Palestine Polytechnic University
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Practical And Advanced Color Mixing Machine For Achieving Your Desired Color Palette

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Abstract

Paint is a covering that protects wooden, iron, and other surfaces while also adding aesthetic appeal. The color is what draws your attention first when you look at any surface or object.When you consider the painting process in its entirety, it is not a simple one because it requires experts into achieve the desired outcome. Especially if you need a color which is not normal, and what is meant is the outcome of combining various colors. Manually combining several colors to create a new color is not an accurate production method. As a result, we are going to create a unique device for combining colors to create a color that is selected from an application linked to the device, or by identifying an existing color through the color sensor and sending the color code using color theory. Based on this, different ratios of the primary colors CMYK are used. The goal of this device is to achieve the required color accurately while saving effort and time.

KEYWORDS: PAINT, SURFACES, COLOR, MIXING, SENSOR .

اَلْخُلَاصَةُ

اَلطِّلَاء أَوْ اَلدِّهَانِ هُوَ مُرَكَّبُ سَائِلٍ وَيُشَكِّلُ طَبَقَةً عَلَى سَطْحِ اَلْخَشَبِ أَوْ اَلْحَدِيدِ أَوْ اَلْمَادَّةِ بِشَكْلٍ عَامٍّ وَكَمَا أَنَّهُ يُعْتَبَرُ إِضَافَةً جَمَالِيَّةً , عِنْدَ اَلنَّظَرِ إِلَى أَيِّ سَطْحِ إِنَّ مَا يُلْفِتُ اَلِانْتِبَاهُ هُوَ لَوْنُ هَذَا اَلسَّطْحِ , اَلْوُصُولُ إِلَى اَللَّوْنِ اَلْمَطْلُوبِ دُهْنُهُ لَيْسَ بِالْأَمْرِ اَلسَّهْلِ وَلَا سِيَّمَا إِذَا كَانَ اَللَّوْنُ اَلْمَطْلُوبُ لَيْسَ مَوْجُودٌ بَلْ يَتَطَلَّبُ اَلتَّحْضِيرُ فَيَكُونُ بِدَرَجَةٍ مُعَيَّنَةٍ مِنْ لَوْنٍ مُعَيَّنٍ , اَلِانْطِلَاقُ مِنْ اَلْأَلْوَانِ اَلرَّئِيسِيَّةِ لِتَشْكِيلِ لَوْنٍ بِدَرَجَةٍ مُعَيَّنَةٍ لَنْ يَكُونَ اَلْحَلُّ اَلْأَمْثَلُ , سَنَقُومُ بِإِنْشَاءِ جِهَازٍ يَتِمُّ مِنْ خِلَالِهِ اَلْوُصُولُ إِلَى اَللَّوْنِ اَلَّذِي تَمَّ تَحْدِيدُهُ مِنْ خِلَالِ اَلْمُسْتَشْعِرِ اَلْمُرْتَبِطِ بِهِ وَبِغَضِّ اَلنَّظَرِ عَنْ دَرَجَةِ هَذَا اَللَّوْنِ مِنْ خِلَالِ إِرْسَالِ قِيمَةِ اَللَّوْنِ بِنَاءًا عَلَى نَظَرِيَّةِ اَلْأَلْوَانِ اَلْأَسَاسِيَّةِ CMYK , وَفِي اَلنِّهَايَةِ يُقَدِّمُ اَلْجِهَازُ لِلْمُسْتَخْدِمِ إِمْكَانِيَّةَ رَشِّ اَلطِّلَاءِ اَلْجَاهِزِ , وَالْهَدَفُ مِنْ هَذَا اَلْجِهَازِ هُوَ تَقْدِيمُ اَلرَّاحَةِ وَالدِّقَّةِ وَتَوْفِيرِ اَلْوَقْتِ .

الكلمات المفْتاحيَّة : دِهَان ، سُطُوح ، لَوْن ، خَلْط ، المسْتشْعر.

