

AN-Najah National University



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Disclaimer statement

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Abstract

At a time when industries are moving towards providing machines and reducing the manpower, we saw the need of doing something similar in the field of food-making.

The goal is to provide an integrated machine suitable for using in public places, that can make cupcake from raw ingredients according to user preference and go through all the necessary stages to complete the process, as we have not seen a currently available project that does this.

This machine produces one cupcake at a time, where data is entered from the user and based on this data, the cup will go through different stages, the first stage where we will add the chosen flavor (chocolate or vanilla), then the liquids (oil & water), and then the mixing stage, the user can choose additional toppings (e.g., chocolate chips) and the cup will finally enter the heating mode (the heating will be a small oven at 90C/70C), the mixer will be cleaned after each order. The system also connected with a mobile application to notify the manager if there is any loss in any ingredient.

For the electronics components, we used the Arduino Mega as the main microcontroller, an LCD and a keypad to enable the user to enter his order, keypad as payment method, Ultrasonic sensors to measure the quantity of the remaining ingredients, stepper motors to control the movement of the cup and the powder dispensing, dc motor for the mixer, servo motors to control the toppings adding, water pumps and relays for liquid dispensing, temperature sensor to keep the heater around the required temperature, and an ESP module to provide wireless communication with the mobile application.

1. Introduction

1.1 Statement of the problem

Our project seeks to solve the problem of providing customers with premade cupcakes and instead supply them with freshly produced ones. And their lack of ability to choose and customize their favorite flavors by giving them choices and allowing customers interaction.

1.2 Objectives

We aim to provide a fully automatic machine specialized in making cupcakes with a goal of meeting customer's requirements and making them feel comfortable during use, by giving the customer the opportunity to interact with the machine to choose the flavors related to the cupcake. We also aim to facilitate the management process by the machine owner, by developing a mobile application for monitoring ingredients' levels and sensors' readings.

1.3 Scope of the work

We used a multiphase, all-encompassing approach throughout the entire process. First, we determined which features would work best for our machine. Next, we took great care in choosing the right parts, including mechanical parts, motors, pumps, sensors, and drivers. To guarantee flawless operation, we also provided the required controller for the system. To make the work easier for us we separated the features of the machine into: user input, ingredients dispensing, mixing, cleaning mixer, heating, and mobile app. Later assessments were conducted on dependent units to verify their smooth functionality. In the final phase, we established a method to efficiently operate the device and tested the combined system thoroughly to guarantee maximum efficiency in every situation.

1.4 Significance of our work

The market is witnessing a growing demand for this degree of automation and customized service, and the stores' managers are looking for simplicity in controlling and monitoring ingredients. Also, for the sake of the environment and food saving, our machine helps in minimizing the unsold leftovers by markets and food stores by preparing what the customer orders and selling it at the same time.

1.5 Organization of the report

There are multiple parts in this report. An outline of the project given in the introduction. The constraints, standards/codes and earlier coursework are described in the second part. The third part discusses previous work. The methodology is outlined in the fourth part followed by the results and discussing the outcomes in the fifth part. Ultimately, the conclusion offers recommendations for further research as well as a summary of the report's main ideas. Additionally, references of the project are supplied.

2.Constraints, Standards/ Codes and Earlier course work

2.1 Constraints

- 1- Heating unit design: We faced a problem in finding a fast method for heating. The purpose was to make the cupcake in a microwave so it will be ready for the user in one or two minutes. But since the microwave needs to work while being closed and we need to move the cup in and out the microwave through the conveyor. Our external design was not compatible with this method. Therefore, we were forced to switch to another method which is the top and down oven which takes around 15 minutes in total.
- 2- Stepper motor for conveyor: We used the stepper Nema23 at first for the conveyor, but it didn't do the job as we needed a motor with higher torque, so we replaced it with Nema34 which worked smoothly in our case.
- 3- Powder dispensing: Implementing a method for the powder to be dispensed smoothly without being clumped was complicated. The spiral conveyor that we designed at first didn't move the powder as we wished, so we had to add the dc motor at the top to move the entire powder before reaching the conveyor.
- 4- Adding the liquid ingredients: In the stages where we want to add water/ oil, the level of water/oil affected the quantity that comes from the pump, so we had to check the level of the water/oil before opening the pump and we divided the levels into intervals, at each interval we opened the pump for a different amount of time.
- 5- High power consumption: Our system has high load on it especially the heating unit and the air jack which both work on 220 volts. This caused malfunction on other parts of the system due to less power reaching. We tried to separate the power that reaches the oven to a different source.
- 6- Work hours: Since the size of our design is relatively big and we needed the air extension which is only available in the laboratory, we had to keep the project inside the lab and we were limited by the time of the lab working hours.

