An-Najah National University

Faculty of Engineering & Information Technology

Computer Engineering Department

Presented in partial fulfilment of the requirements for Bachelor degree in Computer Engineering

Graduation Project 2

STATIONERY SPOT

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Acknowledgement

“

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”

-Aya, Nahida

Disclaimer

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1 Abstract

Our project aims to develop an automated vending machine dedicated to dispensing essential educational supplies such as sticky notes, pens, calculators, and other stationery items. This project's main goal is to provide an easy, fast and efficient way for the students and teaching staff alike to have access to the needed supplies on the go without the need for them to make the trip to a store that sells them. The project's target market is in academic environments like universities, schools, colleges, and libraries. The project offers a solution for accessing educational supplies and saving time. It also ensures that students specifically have the necessary tools for an effective learning experience.

The project's objective is to create a smart vending machine that sells educational supplies. The project covers many elements and aspects including developing an intuitive mobile application and machine interface, integrating an advanced inventory control with real time stock monitoring to keep the machine consistently stocked, and providing secure, adaptable payment options. Adding strong security features, accurate dispensing methods, and remote monitoring capabilities will be essential to enhancing the machine's functionality, security, and user satisfaction. The primary goals are to ensure a smooth user experience, enhanced security to deny unauthorized access, and efficient remote monitoring and maintenance using the mobile app.

The smart vending machine is designed to enhance the user experience and simplify the process of buying the needed products instantly. The hardware consists of multiple slots that store the products. Each slot is equipped with a motor system for precise product dispensing. The user can select the products he wants by multiple methods such as: a keypad system and through a mobile application where he can choose the amount and view the prices. It provides a payment feature, the user can pay by scanning his card with RFID. The purchased products are moved by motors attached to the helical wire, the wire moves to enable the product to be dispensed. If the user didn't get the purchased items a buzzer will be used to inform him that the product needs to be grabbed. The machine also sends notifications to the mobile application to inform the admin about the state of the products and if they have to be refilled.

2 Introduction

2.1 General Background

As students and professionals, we often need basic stationery supplies at inconvenient times, disrupting our workflow. A stationery vending machine offers a quick and efficient solution, providing essential items like pens, sticky notes, and calculators right when needed. Strategically placed in universities, schools, offices, and libraries, these machines enhance productivity by ensuring that supplies are always within easy reach, eliminating the hassle of searching for them elsewhere.

2.2 Problem

In educational and professional environments, the need for basic stationery supplies often arises unexpectedly, making interruptions in workflow and productivity. Finding essential items like pens, sticky notes, or calculators often requires leaving the workspace, going to multiple stores and check if they're open at that time, waiting for the break times to go and search for them, and in some times students have exams and they may forget their pens or calculators, when they are in a hurry they find the store closed and have to wait for it to open or they have to borrow them from someone, which can be time-consuming, inconvenient and takes effort. This doesn't only disrupts tasks but also makes people less efficient and frustrated. The lack of immediate access to necessary supplies disserves the daily activities, causing difficulties to maintain individuals' focus and activity. Our project Stationery Spot aims to solve the problem of inadequate access to stationery in high-traffic areas by providing a convenient, on-demand solution through the implementation of stationery vending machines.

2.3 Objectives

Recognizing these challenges, our project introduces an innovative stationery vending machine created to make the process of buying stationery supplies simpler and easier for students and professionals. Our machine doesn't only facilitate the process of buying stationery supplies on-demand, but also integrates payment solutions and up-to-date information on prices and items in-stock.

Stationery Spot allows the admin to add new items to the vending machine, check the stock, and charge the card. It allows the users to buy the item they want by choosing it, and also pay for it.

Vending machines like this can be placed in many areas such as: universities, libraries, schools and workplaces. They will offer individuals an easy access to essential educational supplies.

These machines save time and effort that may otherwise be spent searching and looking for these items in multiple shops and places. Also, when an urgent situation occurs and the need for these supplies is urgent, these available vending machines in such places play a huge role in serving customers' needs on-demand. The presence of them nearby would undoubtedly enhance individuals' productivity and convenience.

2.4 Scope of the Project

The project mainly targets students in universities and schools, also professionals in their workplaces. It aims to simplify the stationery supplies purchasing process for them. It also targets the shopping markets of these stationery supplies, as they can add these vending machines with their products in multiple areas and also gain money from selling them.

2.5 Importance

We recognize that the development of a stationery vending machine brings essential benefits to both individuals and the community itself. By putting these machines in high-traffic areas like universities, schools, and workplaces, it reduces the time needed to search for these products in multiple shopping markets. This practice is very important in our fast-paced world where having quick access to essential items can make a huge difference in activity and productivity. These vending machines can ensure that people can have the needed stationery supplies on-demand, which is crucial in urgent situations. Additionally, these machines improve efficiency especially during exam periods or work deadlines, having these resources ready and available will surely enhance productivity and success.

2.6 Report Organization

In this report we will go through our journey of building the project, an introduction about it, the constraints we faced during the time of building it, a literature review, the methodology followed in creating the project, an overview of outcomes and data gathered, a discussion and a conclusion covering the things we've done, the things we were challenged to do and the limitations we faced during the process. Additionally, recommendations, references and resources that guided and enriched our development strategy.

3 Constraints, Standards, and Earlier Course Work

3.1 Constraints

3.1.1 Cost and Budget Constraint

Finding a balance between cost and quality is essential to ensure the machine is durable and functional without exceeding financial limits. The problem is that the electronic components cost a lot of money, and sometimes some components get ruined because of the testing process and the multiple usage, this increases the amount of money we have to pay and limits the features we can add to the project.

3.1.2 Procurement, Components Availability, and Logistics Challenges Constraint

Before we started the process of building the project, we asked around multiple shops about the components we needed and we had to wait sometimes for the shop to provide them. We also went to multiple carpenter shops and gave them the exact measurements of the vending machine box, some of them didn't understand exactly what we wanted. Additionally, the size of the project was an obstacle because it was hard to carry and move around. Also, we went to several places to make the springs we wanted to use in the project, but it was hard to shape the steel into a spring form, so we decided to make them using 3D printers.

3.1.3 Time Duration Constraint

We made this project in a limited duration of time on this summer semester, the duration of it was approximately two months and we had to complete the project within this specific time. Additionally, before starting this project we were working on our software graduation project that we discussed on the 2nd of July, this left us with only one week to find the idea and start gathering the information and components needed to start building the project.

After all, we managed to find solutions for each problem we faced to make this project work perfectly as we want. We were determined to finish the project on time and in an efficient way, so we worked daily to make sure the project is successfully completed within the limited timeframe, resulting in a functional and reliable stationery vending machine.

3.2 Standards

When building our vending machine we followed a couple of standards and practices to achieve better functionality and ease of understanding the code.

3.2.1 Programming Language and IDE

The vending machine features and functionalities were programmed using the Arduino IDE, which is written in C/C++. The Arduino IDE was the platform for developing and uploading the code to the Arduino Mega. Similarly, the ESP8266 was programmed using the Arduino IDE to establish communication with the application via Wi-Fi, utilizing the Blynk libraries. [1]

3.2.2 Application Development

The Blynk platform is a comprehensive software suite that enables the prototyping, deployment, and remote management of connected electronic devices at any scale. It allows users to connect their hardware to the cloud and create iOS, Android, and web applications. [2]

We developed a user-friendly mobile application that provides remote control and monitoring capabilities for Stationery Spot vending machine. This integration of Blynk allows a communication between the vending machine and the mobile application over a Wi-Fi network, leveraging the Blynk cloud to ensure reliable and secure data exchange.

3.3 Earlier Course Work

The development and building of our stationery vending machine, Stationery Spot, were significantly influenced by the knowledge and skills acquired from previous coursework. The Computer Engineering courses we took played a huge role to form our abilities to build this hardware project. We took multiple courses that helped us understand the way the hardware components function, such as: Microprocessors and Microcontrollers and their labs. In these courses we learned more about the electronic components such as: stepper motors, keypads, LCDs and many others, we also learned how they work and how to control them. Mainly, the microcontroller lab was very helpful because we made some experiments on Arduino that allowed us to know more about how it works and when to use it. Also, the electronic and electrical courses we took were very useful for understanding the electronic components we used and how they worked. We also took an Arduino course with IEEE that was extremely helpful. We learned the basics of Arduino programming, how to use multiple sensors, and how to connect them with the Arduino and write the codes that control them.

4 Literature Review

Vending machines have improved drastically since they were created, they evolved from a mechanical machine created in the 19th century that operated with coins to now where they are created with complex systems using state of the art technology, this change that happened in the late 20th century marked a significant point for the building of vending machines. Now the use of these technologies allowed for more smooth and accurate transactions using the vending machines, and now using these electronic components help with more complex menus and product selections.

And with the changes that happen every year to vending machine becoming more and more advanced, the market for them keeps going up, the global vending machine market is estimated to be at 23.976 billion USD in 2023, with projected earnings to reach 40.65 billion by 2030, this is due to vending machine utilizing small areas, low labor expenses, and the variety of products they offer.