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List of Acronyms

CMYK	Cyan, Magenta, Yellow, and Black
RGB	Red, Green, and Blue
MFCM	Mixing Filling Colors Machine
MQTT	Message Queuing Telemetry Transport
AMQP	Advanced Message Queuing Protoco
COAP	Constrained Application Protocol

Chapter 1

Introduction

1.1 Overview

Paint is employed in a variety of occupations and sectors, such as those involved in construction, interior design, and more. Each of them also uses a variety of grades and colors. Currently, it is vitally necessary to use technology to make the process easier, more comfortable, and automated.
We'll be turning a manually operated color mixing tool into an electronic one in this project. We will have a mixer that can mix the primary colors (CMYK) in specific proportions for each color to create a variety of colors.
It functions by reading the desired color from a sensor that you control. The sensor then inputs the desired color and uses the CMYK color system to analyze it in order to calculate the relative amounts of the four colors. Along with the application through which the desired color's value is added, the proportions of each of the four colors are added with white paint to the main container's mixer to create the desired paint color. If it does not take the first desired color from an application that does the following:

- The desired color can be selected using the color picker (sensor).
- By identifying the color sensor, it sends instructions to the mixer along with the quantity of each master color (CMYK) that must be combined to produce the desired color.

In this manner, we are able to create an infinite variety of colors. In comparison to manual mixing, it will be more precise and comfortable if there are only three colors.

1.2 Aims and objectives

In the beginning, the professions and trades in which technology was introduced were targeted, which helped make this part of the work easier, more comfortable, and more accurate. The user is also able to reach the color he needs, even if he does not know the name of the color or the degree of color, perhaps only through an existing sample.

1.3 Problem Statement

Manual color mixing[13] makes it challenging to replicate the final color and achieve the desired level of color accuracy. But with an electronic mixing device, all that is required is to choose the color you want; the device will figure out the proportions to produce the shade you want and provide a ready mixture. This method can be repeated multiple times while maintaining the same level of accuracy.

The following are some of the benefits of the electronic mixing machine:

1. Enables quick and accurate coloring.
2. Capable of replicating desired colors with precision.
3. Offers a vast selection of paint tint colors.

1.4 Project Requirements

Some of the functional and non-functional requirements for our system are:

1.4.1 Functional Requirement

- It should be able to read color values through a sensor, or allow manual input of color values via an application.
- It should be able to determine the contribution of each of the three colors (Cyan, Magenta, Yellow, and Key) to the finished color.
- It should be able to transfer the finished color to the last bowl using a pump.
- It should support at least two input methods for color values.
- Its primary objective should be to produce the desired color.

1.4.2 Nonfunctional Requirement

- Ease of use and user-friendliness should be prioritized in the design of the system.
- The precision of the resultant color should be as close as possible to the entered color.
- The system should ensure security and prevent harm to the objects being searched.

1.5 System Description

The Painting machine that is the subject of our project has two parts. The sections are as follows :

1. Section for Reading and Input of Color Values.
2. Analysis and Mixing Section.

We obtain the desired color through two methods. The first method is by directing the sensor towards the surface that contains the desired color. The second method involves directly selecting the color through the application. Afterward, we move on to the stage of achieving the desired color value, where the captured color data is processed from RGB to CMYK through analysis and calculation. This leads us to the stage of pumping the primary colors in varying proportions, with calculations linked to the container and time, to form the main components of the desired color by the user. Finally, we come to the stage of mixing these colors and reaching the final value within the container.

1.6 Project Limitations

The elements that influence a project's limitations are referred to as project constraints[5]. These can include such things as costs, deadlines, and project scope. To improve our chances of successfully identifying and managing project constraints, we need to clarify some of the constraints that we might experience during system implementation.

1. The machine usage is dependent on how the system is designed.
2. Cost constraints include the project's overall budget and anything else that is required to be paid for; these restrictions may have the greatest influence on how the project is carried out.

3. The type of paint used will affect the system's implementation.

4. availability of a few key sensors that are utilized by the system.

5. Because these project requirements are expensive, the resources and budgetary restrictions on your project are closely related. Without proper resource allocation, projects can experience poor project quality, an increased budget, and timeline delays.