2.2 Standards /Codes

The system's software consists of an Arduino C++ program that uses multiple libraries and functions, including max6675.h, Servo.h, LiquidCrystalI2C.h, EEPROM.h, Wire.h, and Keypad.h. Another side of the code for the ESP8266 was used to implement the mobile application which was developed using the Blynk platform. When designing and implementing its software components, the system complies with applicable industry standards and guidelines.

2.2 Earlier Coursework

During the PIC microcontroller lab, taking the Arduino experiments helped us perform the software part while utilizing the components since it gave us the skills needed to operate the sensors, motors, and EEPROM. Our development of the control system for our machine required us to obtain practical expertise with coding and testing the Arduino board, which became possible by this course.

In the PIC microcontrollers course, we improved our knowledge in microcontrollers development, this was necessary for us in order to deal with the Arduino Mega. We learned multiple techniques for working with hardware components such as PWM to control motors, I2C to communicate between a master and a slave, and serial communication to send data between the ESP8266 and the Arduino Mega.

Our strong foundation in the fundamental concepts of electronics that we have gained from the electronics course has enabled us to develop the machine's hardware, and power its components so they work at the most efficient and safest way.

Finally, the project benefited greatly from the Critical Thinking course since it has taught us how to approach projects methodically and make more educated decisions. Our ability to think critically was enhanced by the course, which enabled us during the work to recognize possible problems, evaluate them, take advices from others, and suggest the workable solutions. This was crucial during the project, particularly when we encountered problems with electricity and design.

3. literature review

“Development of an Autonomous Cupcake Machine”

The authors aimed to address the limitations of manual cupcake production by designing and developing an autonomous cupcake machine. They identified the manual process as labor-intensive, time-consuming, and prone to inconsistencies in product quality. The method employed involved using an Arduino microcontroller board, motors, thermocouple, and inexpensive materials like plastic and wood to automate the cupcake-making process. The key focus was on achieving a cost-effective solution that enhances efficiency and product consistency. The paper emphasizes system development, outlines the methodology, and discusses potential applications and commercial viability. (Polichshuk et al., 2018)

“Media on-demand: Continuous reconstitution of a chemically defined media directly from solids”

In the mentioned paper, the authors employed a screw conveyor as part of their continuous on-demand reconstitution system for cell culture media. The screw conveyor is a mechanical device designed to move or transport dry powdered media with precision into the mixing process. The screw conveyor was integrated into the system to facilitate the controlled and continuous feeding of dry powdered media from the hopper to the mixing process. (Komuczki et al., 2021)

“Smart Wireless water level Monitoring & Pump controlling System”

The authors developed a Smart Wireless Water Level Monitoring & Pump Controlling System using ultrasonic sensors. The system calculates water distance using ultrasonic waves, and based on the readings, it sends commands to control the water pump through an RF transmitter. (Santra et al., 2017)

Our machine benefited from previous works, it used some of the above techniques such as the design and implementation of the screw conveyor with additional modifications to suit our purposes, the concept of mixing process and using ultrasonics to detect ingredients' quantity.

What makes our project distinct from what was mentioned is that we employ more precise techniques for each stage of the work, as the project uses IOT to notify manager of ingredients levels, RFID for payment, baking the cupcake under suitable temperatures and user interaction.

4. Methodology

This chapter contains the external design of our project and the hardware components that we used with their functionality and implementation and the software implementation for the whole work.

4.1. External design

In this project we built a conveyor system to go through five stages, The user put his cup in its initial position, then the cup cross all the stages and return to its initial position.