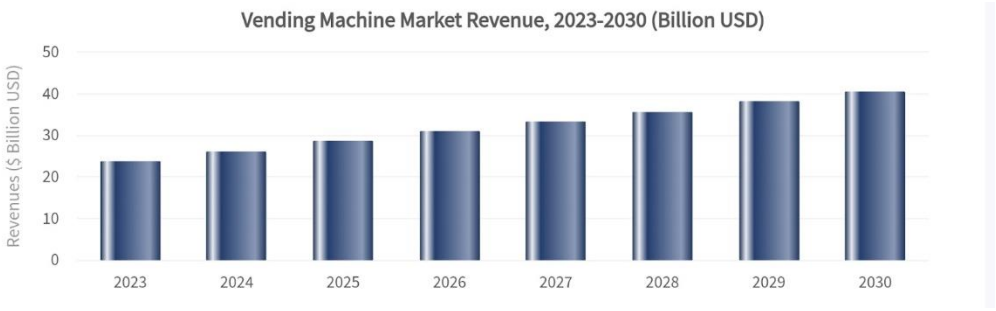

Figure 4.1 Vending Machine Market Revenue

Another reason for this significant growth is the introduction to automated and versatile vending machines. Consumers look to faster solution to help and improve the fast based life these days, and each advancement in the vending machines technologies is only to help cater to the customers' needs and improve their experience.

Some examples of the advanced technologies used for vending machines are Internet of Things (IOT), Artificial Intelligence (AI), and cashless payment systems. The use of these technologies leads to enhancement in inventory management, increase customer satisfaction and expand the market for the vending machines.

You can divide the vending machine market depending on the places that the vending machines are placed in, these can give a general idea on how the vending machines can provide an easy and fast customer experience especially in these environments. It's divided to corporate offices, hotels, restaurants, commercial places, and others. [3]

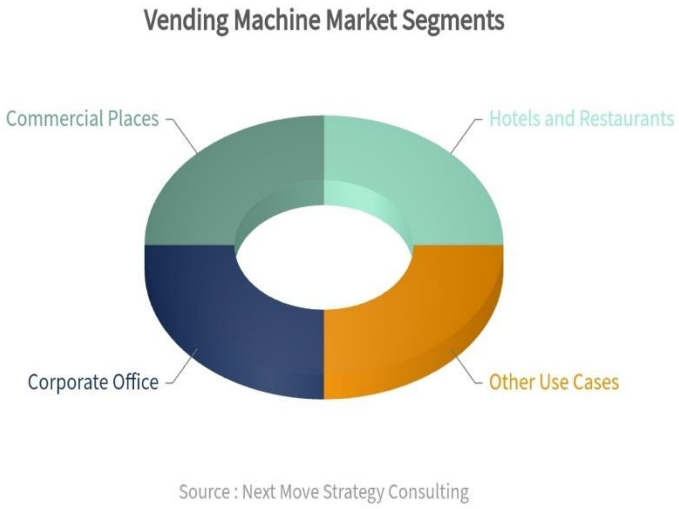

Figure 4.2 Vending Machine Market Segments

With this increase in the advancement in vending machine technologies comes its challenges, with more hardware and electronics to be added into the newly developed machines, the cost increases to adapt to those changes, the more complex the vending machine is the higher the cost. Also software customization and maintenance can hinder the development of the vending machines and create a barrier to its growth. However with the development that happens each year in the different fields there are many opportunities of things that can be added into the vending machines to make it even more accessible than it already is today. [4]

5 Methodology

Upon reviewing the studies, market research, and questionnaires in the literature review, it became evident that the project idea is not only creditable but also well-suited. Given that the development of a stationery vending machine brings essential benefits to both individuals and the community, the project exhibits strong relevance to current trends. Furthermore, it offers the potential for a swifter and less convoluted transaction.

This chapter will delve into our system architecture, hardware components and devices, software and libraries, implementation, final design of the project, and mobile application.

5.1 System Architecture

In this section, we are going to delve deep into how we designed the architecture of the project. We designed a (50 cm, 49 cm, 55 cm) cabinet. At first we designed it without the front door so we can work easily, then we added the CNC and connected it with a basket to collect the stationery items when they fall from the spring because we wanted to keep them safe and to ensure the stationery items fall without ruining or breaking them. Then we added the slots with their springs. And finally we added the front door that had holes we made to add the hardware components later.

- **This was the initial design:**

Figure 5.1 Initial Design

- **CNC with a basket:**
  To design the basket that fetches each product from the slot when ordering a product, we created two dimensional CNC machine that goes along the axis of the product placement, for the horizontal axis , a motor controls the movement of the basket, a linear guide is used as the path the basket will move in, the basket is connected to the linear guide and can be moved by connecting a belt to the motor and on the belt is the slider that holds the basket, this slider is made of 3 wheels so it can be moved easily along the guide. As for the vertical axis we use it to move all of the horizontal axis, the same as the horizontal it is controlled by a stepper motor and moved by a linear guide and the motor is connected to a belt that is connected to the slider that holds the horizontal axis.

Figure 5.2 CNC Linear Guides with Stepper Motors

Figure 5.3 Basket

- **Springs:**
  We made 4 helical coils using a 3D printer to act as discharging units for our stationery items.

Figure 5.4 Springs

5.2 Hardware Components and Devices

- **Arduino Mega 2560:**

  It's a microcontroller board based on the Atmega2560. We used a lot of hardware components so we used it because it has more functionalities than the original Arduino board. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. We used the Arduino Mega as our main processor because it connects all the parts pf the project together, runs the code we wrote using C++ with all its algorithms and functionalities, this code is what controls the flow of how our system works. [5]

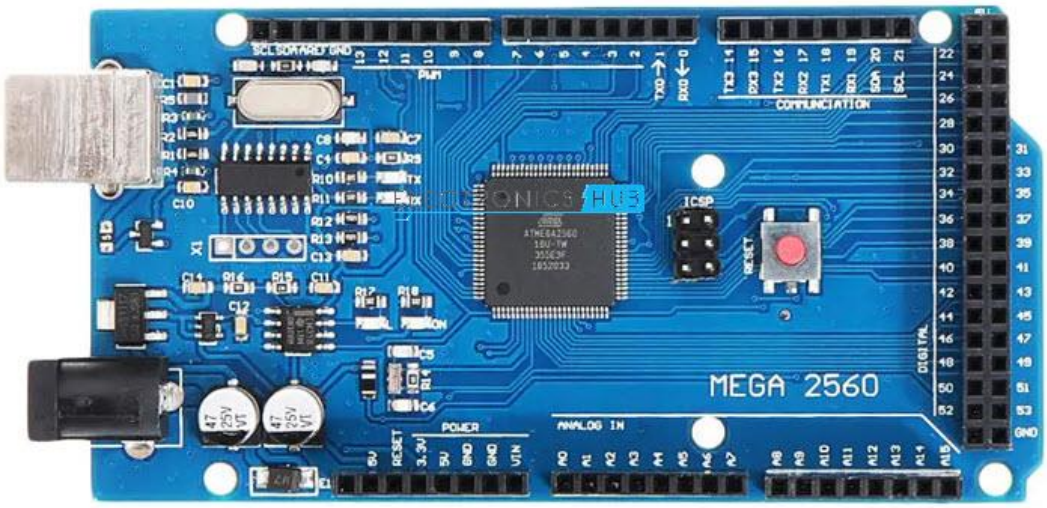

Figure 5.5 Arduino Mega 2560

- **ESP 8266:**

The ESP8266 module enables microcontrollers to connect to 2.4 GHz Wi-Fi, using IEEE 802.11 bgn. It can be used with ESP-AT firmware to provide Wi-Fi connectivity to external host MCUs, or it can be used as a self-sufficient MCU by running an RTOS-based SDK. In our project, we used it to simplify IoT. We used it to connect to the Internet in order to communicate with the phone application that we developed on Blynk and send messages to it. [6]

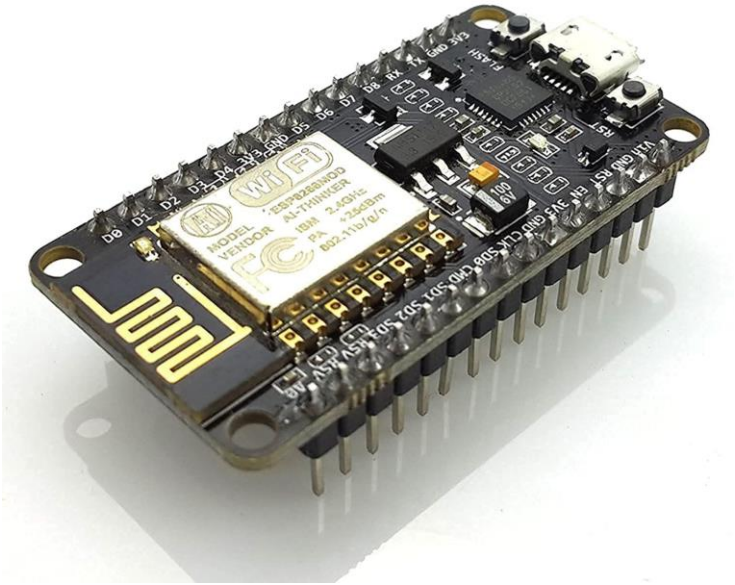

Figure 5.6 ESP 8266

- **Power Supply:**

Our power supply source was connecting the machine with main power supply 220v, we used a switch to connect this switched-mode power supply circuit as our converter module from AC to DC to power the electronic devices.