1.7 Project schedule

Table 1.1:Schedule Time

Task Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Proposal																					
Information Planning and Collecting																					
Analysis																					
Requirements																					
Design																					
Implantation Hardware																					
Implantation Software																					
Testing and Validation																					
Conclusion																					

1.8 Report outline

In this chapter, the general definition of the project and the aim of the problem it is meant to solve are both defined. This chapter also covers the functional and nonfunctional requirements, which describe potential problems and a plan for advancing the work.

1.9 The Machine's shape

The shape of the project is shown in Figure[2.1],

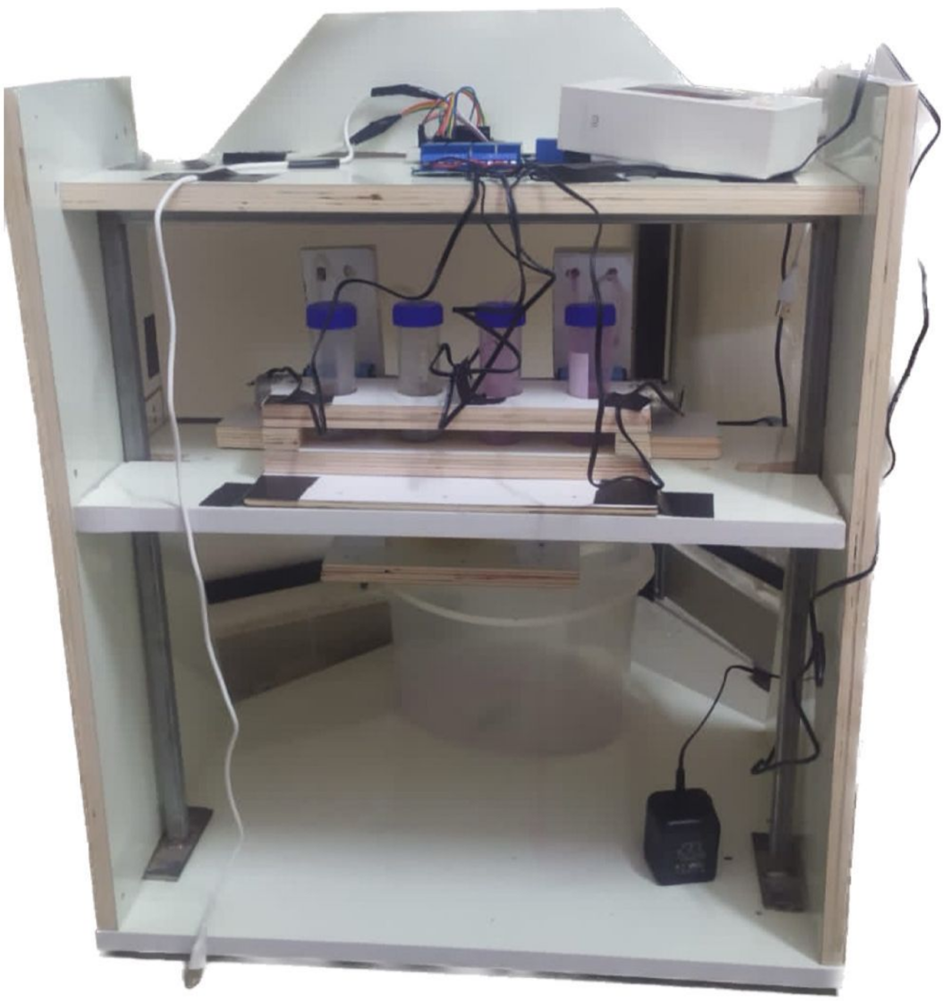


Figure 1.1: The Machine's shape

Chapter 2

Theoretical Background

In this section, we will discuss the project in terms of the theories that we intend to employ, as well as related and related projects that have been done in the past. We will also clarify each project's concept, compare it to our project, and explain the differences between the two, as well as how to build on earlier projects by incorporating them into our project.