Figure 1: External design

4.2 Software Implementation

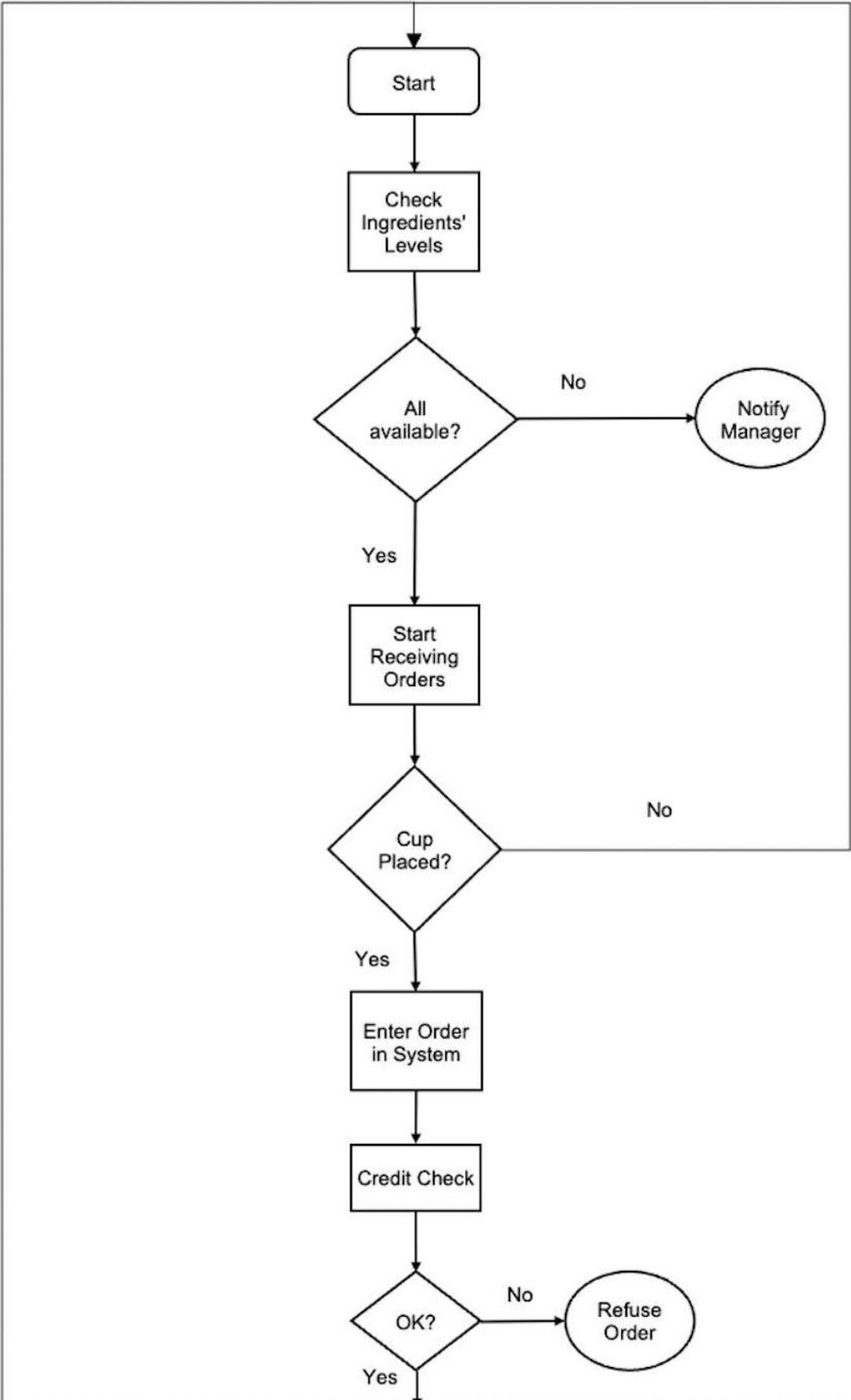
At first, the system is in the idle state, if the machine has enough ingredients, it will be ready to receive orders otherwise the user can't order and the system will send the manager a notification to the mobile app. If there are enough ingredients the user has to place the cup, the system will wait for an amount of time and if the user hasn't placed the cup it will return to the initial state.

After placing the cup, the user has to enter his order, first is the flavor of the cupcake (chocolate or vanilla) then if he wants to add chocolate pieces on top or not. While entering his order the user can cancel it at any time before the purchasing state. If the user reached the purchasing state, he will have to scan his card, if it is valid and he has enough money to pay the machine will start preparing the order, he can either retry or cancel.

