltage to a regulated level required by various components. The attached heatsink ensures effective heat dissipation.



Figure 12: LM2596 DC-DC Converter Step Down With Heatsink

3.3.2.9 5V Four-Channel Relay Module

The relay module serves as a control interface, enabling the activation and deactivation of buying items through the mobile app.

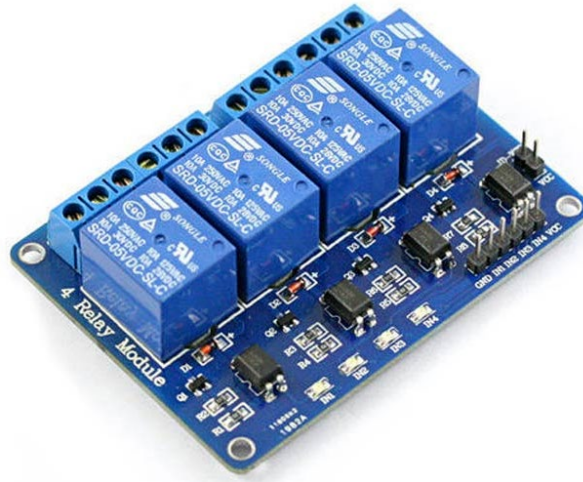


Figure 13: 5V Four-Channel Relay Module

3.3.2.10 Infrared (IR) Sensors

IR sensors are strategically positioned within the vending machine to detect the presence or absence of products. These sensors play a crucial role in ensuring that product availability is accurately monitored and displayed to users in the mobile app.

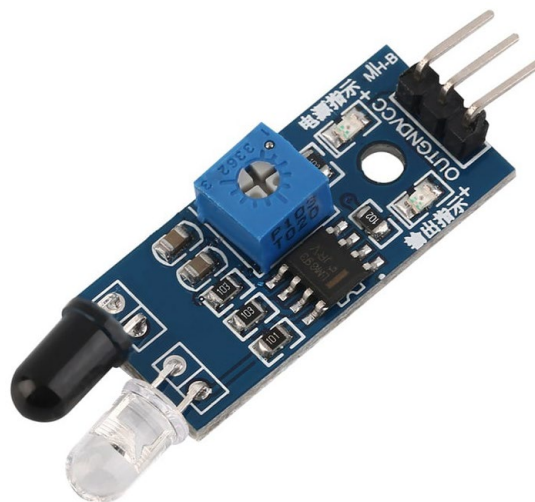


Figure 14: Infrared (IR) Sensor

3.3.2.11 Micro Switch (Limit Switch)

The micro switch acts as a limit switch, indicating the end points of the collecting box's movement, ensuring precise positioning.



Figure 15: Micro Switch (Limit Switch)

3.3.2.12 ESP8266

The ESP8266 module acts as a communication bridge, facilitating remote control and monitoring of the vending machine via the mobile app (RemoteXY, n.d.).