2.1 Preface

The subtractive color mixing model is used to create any color you see on a physical surface (paper, signage, packaging, etc.)[1]. Since we learned how to mix finger paint using this color model in kindergarten[6], most people are more familiar with it. Red, yellow, and blue were historically the primary colors used because they were the colors that painters mixed to create all other hues. They were later replaced by cyan, magenta, yellow, and key/black (CMYK), which allowed printers to produce a wider range of colors on paper as color printing became more common. Since not everyone is able to name or even describe colors in terms of degrees, it was necessary to use technology to access the desired color quickly and accurately. This is being detected by a "photoelectric sensor,"[2] a type of sensor that first emits light from a transmitter before detecting light reflected back from the object it is trying to detect. A typical mixing operation in the chemical and process industries is blending. The objective is to combine two or more miscible liquids to a particular degree of homogeneity. Liquids are blended in order to achieve the desired level of uniformity within a reasonable mixing time. For high production rates and good product quality, an old mixer design is crucial. To get the paint that the user wants to spray, an algorithm and a percentage control of the quantity of each color must be followed in order to achieve the desired color.

2.2 Theories

The color model is a mathematical model that describes the way colors are represented, and it consists of three or four primary colors[3]. We can extract from these colors other secondary gradations. For example, if we mix two main colors, we will get a secondary color, such as yellow with red. It gives us orange or yellow, and blue gives us green[3], and so on.

2.2.1 Color Theory

The science and art of using color are both part of color theory. It explains how color is perceived by people as well as the visual results of how colors blend, complement, or contrast with one another. Color theory also covers how colors are reproduced and the messages they convey.

Primary colors, secondary colors, and tertiary colors are the three categories into which colors are divided in color theory.

The subtractive color mixing model is used to create any color you see on a physical surface (paper, signage, packaging, etc.). Since we learned how to mix finger paint using this color model in kindergarten[6], most people are more familiar with it. In this instance, the term "subtractive" simply means that more color is added to the paper in order to subtract light from it.

Red, yellow, and blue were historically the primary colors used in the subtractive process because these were the colors that painters mixed to create all the other hues. Later, as color printing gained popularity, they were replaced by cyan, magenta, yellow, and key/black (CMYK), which is used in this project and allows printers to produce a wider range of colors on paper.

Comparisons between RGB displays and CMYK prints can be difficult due to the significant differences in color reproduction technologies and characteristics[9]. On computer monitors, colored images are created by combining red, green, and blue light tones. Instead, cyan, magenta, and yellow inks that are mixed using dithering, halftoning, or some other optical technique are used in CMYK printers.

Despite the fact that each color mode has a distinct range, printing inks produce a color gamut that is "only a subset of the visible spectrum." The appearance of items displayed on a computer monitor may differ slightly from the appearance

of items printed as a result of the combination of opposing color modes in both media. Designers choose colors for printed items while viewing them in RGB color mode on their computer screens; as a result, it is frequently challenging to picture how the color will look after printing[9].
As indicated in the image[2.1], here is an illustration of the two color groups, RGB and CMYK, as well as an illustration of each of them.

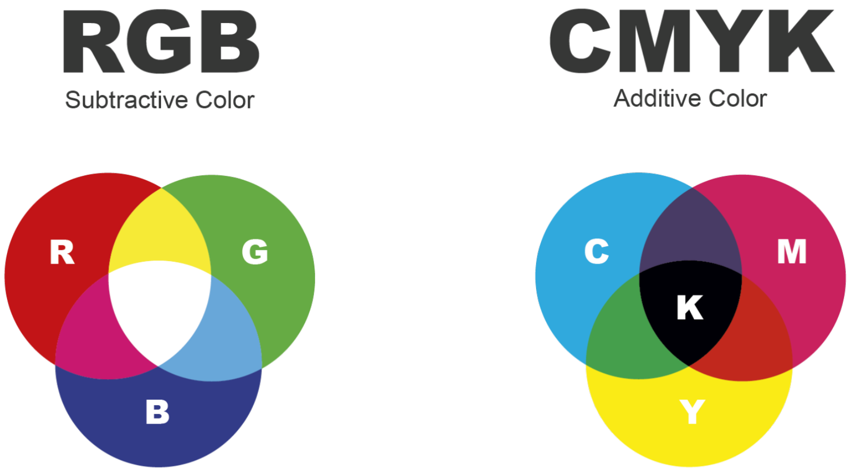


Figure 2.1: RGB and CMYK(6)

- **RGB**: It is a gradation of colors in three main colors (red, green, and blue) or (red, green, and blue) and consists of more than 16.5 million[7] shades and is saturated with white, which is the reason behind it. It produces our white color.