The machine starts adding the powder depending on the flavor chosen, then the rest of the ingredients (water and oil), after that the cup will go to the mixing state and the DC for the mixer is turned on. If the user has chosen addition of chocolate pieces the servo for the chocolate will move for 60 degrees to allow dispensing of chocolate. Then the cup is moved to the oven.

Before the heating, the mixer will be cleaned, then the cup will spend around 10 mins in the down oven. We make sure that the heat of the down oven will not exceed 90 and not less than 70. After that the cup will move to the top oven for about 3 minutes the heat of the top oven is kept between 90 & 70 degrees. Finally, the cup returns to its initial position to be served to the customer.

4.2.1 Flow Chart of the System



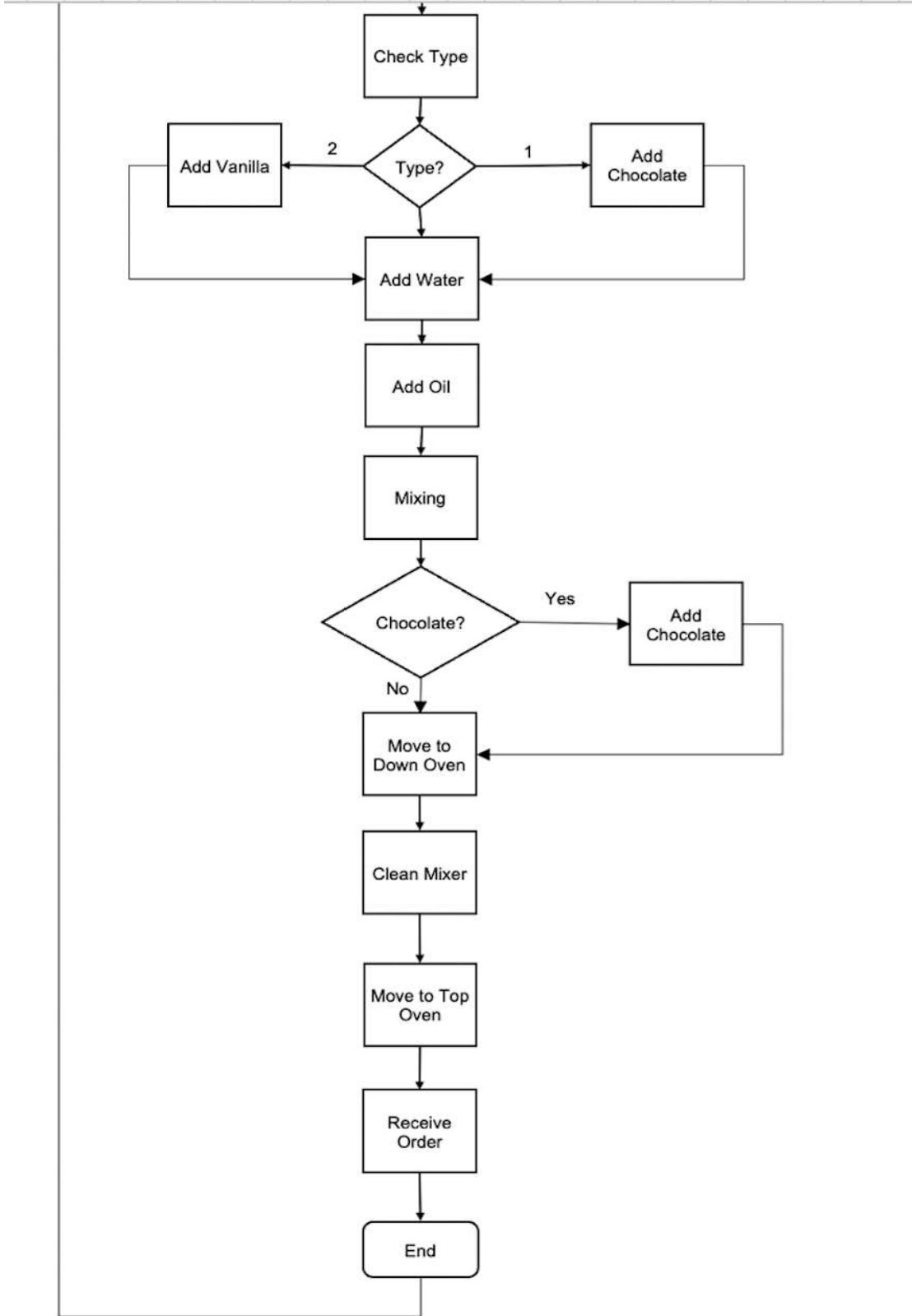


Figure 2: Flow Chart of the System

4.3. Hardware components

4.3.1 Microcontrollers

- *Arduino MEGA 2560*

In this project we used Arduino mega as microcontroller according to its large memory space and large number of I/O pins comparing with other microcontroller, also its serial communication capacity provide a good interaction with ESP module, moreover it contain two voltage regulator 3.3v and 5v regulator which provide flexibility to control devices with this voltages.