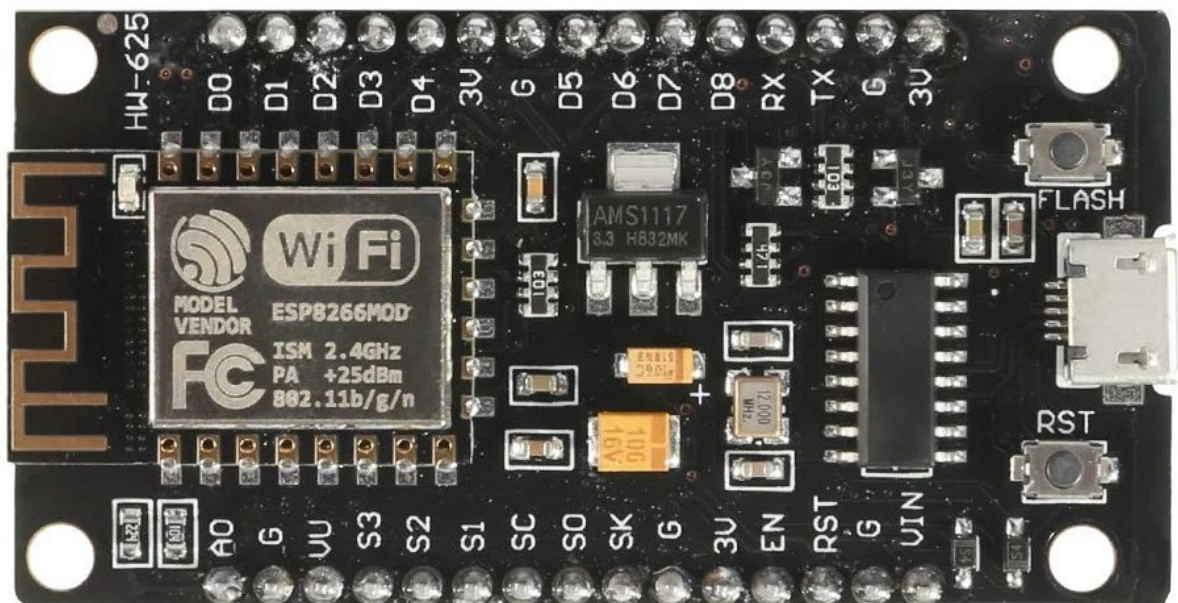


Figure 16: ESP8266

3.3.2.13 Rocker Switch

The rocker switch is integrated into the vending machine's design and is used for powering the machine on and off. It provides a convenient means of controlling the vending machine's power supply.



Figure 17: Rocker Switch

3.3.2.14 RFID Door Lock

The RFID door lock enhances security by restricting access to authorized personnel only using their cards.



Figure 18: RFID Door Lock

3.3.2.15 Power Supply

The power supply unit delivers the required voltage and current to ensure stable operation of all components.



Figure 19: Power Supply

3.3.2.16 Cooling Fan

The cooling fan ensures optimal temperature management within the vending machine to prevent overheating.



Figure 20: Cooling Fan

3.3.2.17 Male to Male and Female to Male Wires

These wiring harnesses establish electrical connections between various components, enabling seamless communication.



Figure 21: Male to Male and Female to Male Wires

3.3.2.18 LED Strip Lights

LED strip lights serve as visual indicators and contribute to the machine's aesthetics.