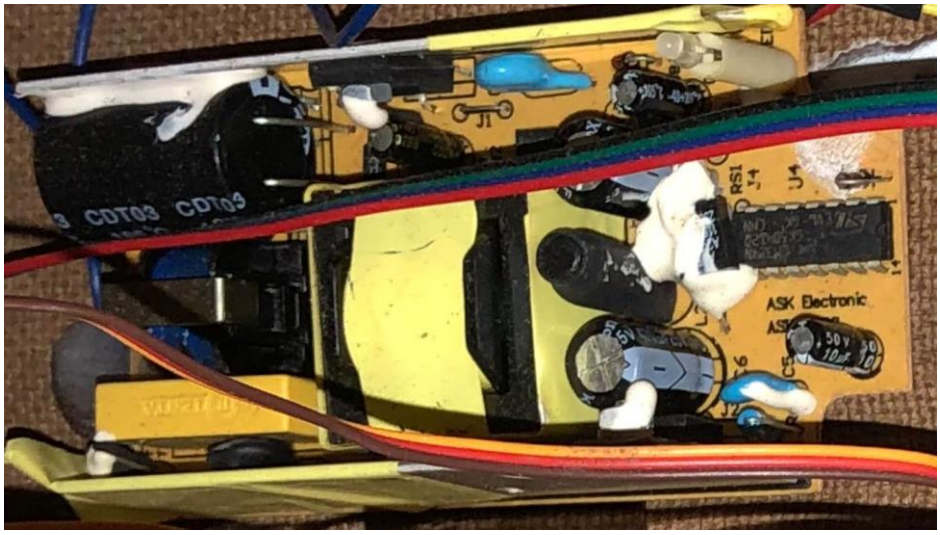

Figure 5.7 Power Supply

- **Stepper Motors:**

We used 2 Nema 17 stepper motors for the CNC, one of them is used to move the CNC horizontally (x-axis) on a linear guide, and the other one is used to move the entire linear guide vertically (y-axis). [7]

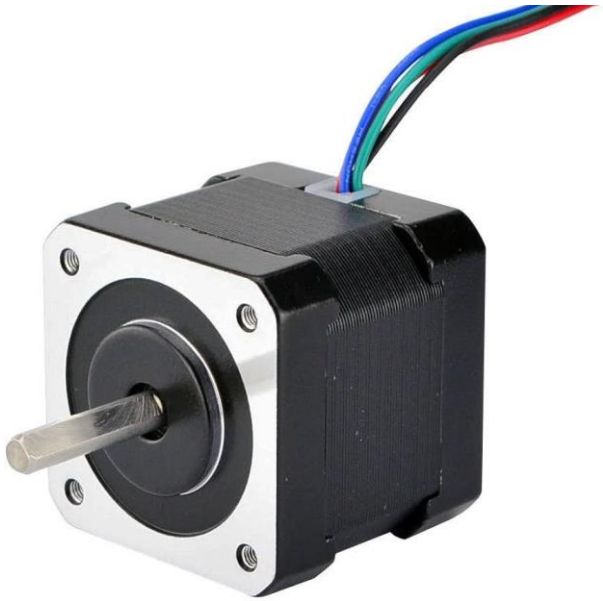

Figure 5.8 Nema 17 Stepper Motor

- **Linear Guides:**

We used linear guides as tracks fixed with stepper motors so the CNC of our vending machine can move vertically and horizontally.

Figure 5.9 Linear Guides

- **Limit switch:**

A limit switch is an electromechanical device operated by a physical force applied to it by an object. We used 2 limit switches one for x-axis and the other for y-axis, It's connected with the CNC to detect the position of the basket, when the basket reaches its reference (home position) the limit switches state is (0,0).

Figure 5.10 Limit Switch

- **Servo Motors:**

We used 4 MG995 servo motors that rotate up to 360 degree. Servo motors are a high-torque, standard-sized, high-speed standard, and a heavy-duty reliable motors. They are low-power and cost-effective motors. They are commonly used in robotics and other projects that need precise rotational movement. They are durable and reliable due to their metal gears and robust construction. The MG995 can rotate up to 360 degree modifying it by code, offers a torque of up to 10 kg/cm, powered by a standard 4.8 to 7.2V power supply. It receives signals from Arduino or any other microcontroller due to its internal control circuitry that allows this action. It moves to a specified angle such as requested which makes it ideal for projects that need both strength and precision such as our vending machine.
In our vending machine we connected them to the back of each spring of the 4 springs to allow their movement. The servos were responsible for pulling the stationery items into the basket by rotating in 360 degrees. [8]

Figure 5.11 Servo Motor

- **Motor Power Supply Circuit:**

We made a circuit specifically designed to supply and regulate the electrical power needed for motors. It includes components like voltage converters and motor drivers to manage the motor's power requirements.

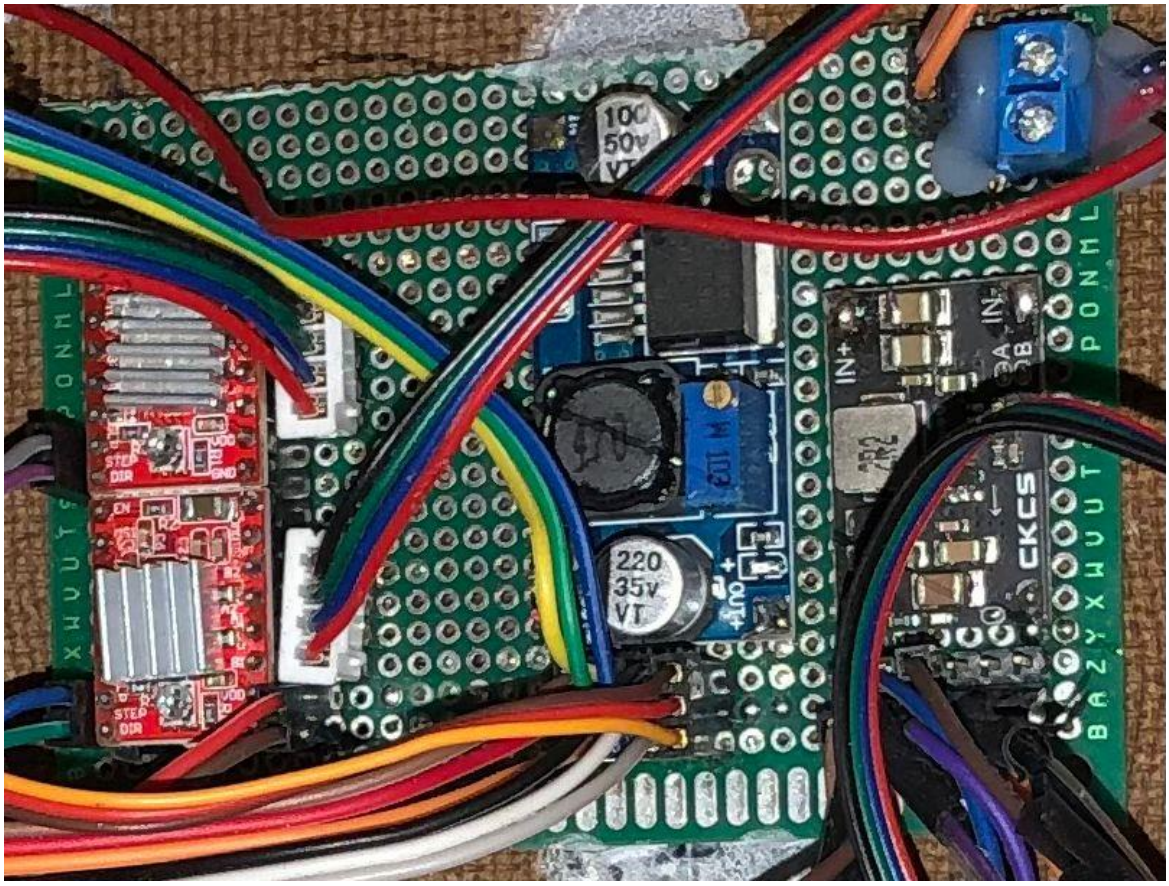

Figure 5.12 Motor Power Supply Circuit

It includes the following components:

- **A4988 Stepper Motor Driver Module:**

A stepper driver module controls the working of a stepper motor. Stepper drivers send the current to the stepper motor through various phases. It is a complete microstepping motor driver with built-in translator for easy operation. It has a built-in translator which means that we can control the stepper motor using very few pins from our controller. We used 2 drivers because we have 2 stepper motors. [9]

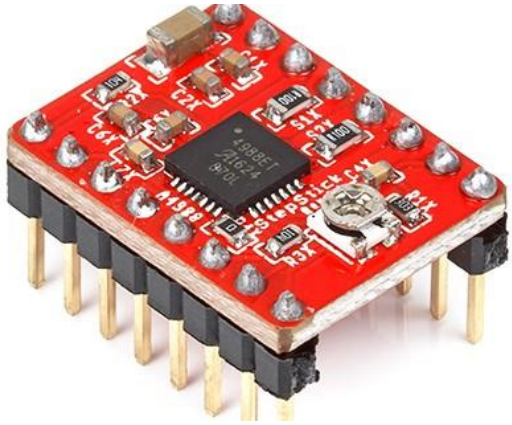

Figure 5.13 A4988 Stepper Motor Driver Module

- **DC-to-DC Converter 12v-5v:**

We used 2 DC to DC converter module (12V to 5V) for use with servo motors and Arduino. It has components such as capacitors, inductors, and a voltage regulator chip. This one is used for stepping down voltage from 12V to 5V to safely power the servo motors. It passes a current of 2A.