Figure 3: Arduino Mega 2560

- *NODEMCU ESP8266*

In this project we make a serial communication between Arduino mega and ESP module. This module provide a wireless connectivity to our project, to empowered the admin to monitor the levels of ingredients through a mobile application.



Figure 4: NODEMCU ESP8266

4.3.2 Input/Output Devices

- *LCD with I2C module*

In this project we used a 20x4 LCD as an output device to interact with the users and provide them with instructions, choices and processing status during their order.

We used I2C serial interface adapter to simplify the connection between LCD and the microcontroller since its only need two wires for control rather than connect six wires.



Figure 5: LCD with I2C module

- *RFID*

In this project we used RFID as a payment method, by enabling users to scan their cards that contains a unique ID, and their balance.



Figure 6: RFID

- **Keypad**

We used 4x4 Matrix Keypad to allow the user to start his order, choose the cupcake flavor, add optional chocolate pieces and cancel his order if needed.



Figure 7: 4x4 Matrix Keypad

- **Flash Buzzer LED Indicator**

We used Flash Buzzer to notify the user when his order is ready.



Figure 8: Flash Buzzer LED Indicator

4.3.3 Sensors

- ***IR Obstacle Avoidance Sensor Module***

In this project we used IR to make sure that the cup present on its initial point before starting, and the user received his cup after the process is ending.



Figure 9: IR Obstacle Avoidance Sensor Module

- ***Ultrasonic Sensor Module HC-SR04***

This sensor used to determine the levels of the ingredients, this levels will be send to the admin to avoid any shortage in this ingredients and stop the machine if it is happen.



Figure 10: Ultrasonic Sensor Module HC-SR04

- ***Thermocouple Temperature Sensor Module MAX6675***

We used this sensor to monitor the oven temperature and maintain the right temperature for baking the cupcake, and avoid any risk of high temperature, by using its reading we turn on/off the oven to maintains the right temperature range.



Figure 11: Thermocouple Temperature Sensor Module MAX6675

4.3.4 Motors and drivers

- *Stepper motors*

In this project we used **NEMA 34** stepper motor to move the conveyor in precise distances to control its position precisely under the ingredients. Also we used **NEMA 23** to control the movement of powder screw conveyor to download the powder in precise amount.

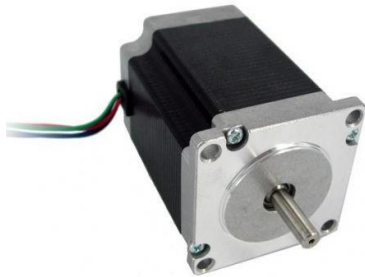


Figure 12:NEMA 23 stepper motor



Figure 13:NEMA 34 stepper motor

- *DC motors*

We used **High Torque DC Gear Motor 12V** to stir the powder and prevent it from clumping, and **3V DC Mini Motor** in mixing process.



Figure 14: High Torque DC Gear Motor 12V



Figure 15: 3V DC Mini Motor

- **Servo motors**

We used **Micro Servo** to control the downloading of chocolate pieces, and **MG996R High Torque Servo** to rotate the cake beater from mixing stage to cleaning stage and vice versa.



Figure 16: Micro Servo



Figure 17: MG996R High Torque Servo

- **HY-DIV268N Stepper Motor Driver**

We used this driver to control stepper motor rotate direction and number of steps to move, also to control the frequency and current that reach the motor.



Figure 18: HY-DIV268N Stepper Motor Driver

4.3.5 Power Devices

- *Power supply*

In this project we used **computer power supply** that provide 5 , 3.3 and 12 voltages for pumps and DC motors, and **24v power supply** for stepper motors.



Figure 19: 24v power supply



Figure 20: computer power supply

- *Arduino power cable*

In this project we used **Power bank** to provide a stable power to the arduino board and ESP.