- **CMYK**:The CMY color model, or CMYK[11], is an archive color model of four main colors (cyan, magenta, yellow, and black) or (cyan, natural, yellow, and black). Black is added to it to improve some of the dark colors that are used in printing ink.

We Prefer CMYK Over RGB for Our Paint Making Machines: Here's Why.

CMYK (Cyan, Magenta, Yellow, and Key) and RGB (Red, Green, Blue) are two different color models used for color representation, and they each have their own advantages and disadvantages.

CMYK is a subtractive color model used in printing, where the primary colors of ink (cyan, magenta, yellow) are mixed together to create other colors. The "K" in CMYK stands for "Key," which represents black ink used to enhance contrast and detail. CMYK is preferred in printing because it can produce a wide range of colors and can handle subtle variations in color.

RGB is an additive color model used in digital displays, where the primary colors of light (red, green, blue) are combined to create other colors. RGB is preferred in digital media because it produces bright and vibrant colors, and can produce a wider range of colors than CMYK in certain cases.

2.2.2 Color Sensing Theory

Electronics use sensors as the components, units, detectors, or subsystems to recognize and react to electrical and optical signals. There are many different types of sensors. There is a temperature sensor, proximity sensor, touch sensor, color sensor, pressure sensor, light sensor, ultrasonic sensor, humidity sensor, and many more. The project uses a color sensor[25].

Color sensors can measure the light intensity of primary colors (red, blue, green, and white) and illuminate an object with a variety of light wavelengths. The light intensity ratio determines how much light the object will reflect and absorb.

- **What is the color sensor**?

These photoelectric sensors have the capacity to emit light and can distinguish between different colors of reflected light from objects[14]. These sensors are able to distinguish between primary colors like red, blue, and green as well as the brightness of light reflected from an object. They are additionally known as "color detectors."

Color sensors can measure the light intensity of primary colors (red, blue, green, and white) and illuminate an object with a variety of light wavelengths. The amount of light that is reflected and absorbed by the object depends on the light intensity ratio.

The color sensor circuit is made up of sensitive filters, sensor arrays, LEDs, target surfaces, and a receiver[4]. The same bright red light is reflected, and the blue light is absorbed, when it shines on the surface of the object. The reflection and absorption are determined by the filters used in these sensors.

2.3 Literature Review

This section will present a selection of earlier project that are comparable to ours and compare them.

1. **modeling and experimental investigation of paint mixing process dynamics[19]**
   The design and construction of an automatic paint mixing device with a monitoring and control system. This machine aims to mix and analyze the desired paint color. An Arduino Mega was used as a microcontroller, and a high-resolution camera was used for image capture. A mixing algorithm for water-based paints was proposed. This algorithm ensures that a user can get a predetermined paint color in a certain amount of time. That implies that the algorithm's inputs for paint volume and color are determined by the user. The algorithm will then specify the ratio of each of the three primary colors (red, green, and blue paints) to be mixed based on the paints' commercial databases.

2. **Design and implementation of mixing and filling colors machine[12]**
   This project shows the design and implementation of a color mixing and filling device that blends the primary four colors at predetermined ratios to produce a broad spectrum of colors that extends at least 40 shades deep across the interacting PC panel. The design process was broken down into four stages: problem formulation, field research and data gathering about the existence of these types of machines in the industry, proposed design, and the final stage, mixing optimization and calibration for the filling process. Testing of the machine prototype was done while keeping in mind that time-rate flow is what determines how much liquid is present. The results were accurate and of high quality.