Figure 5.14 DC-to-DC Converter 12v-5v

The other one is used for stepping down voltage from 12V to 5V to safely power the Arduino. It passes a current of 1.5A.

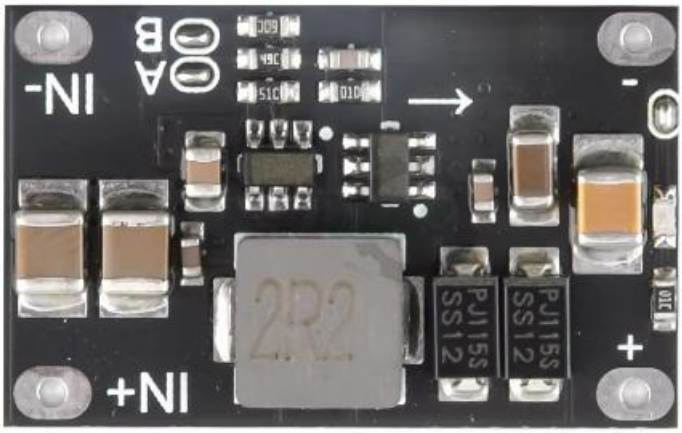

Figure 5.15 DC-to-DC Converter 12v-5v

- **Keypad 4x4:**

  The 4×4 matrix keypad is an input device, used to provide input values in a project. It has 16 keys in total, which means it can provide 16 input values. We used it to enter values on the machine and to control it.

Figure 5.16 Keypad 4x4

- **RFID Reader:**

  Radio Frequency Identification (RFID) refers to a wireless system comprised of two components: tags and readers. The reader is a device that has one or more antennas that emit radio waves and receive signals back from the RFID tag.
  We used it in our project to read the admin's tag for admin's privileges, and to read the customer's card as a payment method when purchasing.

Admin's tag:

Customer's card:

Figure 5.17 RFID Reader

- **LCD 20x4:**

The LCD 20x4 is a 20 characters by 4 lines liquid crystal display module. It's used for displaying output like text and simple graphics. We used it to display text such as the products available in the vending machine (names and prices), the order, the total amount of money, and instructions such as scan the card request for the customer.

Figure 5.18 LCD 20x4

- **LCD Driver Module with I2C Interface:**

A specialized electronic component designed to make it easier to integrate a liquid crystal display (LCD) into electronic systems is a LCD driver module with an I2C interface. 4 wires GND, VCC, SCL, and SDA come out of it. VCC is connected with 5 volts and SCL, SDA from the driver with SCL, SDA from Arduino.

Figure 5.19 LCD Driver Module with 12C Interface

- **IR sensor:**

  An infrared sensor (IR sensor) is a radiation-sensitive optoelectronic component. The IR transmitter continuously emits the IR light and the IR receiver keeps on checking for the reflected light. If the light gets reflected back by hitting any object in front it, the IR receiver receives this light. This way the object is detected in the case of the IR sensor. We used it to detect the products when the basket return to home loaded, so the buzzer is informed to make a sound.

Figure 5.20 IR Sensor

- **Buzzer:**

  A buzzer is an electronic component that generates sound through the transmission of electrical signals. Its main function is to provide an audible alert or notification and typically operates within a voltage range of 5V to 12V. We used a buzzer in our vending machine to give a sound alert about the presence of items in the output box. When the IR sensor detects that the loaded basket has reached the home point and is loaded with products, the buzzer makes a sound.

Figure 5.21 Buzzer

- **Ultrasonic Sensor:**

An electronic component that uses ultrasonic sound waves (through air) to measure the distance of the target object and the reflected sound is converted into electrical signal. We used it on the door of the vending machine so when someone approaches it within 50cm it uses this information to turn on the interior lightening in the machine.

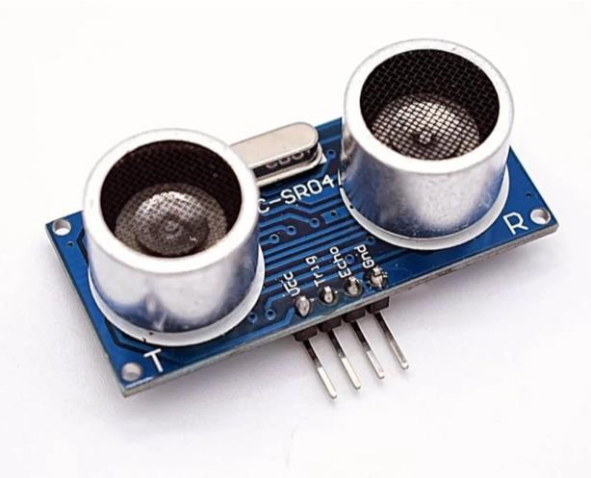

Figure 5.22 Ultrasonic Sensor

- **Strip Light:**

A strip light is a multi-circuit stage lighting instrument. We used it for illumination by connecting it to the Arduino. It takes the information from the ultrasonic sensor, when someone approaches the vending machine within 50 cm, the strips light.

Figure 5.23 Strip Light

- **Lock:**

We used a lock on the front door of the machine to ensure the security of the cabinet, this lock can only be opened by the admin, when a valid tag is detected.

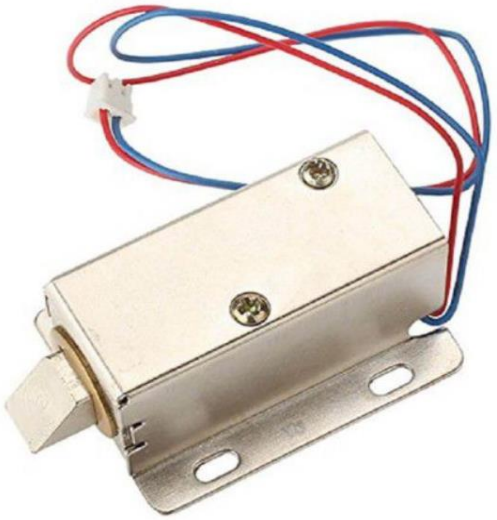

Figure 5.24 Lock

- **Single Channel Relay Module:**

A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. We used 2 relays one connected with the ultrasonic and the other with the lock so that we can control them.

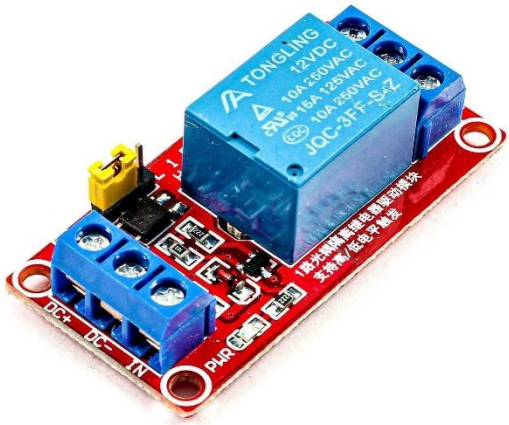

Figure 5.25 Single Channel Relay Module

- **Wires:**

We used jumper wires and standard wires for the connections between components.