Figure 21: power bank

4.3.6 Other devices

- **12V DC Water Pump**

We used water pumps to download water and oil to the cup, and two pumps in cleaning unit.



Figure 22: 12V DC Water Pump

- **Relay**

We used **optocoupler-4-channel-5v-relay-module** to enable on/off control to pumps, oven, DC motors and air jack.

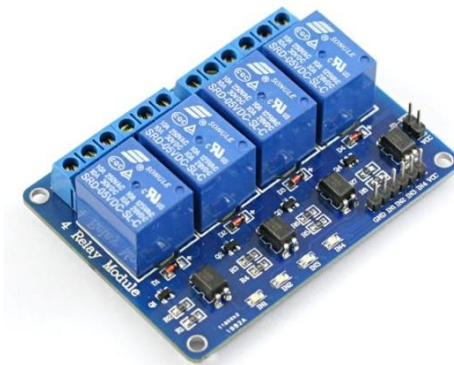


Figure 23: optocoupler-4-channel-5v-relay-module

- ***Air valve***

We used **Air Solenoid Valve** to connect/disconnect air to air jack.



Figure 24: Air Solenoid Valve

4.4. Hardware Implementation

4.4.1 Input / Output unit

We have LCD and keypad to allow the user to enter his order. Firstly, the IR sensor makes sure that the user puts the cup in its initial and correct place before ordering, then the LCD shows choices to the user about the order, and the user uses the keypad to select his choices, finally, the machine shows the bill to the user and waits for the user to scan his card on RFID or cancel his order, if the card doesn't have enough money the order will be canceled.

We store an initial balance for each user in EEPROM and this balance will be discounted on each order.

When the order is ready, the buzzer will notify the user and the cup returns to its initial state and still waits in this state until the user takes it, then the machine will be ready to receive a new order.



Figure 25: Input / Output unit

4.4.2 Ingredients unit

We have five ingredients: chocolate powder, vanilla powder, water, oil and chocolate pieces.

To download the powder we used two motors: stepper motor to rotate a screw conveyor to ensure a consistent download amount every time, and a DC motor the rotate the powder and prevent it from clumping.

We used water pump to download water and oil, and since the downloaded amount affected with the liquid level we used the ultrasonic sensor to read the level and according to this level we open the pump for specific time.

We used a servo motor to open/close the chocolate pieces container slot.



Figure 26: Ingredients unit

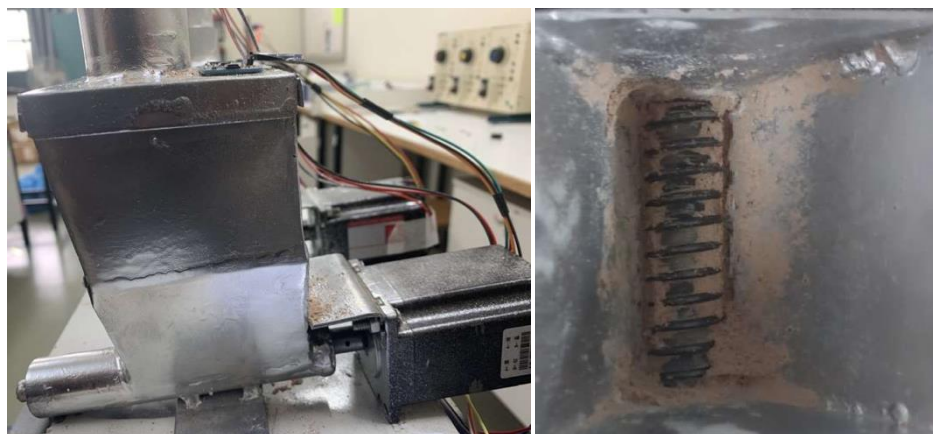


Figure 27: powder container with screw conveyor

4.4.3 Mixing unit

In this unit we used three types of movement vertical, horizontal and rotational.

For vertical movement we used air jack to allow the beater to move up and down. To make sure that all the ingredients were mixed well, we moved the beater horizontally inside the cup using a servo motor. Finally the mixing process done with dc motor.

4.4.4 Cleaning unit

This unit consist of cup and two pumps, when the mixing process ending the servo motor that carry the beater rotate for 90 degree and the beater go down to cup, then one pump turn on to fill the cup with clean water, after that the dc motor that connected with the beater rotate for specific time and the beater go up, finally the second pump open to drain polluted water.