Figure 22: LED Strip Lights

3.3.3 Circuit Diagram

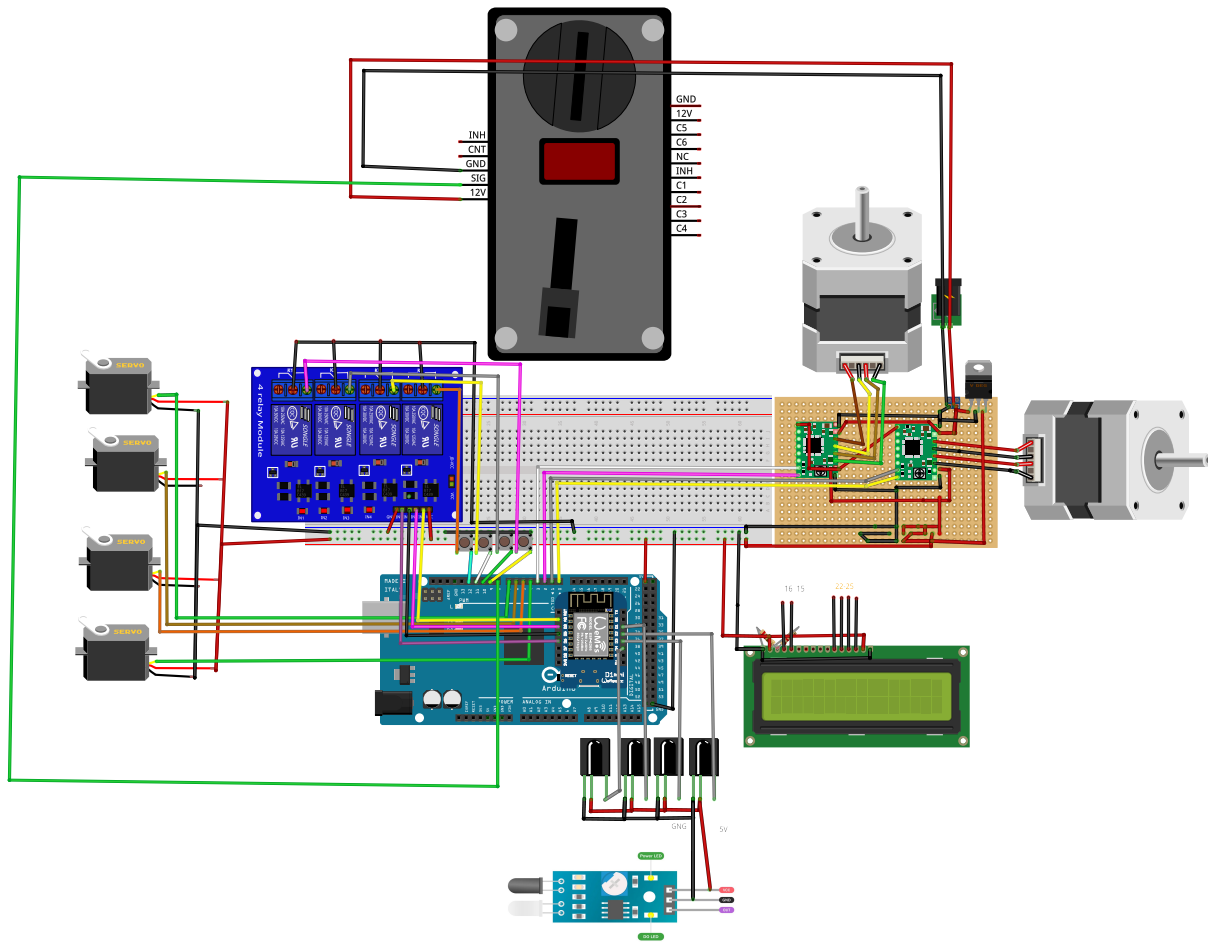


Figure 23: Circuit Diagram

3.4 Software Development and Optimization

3.4.1 Microcontroller Programming

In the software development phase of this project, the Arduino Mega microcontroller played a central role in orchestrating the vending machine's operation.

3.4.1.1 Coin Detection

The Arduino Mega was programmed to interface with the coin acceptor, which validates and processes currency. The software included algorithms for detecting and verifying coins of different denominations. Upon successful validation, the corresponding credit was added to the user's account.

3.4.1.2 Item Selection

To enable user-friendly item selection, the software was configured to respond to inputs from the momentary push buttons. When users pressed a specific button corresponding to their desired product, the software registered the selection.

3.4.1.3 Product Delivery

The software controlled the movement of the collecting box to the selected item slot. Using the data from the momentary push buttons, the Arduino Mega executed precise commands to position the collecting box, ensuring that the chosen product could be retrieved accurately.

3.4.1.4 Communication

To enhance the vending machine's capabilities, a complementary mobile app was developed. This app allowed users to interact with the vending machine remotely. It was designed for seamless communication with the vending machine through the ESP8266 module. Users could use the mobile app to select items, check product availability, and make purchases. The app greatly expanded the vending machine's accessibility and user convenience.

3.4.2 Mobile App Development

The mobile app was designed with a user-friendly interface to provide a convenient and modern way for users to interact with the vending machine.

3.4.2.1 Item Selection

Four distinct orange buttons were prominently displayed on the app's interface, each corresponding to a slot within the vending machine. These buttons allowed users to select their desired product slot.

3.4.2.2 Slot Availability Indicator

Beneath each orange button, a circular indicator was positioned. This circular indicator played a crucial role in informing users about the availability of products within each slot. Two distinct states were represented:

- **Red Circle:** When the circle was displayed in red, it indicated that the corresponding slot contained products.
- **Gray Circle:** A gray circle signified that the slot was currently empty.



Figure 24: Screenshots from the mobile app

Chapter Four: Results and Analysis

4.1 Performance Testing

To evaluate the performance of the vending machine system, a series of tests were conducted. These tests assessed various aspects, including product delivery accuracy, payment processing speed, and user interface responsiveness. The results of the tests revealed a high level of accuracy in product dispensing, rapid payment processing times.