Figure 5.26 Jumper Wires

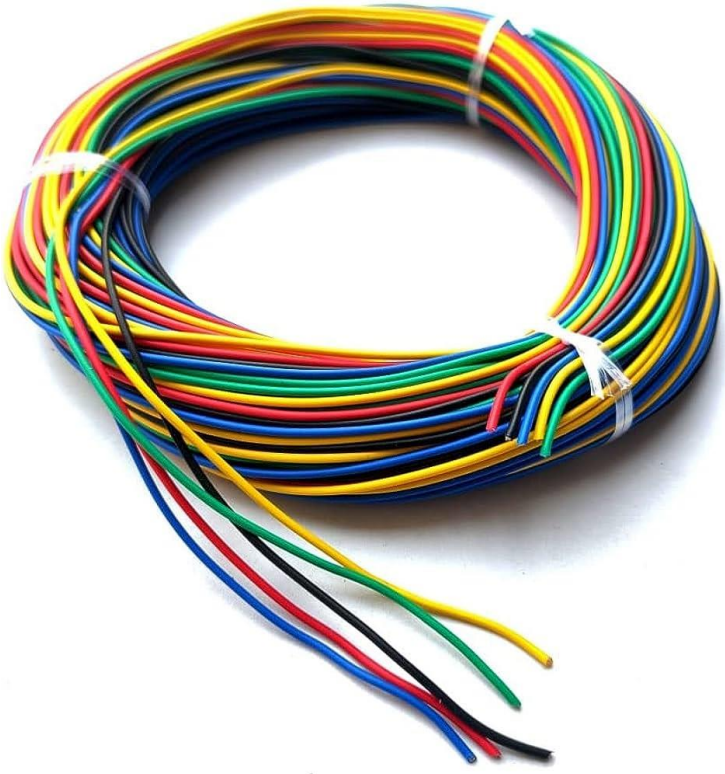

Figure 5.27 Standard Wires

5.3 Software and Libraries

5.3.1 Libraries used in Arduino code

- **SPI.h**: A built-in library in the Arduino environment that is used to provide functions to use SPI (Serial Peripheral Interface) protocol which is used to connect microcontrollers to peripheral devices.

- **RFID.h:** A library simplifies the integration of RFID functionality into Arduino projects. It enables communication with RFID readers.

- **Servo.h:** An Arduino library that provides an easy way to control servo motors using Arduino.

- **Keypad.h:** Matrix keypads can be linked using the keyboard library, it makes it easy to read the input from these types of input devices, we used it to manipulate keypad buttons and read their values.

- **SoftwareSerial.h:** A standard Arduino library that is used to provide software-based serial communication ports.

- **LiquidCrystal_I2C.h:** An Arduino library that interacts with LCD displays that use the I2C communication protocol. I2C communication makes connecting an LCD display to an Arduino board easier and uses fewer pins.

5.3.2 Libraries used in ESP8266 code

- **FS.h:** A library that provides an interface for working with file systems stored on the microcontroller's flash memory.

- **LittleFS.h:** An alternative file system library for the ESP8266 microcontroller that gives more reliable and efficient way to handle file storage on the device's flash memory.

- **ESP8266WiFi.h:** The ESP8266 platform's ESP8266WiFi.h header file offers the definitions and functions required to operate with WiFi connection.

- **BlynkSimpleEsp8266.h:** A necessary component for developing IoT applications with the ESP8266 microcontroller and the Blynk platform.

5.4 Implementation

5.4.1 System Design

We used the Arduino Mega as the main controller unit in our project, due to it having multiple serial ports that allow us to use it as the main hub that connects all the different components together.

When the vending machine is connected to the power source, it turns on both the Arduino and ESP-8266, once they are on the ESP tries to connect to the internet access point, and transfers all the data it got about the state of the products in the vending machine to the Arduino which setups the system according to the data received, the ESP also connects to our mobile application which through it we can get admin privileges and edit and change the data about the products, or we can order a product directly from the application.

The project uses the ultrasonic sensor, IR sensor, keypad, and the RFID reader as the main input points, and the system checks for inputs all the time it is running, for example for the ultrasonic sensor, it will always check if there is a body in front of it in a 50 cm radius, and once a body is detected, it sends a signal to the Arduino which tells that a body is within the radius and then the Arduino sends a signal to turn on the lights. The same thing goes for the IR sensor, the sensor always checks if there's a product inside the basket so the user can pick it up, if there was a product it sends a signal to Arduino telling it to activate the buzzer to let the user know that the product is ready for pickup.

For the keypad, it waits until a button is pressed and once it is, it sends a signal to check what is the functionality that is mapped for the button, for example if the first button pressed is (A) it knows that the user has selected the product in slot A to be purchased and if an order confirmation is sent, the keypad sends the signal to the Arduino of each product that was purchased and then the Arduino sends a signal to the stepper motors connected to the CNC with how many steps they should move depending of the mapped location of the selected products.

For the RFID reader it has two uses first, it reads the tags that grant admin privileges, when read, it sends a signal to open the door and removes the lock on it, the other use is when the product is purchased, it reads the balance inside the card and depending on it, it sends the signal that determines if the order is accepted or denied.

The Arduino is also connected to the LCD as it is used as the user interface for our project, when the machine is turned on the Arduino sends the LCD a list of the products and their prices, and when trying to order, the LCD displays each product selected to be ordered and through it you can see the change when the quantity for each product selected is changed, also it displays messages, so when trying to buy a product that is out of stock, the Arduino sends the LCD a message to be displayed saying the product is out of stock, or when trying to buy with insufficient balance, the Arduino sends a signal to the LCD telling it to display that the funds are insufficient.

Lastly, the Arduino is connected to servo motors, when an order is placed and the basket reaches the desired location, the Arduino sends a signal for the servo motor in that location, then the motor starts to move the spring that it is connected to allow the product to be dispensed properly.

All of this is possible because the Arduino MEGA provides many serial ports which allow all of these components to be connected together, and through it each of these components can work in harmony with each other to provide an easy and immersive experience for the customer.

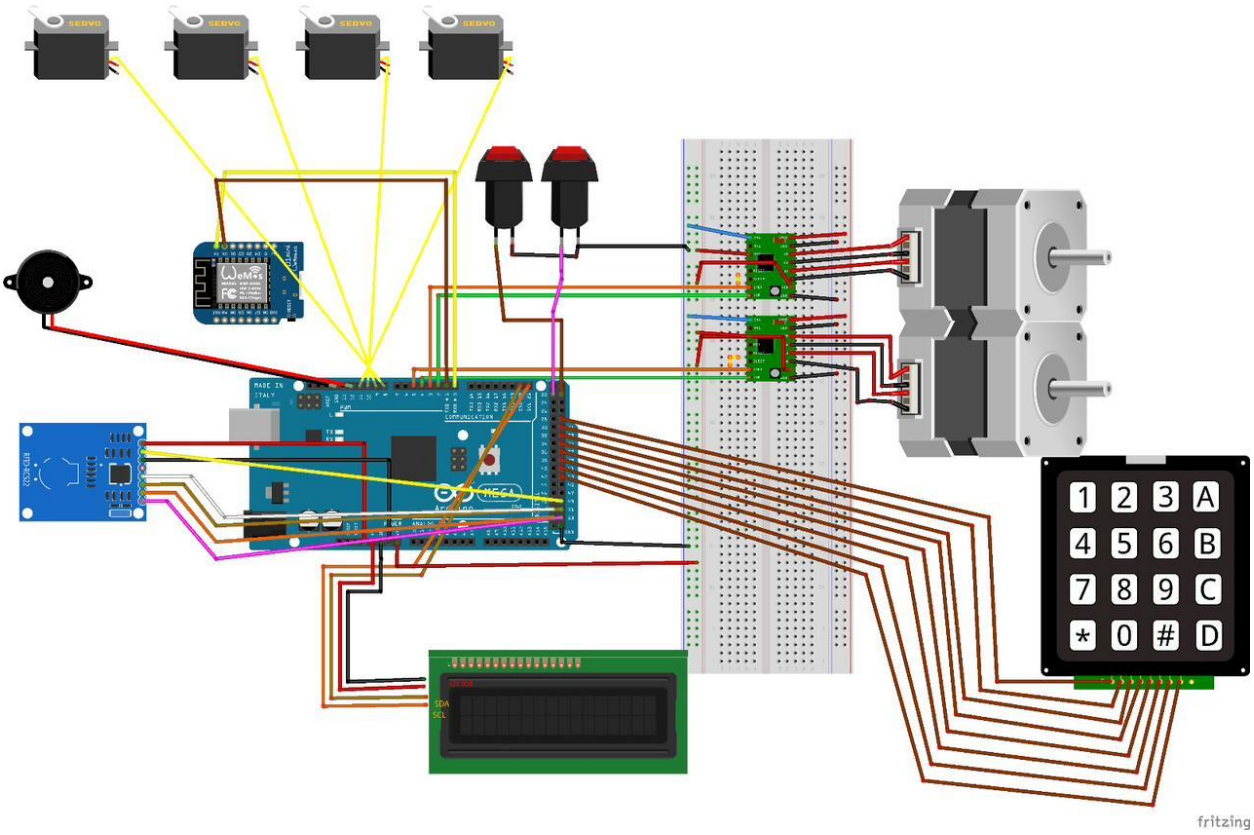

Figure 5.28 Diagram for some of the Connections

5.4.2 System Process of Work

At first, the lightening in the vending machine will be of, then when someone approaches it within 50 cm, the strip lights in it turn on as a result of proximity information taken from the ultrasonic sensor. The lock on the front door can't be accessed except from the admin. When the admin approaches and scans his tag on the RFID reader, the lock opens, and the admin now can add the products into the slots of the vending machine and set their names, prices, and quantities using the mobile application. He can also charge the customers' cards with a balance of money. The CNC with the basket is at first located in home reference which is when the two limit switches connected to the horizontal linear guide and the vertical one of the CNC are in a state of (0,0).