Where the table shows a comparison between previous projects and our project

Table 2.1: Comparison of two projects that are comparable to ours

	Release year	color limitation	How are colors read	the primary Colors
modeling and experimental investigation of paint mixing process dynamics [14]	2020	There are infinite hues.	Using a commercial paint database, the user chooses a paint color.	RGB
Design and implementation of mixing and filling colors machine (MFCM) [15]	2009	forty colors only.	There are 40 colors on the device that can be selected as colors.	CMYK

Our project and the earlier projects were only similar in one area, and that area was the analysis of the value of the color that would be produced based on the primary colors. There are two parts, which are the input and reading part and the color spraying and pumping part. While our project depends on obtaining the color value through a sensor that is directed directly at the color or by entering the color value through the application, previous projects used to choose the color value based on stored colors. The last part, which is not present in the previous projects, is the output part. The color is sprayed and pumped through a specialized pump for this.

Where the table shows a comparison between previous projects and our project

Table 2.2: Comparison of our project with the two previous ones

	the number of project part	How do you read a color	Is there a pump	names of the stages
Previous projects	1 part	Direct reading is not possible. A value that is stored in the file is used to determine the color value.	Since the project's sole objective is to produce color, it lacks a pump.	section for mixing and analysis.
our project.	3 part	A sensor or an application's addition of the color value can be used to make the reading.	Yes, there is a pump, and it is used to spray the product color at the very end.	1- Section for Reading and Insertion 2- Section for Analysis and Mixing 3- The production and pumping departments

2.4 Summary

Our creation is a sophisticated device that squirts and blends color over the course of several stages. The device first reads the color value from the specialized sensor, in addition to another method that entails directly entering the color value through the application. The second stage then receives the color value and, after figuring out how much of each color is present, uses algorithms to analyze the color based on the three colors. The colors are added to a bowl with a mixer as part of the color manufacturing process. The mixer blends them to the desired hue.

Chapter 3

System Design

This chapter gives a description of the system, detailed design, and important information about the design.

3.1 Preface

Most color mixing devices only have the motor that does the mixing, and as a result, they rely heavily on the workers' hands. To provide better service, it was necessary to use more electronic and solid components. These elements that aid in the mixing processes are described in this chapter. colors that are accurate, comfortable, and finish the process. In reality, there are many different types and sizes of parts, and the field of parts and their types is very broad. The pieces for this project were selected with consideration for the materials used in each piece as well as the extent to which the mixing process had been completed. Connecting these components and using them to create a new color by combining the primary colors, CMYK.

3.2 The system components and design option

This section explains the components of our project and why we picked them.

3.2.1 hardware components

In order to get the best value at the lowest possible cost, we carefully examined the design and chose the best components and controls for our project.

1.Microcontroller

We need Microcontroller to processes the data that we will give to a robot.The Microcontroller is considered as one of the essential parts of the project. The choice of the type of the processor depends on specific characteristics such as :

- Cost
- Sufficient memory
- Suitable size.
- Speed
- Number of I/O pins

After researching different controller types, we selected the ESP8266 controller because it best fits our design.There are the many types of microcontrollers :

- **Raspberry Pi 4 Model B**: it is the latest product in the popular Raspberry Pi range of computers. It offers ground-breaking processor speed, multimedia performance, memory, and connectivity[17].

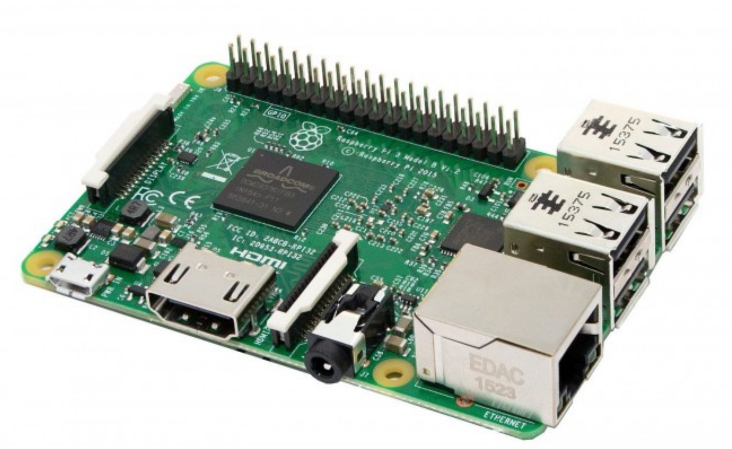


Figure 3.1: Raspberry Pi 4 Model B (15)

- **Jetson Nano Developer Kit**: This is a small, powerful computer that lets you run multiple neural networks in parallel for applications like image classification, object detection, segmentation, and speech processing[8].