4.2 Analysis of User Experience

The design and engineering of the vending machine system were driven by a user-centric approach. The following aspects were analyzed to evaluate the user experience:

- 1. Ease of Use:** The momentary push buttons and the mobile app interface were designed with simplicity in mind. Users could easily navigate the app, select items, and initiate transactions. The physical buttons on the vending machine provided a tactile and straightforward means of item selection.
- 2. Product Availability:** The incorporation of red and gray indicators beneath each item selection button in the mobile app allowed users to quickly determine product availability. This visual cue minimized the frustration of selecting empty slots.

Chapter Five: Discussion

The results of this project underscore the importance of integrating modern technologies and innovative features in vending machine systems. By enhancing hardware components and optimizing software functionalities, the project achieved its objectives of improving functionality, efficiency, and user experience.

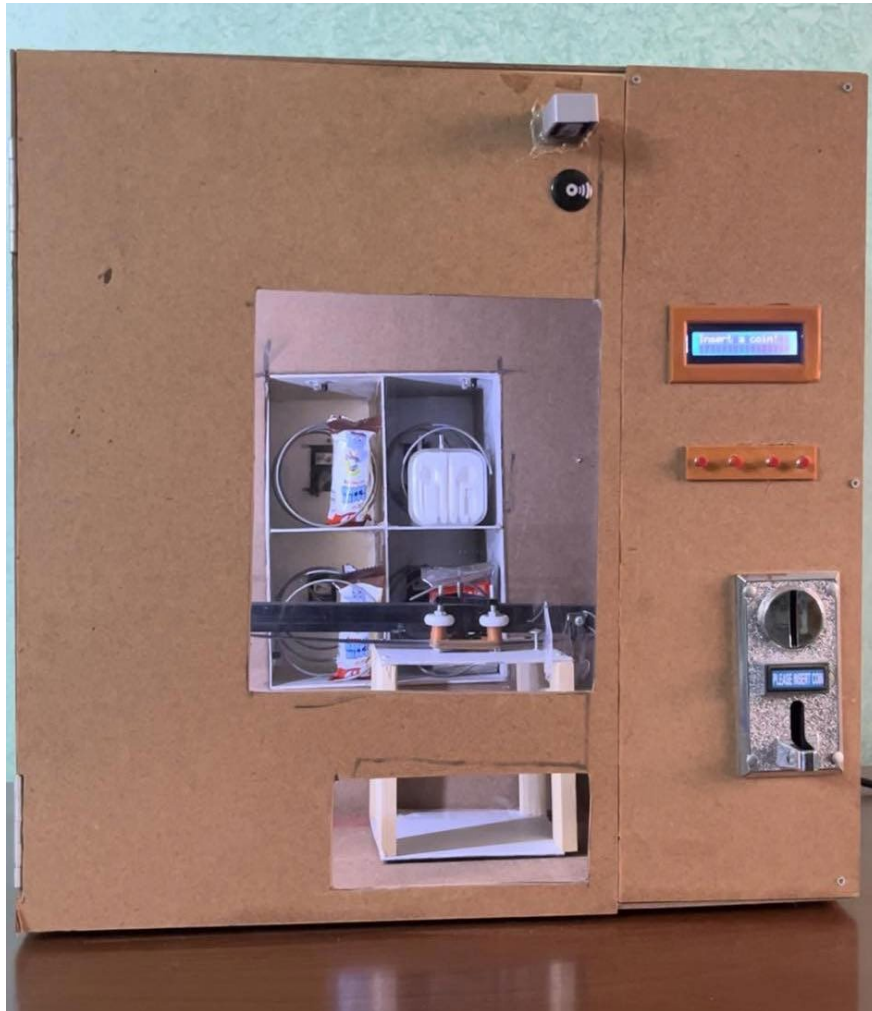


Figure 25: Vending Machine System

Chapter Six: Conclusion and Recommendations

6.1 Conclusion

In conclusion, the completion of this vending machine project marks a significant achievement in the development of a modern, user-friendly, and efficient vending machine system. The combination of robust hardware components and advanced software functionalities has led to a vending machine system that offers a seamless user experience and efficient operation.

6.2 Recommendations

While the project has achieved its primary objectives, there are opportunities for further enhancement. Future work could focus on integrating additional smart features, such as personalized product recommendations based on user preferences and purchase history. Moreover, the implementation of machine learning algorithms could optimize inventory management and predict user preferences, further enhancing the vending machine's capabilities.

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