For the customers (users), they can view the available items in the machine displayed on the LCD with their prices, and through the glass door they can know the quantities available or if a product is out of stock. They can order from the vending machine through two methods:

- Order from machine:

  Customers can order from the machine by placing their order using the keypad. They can order different items from multiple slots with multiple quantities as they want. Once they add the input on the keypad, they can see on the LCD screen each product with its price and they can choose the quantity they want. A # is pressed when they want to confirm the order, and a * is pressed when they want to cancel it. After they place the order, the total money is displayed on the LCD screen and the user is requested to scan his card for payment. When the customer scans his card using the RFID reader, the items begin to be dispensed in the order the user requested. The CNC that is connected to two stepper motors with the basket moves in 2D (horizontal and vertical) from its home reference which is (0,0) to reach the first slot, the spring in that slot that is connected to a servo motor starts to rotate to push the item to fall on the basket, then the basket returns to the reference which is (0,0) very quick before it moves to the next slot that has the next ordered product, this process keeps going until the order is all dispensed. When the basket is loaded with all the purchased items, it returns to the reference. An IR sensor detects that the basket is loaded with the items, so a buzzer starts to make a sound to inform the customer to pick his order.

- Order from mobile application:

  Customers can also use a mobile application for an easy purchasing method, this way is more suitable if the customer only needs one item from one slot, so it's suitable if the order is quick. Then the customer is required to scan his card on the RFID reader, the CNC connected to stepper motors moves to the located slot that has the ordered product,

the spring's servo motor rotates to dispense the product to the basket, the basket returns to its reference, the buzzer makes a sound and the item is ready to be collected.

A notification is sent to the admin on Blynk when any product is out of stock to inform him to restock it.

This is the use case diagram for both admin and customer: [10]

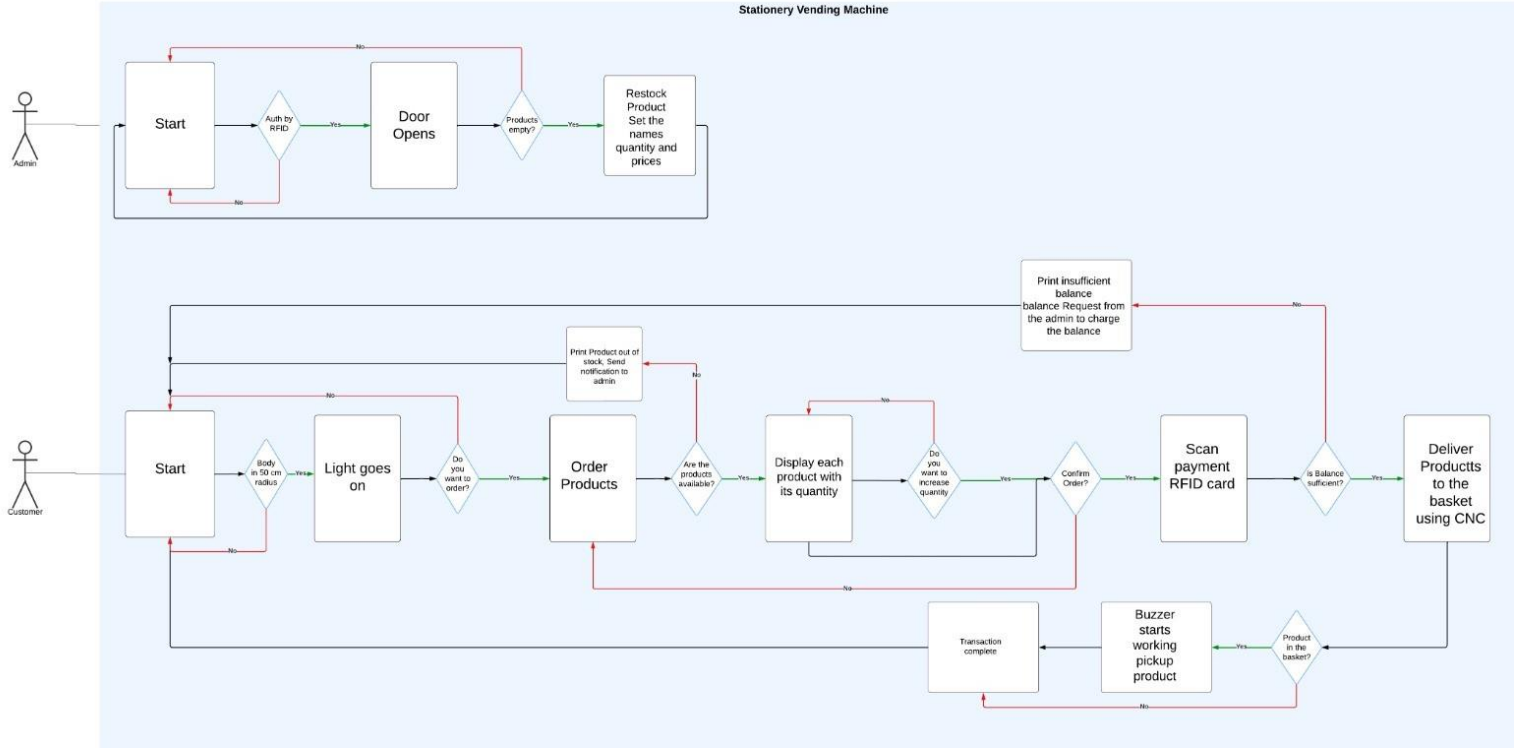

Figure 5.29 Use Case Diagram

5.5 Final Project

This picture shows the final project “Stationery Spot” smart vending machine which is used for dispensing stationery items to allow customers to have an easy and effective experience while purchasing these items on-demand at any time and any place, whatever the circumstances. It shows all the components we explained earlier in the report. Mainly, the front door with its components, the vending machine slots with springs attached and the CNC connected to the basket.

Figure 5.30 Final Project

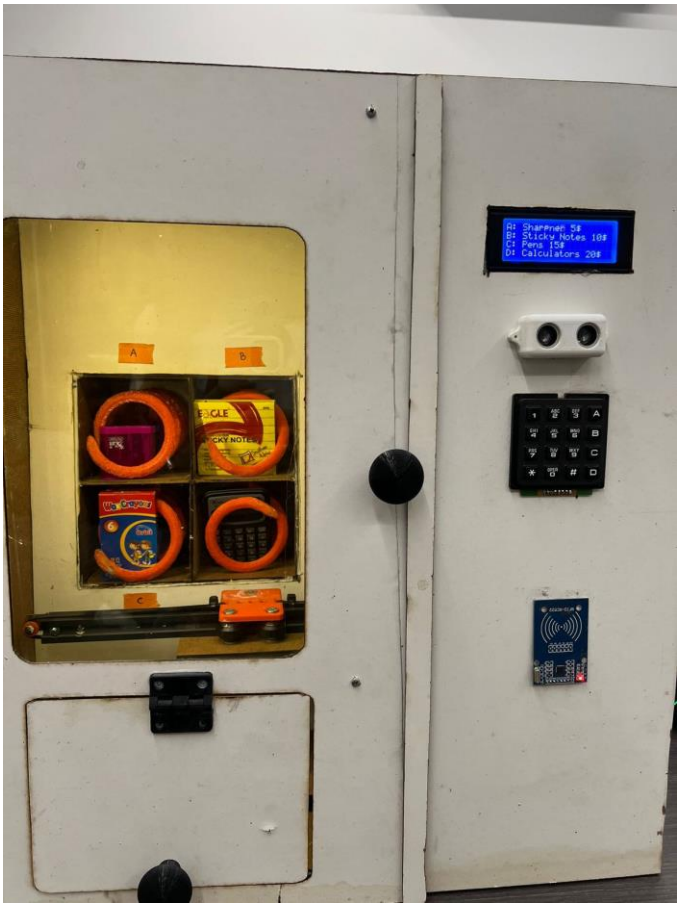

Figure 5.31 Final Project from the Inside

5.6 Mobile Application

We developed a mobile application on Blynk with many features. There's a section for the admin and another for the user (customer).