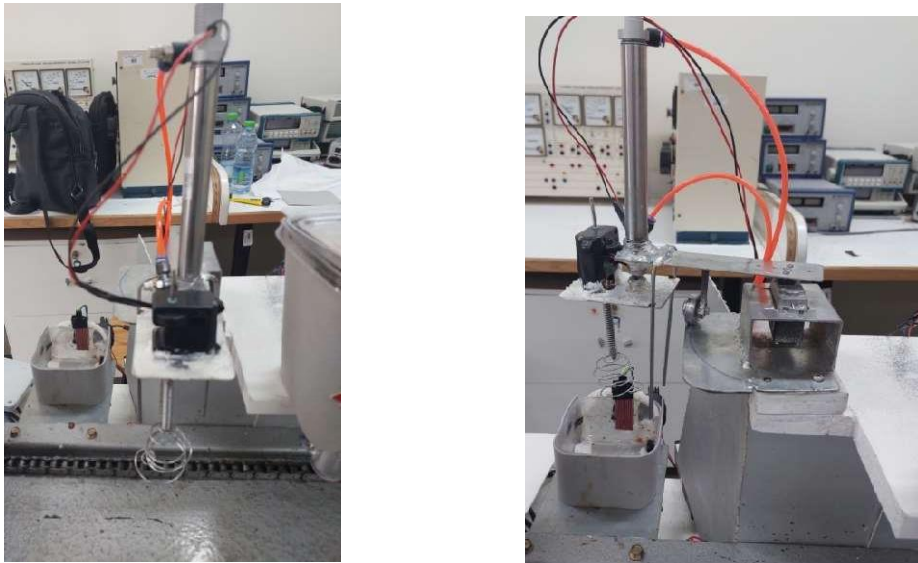


Figure 28: Mixing and cleaning unit

4.4.5 Heating unit

In this project we used two ovens: top and down. We used Thermocouple Temperature Sensor monitor the oven temperature and we turned on/off the oven to maintains the right temperature range for baking the cupcake which is in our project 70-90 °C.

The cup firstly enter the down oven for 10 minutes then enter under the top oven for 3 minutes.

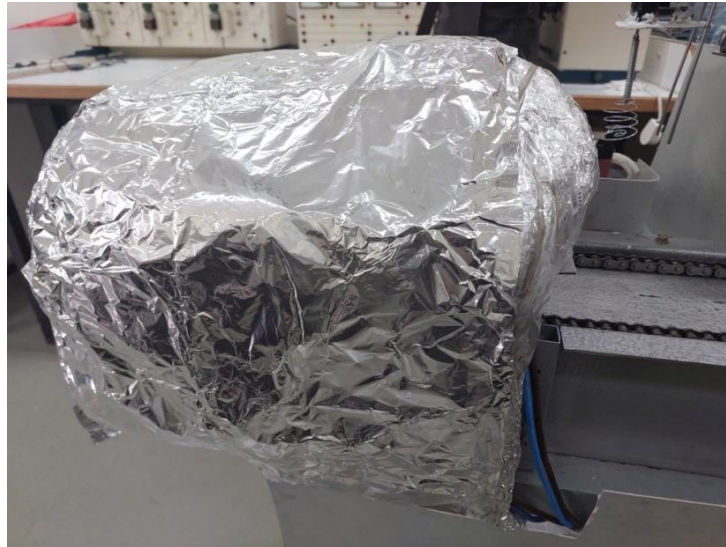


Figure 29: Heating unit

4.4.6 Monitoring and control unit

The Arduino is control the overall operation in our project. To enable the admin to monitor the ingredients levels, we used Blynk platform to build a mobile dashboard which view the percentage for each ingredient, these levels which is read from ultrasonic sent to admin mobile through wifi by using NODEMCU ESP8266.

If there is lack of one ingredient or more, a notification will be send to admin, and a message will appear to user prevent him from order, so the machine still stopped until the admin refill the shortage ingredients container.