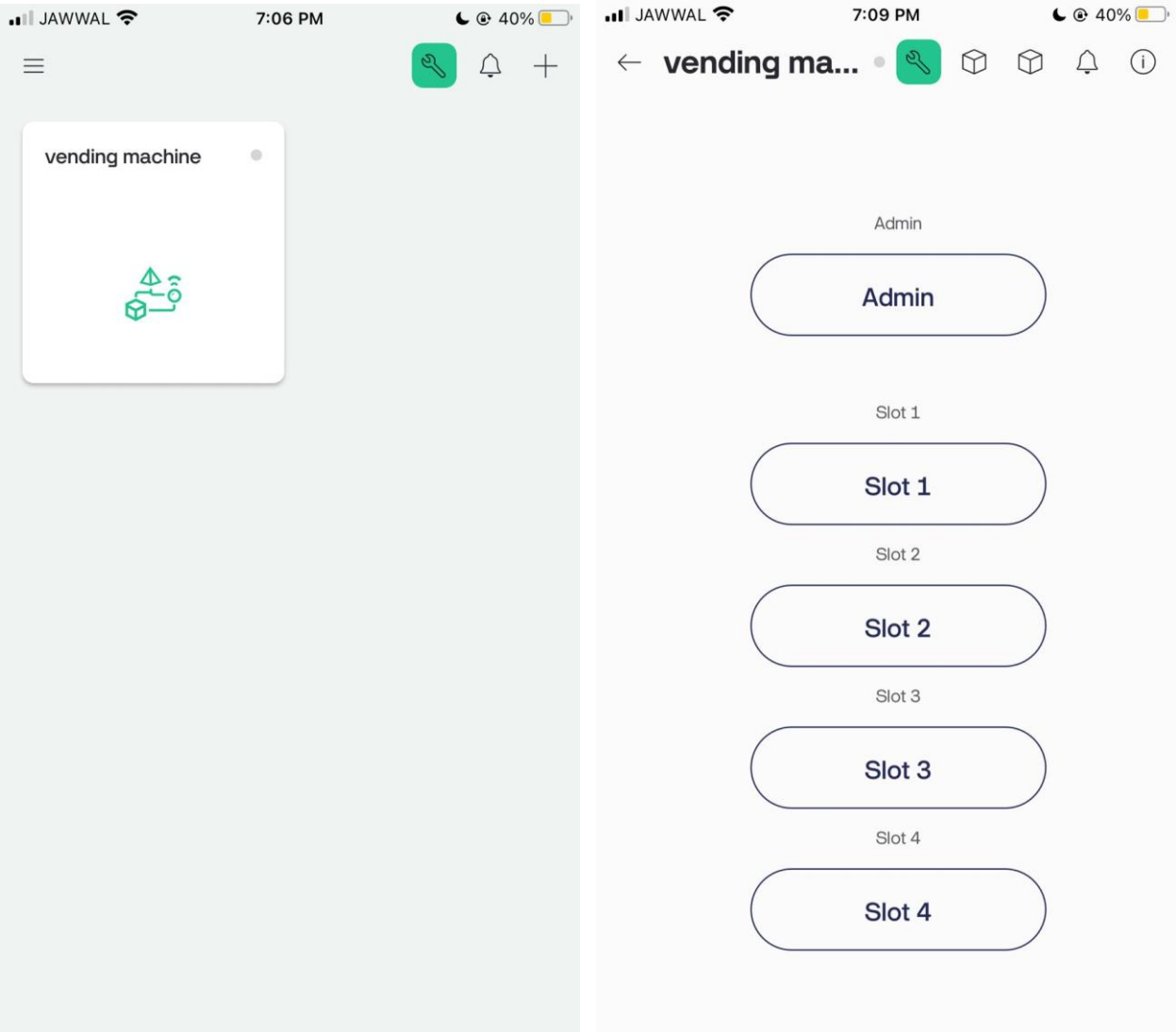

Figure 5.32 Mobile Application Dashboard

- **Admin Page:**

The admin can set the quantity, price and change name of any slot from the vending machine's slots. He can also charge the customer's card with a balance.

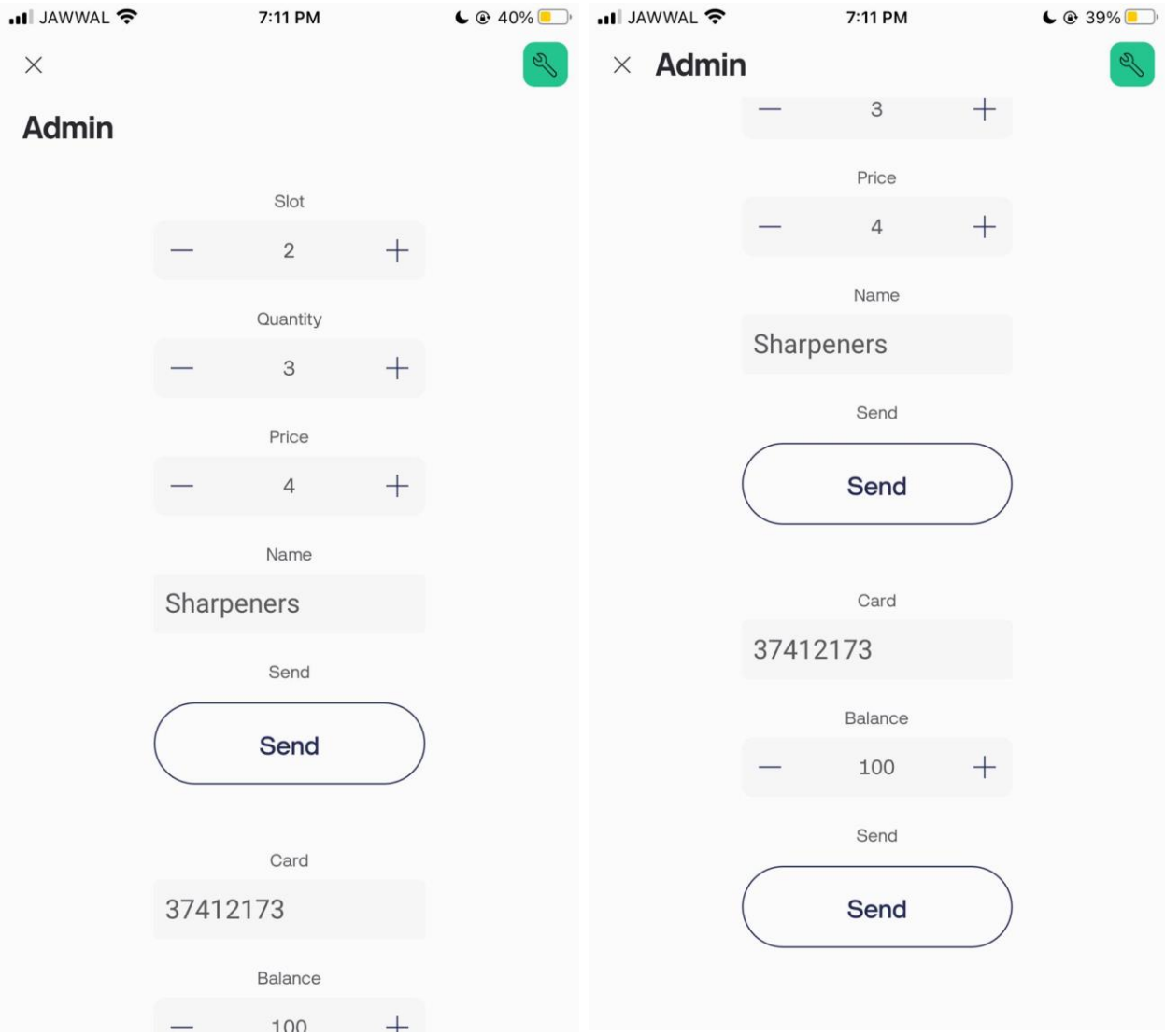

Figure 5.33 Admin Page

- **Customer (user) Page:**

The user (customer) can order a product from any slot he wants.

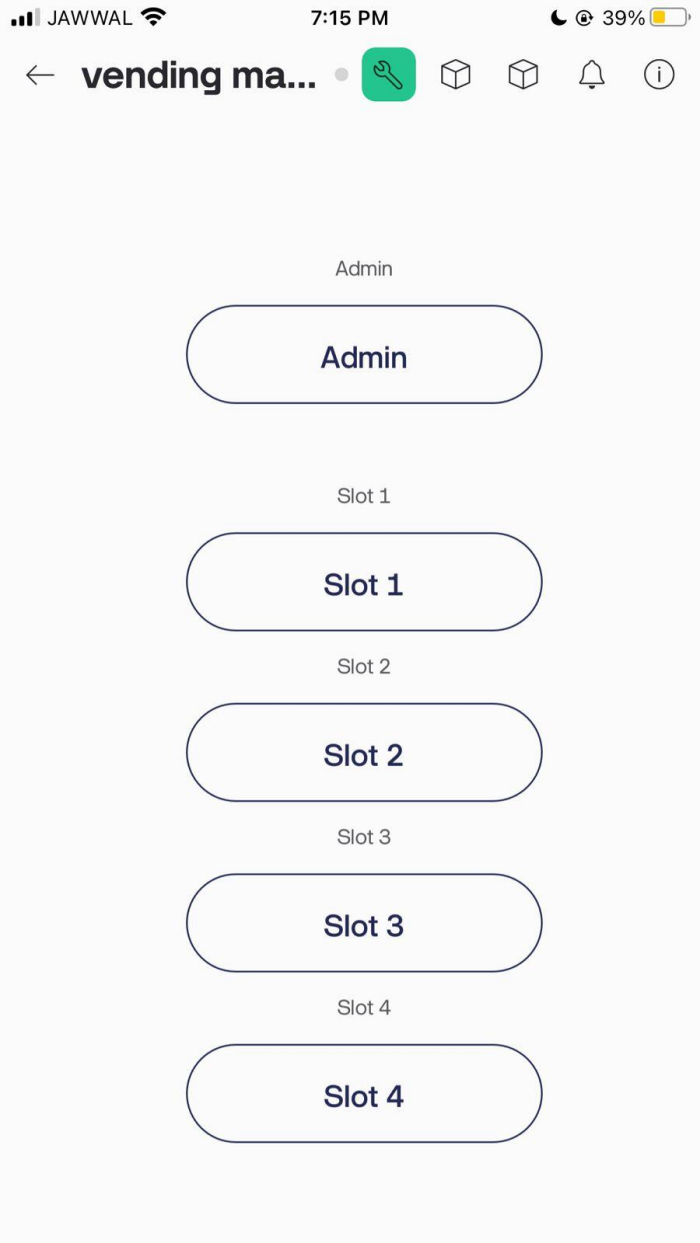

Figure 5.34 Customer Page

- **Notifications:**

  Notifications are sent to the admin on the app whenever a slot of the vending machine is out of stock, so he gets informed to restock the items.

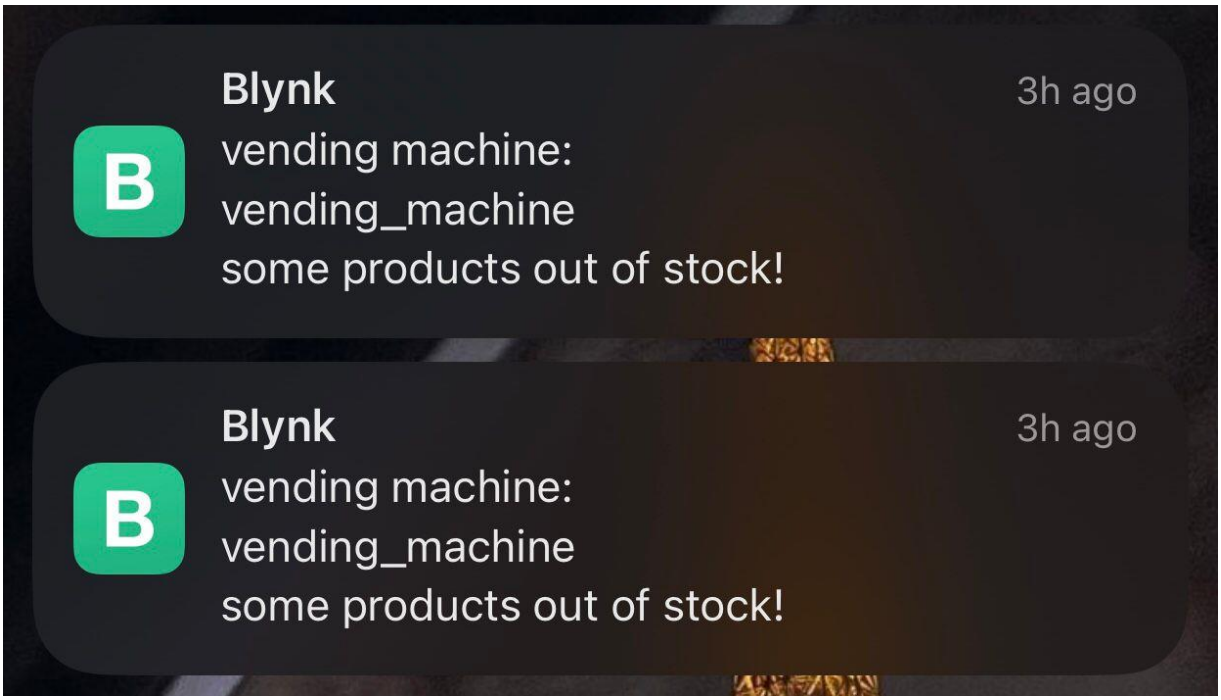

Figure 5.35 Notifications

6 Results and Discussion

The stationery vending machine which purpose is to sell appliances like pens, calculators, and so on to help cater to the students' needs, uses the latest technologies, these technologies help provide a great customer experience and helps make purchasing these products way faster and easier.

6.1 Results

At the end we were able to design a smart vending machine used to dispense products in an efficient, fast, and easy to use by the customers. Using the features that we implemented we were able to create an immersive experience for the user, for example, the way each product is fetched from the slot it's in using a basket to ensure that the products are given to the customer in the best condition possible, turning on the lights when using the machine or the buzzer that creates a sound alert that notifies that user that product is ready for pickup, also the ability to order a product through the machine itself from keypad and pay through card is a user-friendly experience, and the ability to order in a digital way through a mobile app with cashless payment is great to decrease the time for the transaction. Also security was a great concern, so our final product ensures that no one has access to the products inside the vending machine except through buying the product or having admin access to open the machine door to supply the machine with products when the stock is empty.

6.2 Discussion

The development of the Stationery Spot smart vending machine reflects an innovative approach to providing easy access to educational supplies in public spaces like universities, schools, parks, and workplaces. This machine has automation and CNC technology for dispensing stationer items such as: pens, calculators, sticky notes, etc. By adding a basket collection system and creating a user-friendly and appealing design for user convenience, Stationery Spot aims to solve the problem of inadequate access to stationery in high-traffic areas.

When starting with the design of our stationery vending machine, we faced many challenges. The first was learning how to implement it, even though we have a lot of knowledge we gained from our courses in university, it was still not enough to cover the whole implementation of our project, we enhanced our experience in writing Arduino code for our Arduino and ESP. We also learned how to deal with the mechanical parts and how to connect each piece together to ensure

smooth operation. Also we went along with testing our project as we were implementing it to ensure that each part of it worked correctly.

Another challenge was providing the parts needed for our projects, some of the parts especially the ones needed for the CNC implementation took a lot of time and effort, also the cost of these parts was high so we needed to provide the money needed for our project. Another big constraint was time, the time frame to come up with a design and implement our project was fairly short, so a lot of effort was spent to create everything from the ground up.

Furthermore, the project highlighted the importance of designing for scalability and flexibility. The design of the machine allows for easy customization and adaptation to any new additions needed to enhance the users' experience and to operate on multiple levels and multiple areas. For example: our machine could be adapted to dispensing a wider range of slots or incorporates additional features such as digital displays for advertisements.

Overall, Stationery Spot vending machine delivers an innovative and a practical solution for giving access to stationery items in public places. With its extensive features and appealing design, our machine has the potential to transform the purchasing method of stationery items and having access to them on-demand, making sure that the whole customers' experience is efficient and effective.

7 Conclusion and Recommendation

7.1 Conclusion

In conclusion, our project Stationery Spot smart vending machine successfully shows an innovative solution for a convenient access to stationery items in public places such as universities, schools, work places, and offices. By using advanced automation ways and techniques such as: CNC system with a basket to ensure the products are dispensed safely without breakage or harm, stepper motors, servo motors, sensors like IR and ultrasonic, relays, and so on, the machine achieves precise and efficient product dispensing. The unique and decorated design also emphasizes scalability and adaptability, making sure that this vending machine can be customized based on various settings and user needs.

This project not only addresses a common problem of stationery items accessibility but also provides a base for many future enhancements. Stationery Spot symbolizes a step forward in automating the supply of everyday stationery items, boosting convenience, and providing the needs of students, educators, and professionals in busy environments.

7.2 Recommendation

Based on our current progress with the project development, there are multiple avenues that can be explored when evaluating opportunities for future growth and improvement. First, implementing real-time inventory monitoring with sensors or IoT technology will create a better stock management. Additionally, expanding product variety and customization, we can add more slots to the vending machine that contain more products such as USB cables, rulers, erasers, and so on. Another thing to explore is improving energy efficiency, by using energy-efficient components with a higher cost but more environmentally friendly. Finally, promoting through strategic placement and marketing, by placing the Stationery Spot vending machine in high-traffic areas such as libraries, parks, and main entrances. Also, engaging in marketing campaigns to highlight the machine’s convenience and products selection.

By adding these recommendations, our project will have an enhanced functionality, a better user experience, and a higher reach to the market.

7.3 Future Work

Looking ahead, there are several areas of future work for further development of Stationery Spot. In order to improve the vending machine, we can:

- Enhanced Security Measures: Using more enhanced security methods such as biometric access controls, and enhanced surveillance systems will protect the machine from vandalism.
- Integration of Digital Advertisements: Adding digital screens on the vending machine to display items, sales, offers, advertisements about the products, and promotions. This will attract more users to use the vending machine and the revenue will increase.
- Interactive Touch Screens: Adding these screens allows the users to browse the products and all their details is a very user-friendly touch.
- Integration of Voice Control for User Interaction: Implementing a sound module with a microphone as an input to allow voice commands for the vending machine. This provides a hands-free way of ordering and is suitable for busy environments.
- Utilization of IR Sensors for Stock Monitoring: This would enable an efficient way to track the inventory.
- Integration of AI and Machine Learning: This would enhance the functionality of the vending machine by providing algorithms that predict product demand and optimize inventory levels based on usage patterns.
- Multi-language Support: This would support to cater to a global audience, enhancing accessibility for international vending machine users.
- Tokens and Coupons: Adding a feature of tokens for each user. For example when a user purchases more than 2 times using the machine, tokens are added to his card, he can use them as coupons for future sales and discounts on his purchases.

8 References

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