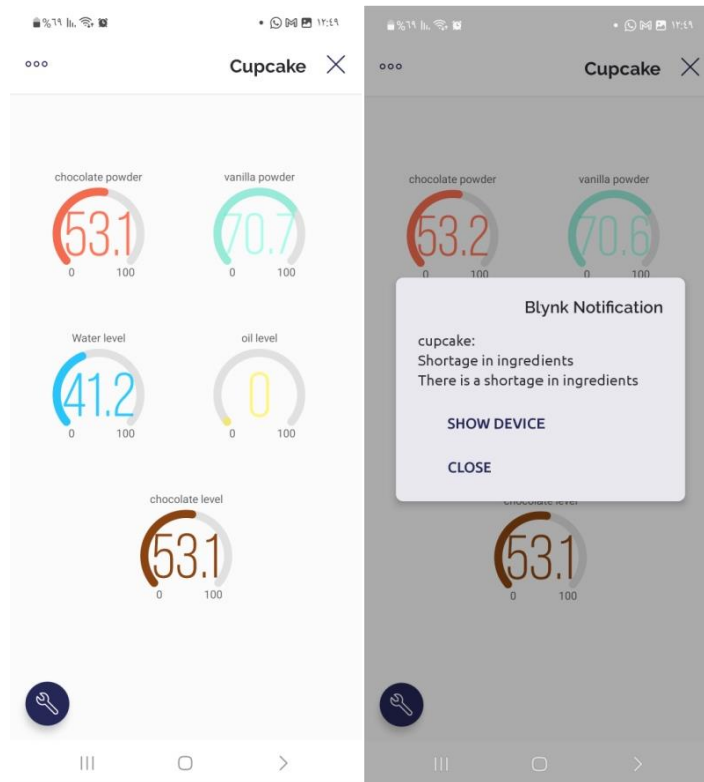


Figure 30: Admin dashboard



Figure 31: lack of ingredients alert

5. Results and Discussion

At the end of this project we achieved our aim to build a cupcake maker machine, that receive the user order and start its work by butting the ingredients in the cup and mixing them, then cleaning the beater , and finally baking it and stay monitoring the oven temperature until the order being ready.

Through the implementation of our project we facing some challenges, the main one is the powder clumping and the difficulty to download it from the container, after multiple trials this challenge solved by using screw conveyor moved by stepper motor, and a DC motor to ensure the separation of powder particles.

Since the last stage of our project is the baking stage with the electrical oven the conveyor body had to be from metal material to withstands high heat, and that metal conveyor need a high motor torque to move it, so we used a NEMA 34 stepper motor.

The electric oven consume a lot of power when run, so we powered it from separate electrical socket, to ensure that the rest of the parts and devices have the appropriate voltages for their work.

Finally, we suggest to use a faster heating unit like microwave to give the opportunity to add more characteristics to the project, such as the producing multiple cups in short time.



Figure 32: final output

6. Conclusions and Recommendation

6.1. Summary

In conclusion, we have successfully developed a cupcake maker machine, that allow the user to prepare a fresh and delicious cupcake with the flavour he prefer, in a easy way.

This machine is suitable for using in public places such as the malls, as it receives the user's request and begins making cupcake from raw materials that have a long shelf life and are suitable for leaving in public places without any sharpeners for preservation under special conditions.

6.2. Recommendation

1. Use the Italian version of Arduino board since it is provide a stable output voltage suitable for connect large number of devices.
2. Use Arduino board just for control the devices and avoid using its output voltage to power them, you must use external power supply instead.
3. Use a Separate electrical socket for devices that consume large power when turned on such as electric oven, to avoid any voltage drop can lead to problem in other devices work.
4. Use optocoupler-relay-module instead of traditional relays, since its ability to isolate a low voltage system against high voltage system, such as 5VDC and 220VAC, and allow electronics with low voltage to control high power load without any power consuming.
5. Use a wire collector to avoid a large number of connection to white board, and solder the wires to avoid any disconnection.

6.3. What we have learned

1. How to use different types of motors such as DC, stepper and servo.
2. How to deal with different sensors like IR, ultrasonic and Thermocouple Temperature Sensor.
3. How to set different levels of voltages and current to be suitable for each device.
4. How to make a serial communication between ESP8266 and Arduino, and how to connect ESP with WIFI, and dealing with Blynk platform.

6.4. Future work

1. Placing the cup automatically in the conveyor.
2. Refilling ingredients container automatically.
3. Develop the conveyor system and oven size to produce multiple cups with different flavor and size.
4. Develop the mobile app to allow the user to order from a user-friendly interface instead of keypad.

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