Figure 3.2: Jetson Nano Developer Kit (16)

- **ESP8266 Core board**: is a mini development board designed based on the ESP-WROOM module. This development board leads out 2.54mm-pitch headers from I/O to both sides. The users can connect peripheral devices according to their needs. When using and debugging, the standard headers on both sides can make your operation more concise and convenient[21].

Figure 3.3: ESP8266 Core board (17)

The top Wi-Fi and Bluetooth solution with fewer than 10 external components is the ESP-WROOM module. It incorporates filters, power amplifiers, low-noise amplifiers, RF baluns, antenna switches, and power management modules. Additionally, it uses the low-power 40nm technology from TSMC. The economic performance of radio frequency technology makes it risk-free and reliable for expanding various applications[21].

ESP-NOW One of the main features of ESP8266[21] is ESP-NOW, a protocol developed by Espressif that enables multiple devices to communicate with one another without using Wi-Fi. The protocol is a lot like the 2.4 GHz low-power wireless connectivity that is frequently used in wireless mice. So, the pairing of devices is needed before their communication. After the pairing is done, the connection is secure and peer-to-peer, with no handshake being required.

The table 3.1 compares the hardware specifications of the Raspberry Pi 4[17], NVIDIA Jetson Nano Developer Kit[8], and ESP8266[21]:

Table 3.1: Comparison between microcontrollers

Category	**Raspberry Pi 4**	**NVIDIA Jetson Nano**	**ESP8266**
CPU	Quad-core ARM Cortex-A72 65-bit @ 1.5 GHz	Quad-core ARM Cortex-A57 65-bit @ 1.42 GHz	Dual-core Xtensa LX6 32-bit @ 600 MHz
Memory	4 GB	4 GB	984 KB
Networking	Gigabit Ethernet / Wi-Fi 802.11.ac	Gigabit Ethernet / Wi-Fi 802.11.ac	Wi-Fi 802.11bgn
Other	40-pin GPIO	40-pin GPIO	40-pin GPIO
Storage	Micro SD	Micro SD	Micro SD
Price	55$	99$	15$
USB	2x USB 3.0, 2x USB 2.0	4x USB 3.0, 2x Micro-B	-

Both the Raspberry Pi 4 and the NVIDIA Jetson Nano have high memory and processing capacities in addition to other top-notch specifications. Even though the Keyes ESP8266 has inferior hardware compared to the other options, we will still use it. It offers our project the necessary connectivity and processing power at a more reasonable cost, as well as a more dependable connection via the ESP-NOW protocol that enables us to use two ESP8266 with robust connectivity.

2.Dc Motor With Gear

A DC motor with gear refers to a type of direct current (DC) motor that incorporates a gear mechanism. The gear system is designed to provide mechanical advantage by increasing torque or reducing the speed of the motor's output shaft. This configuration is commonly used in various applications where precise control of rotational motion and increased torque is required, such as robotics, automation, and electric vehicles. The gear mechanism allows for efficient power transmission and enables the motor to generate higher torque while maintaining a lower rotational speed. This makes DC motors with gears suitable for applications that require a combination of power and precision.[16].

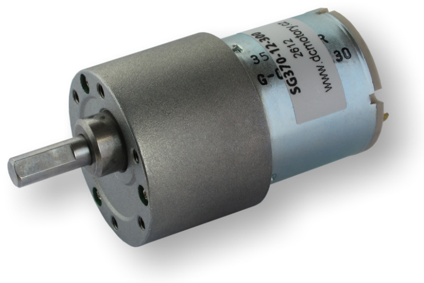


Figure 3.4: Dc Motor With Gear(18)

3.Paddle agitators

Propeller blades in the shape of paddles are used in paddle agitators, which extend to the tank walls. When extensive axial and radial flow is not necessary, they are used. These impellers, which have a close connection to DC motors, are used for heat transfer, crystallization, dissolution, and mixing of low-viscosity fluids. They can also produce low laminar shear flow[19].

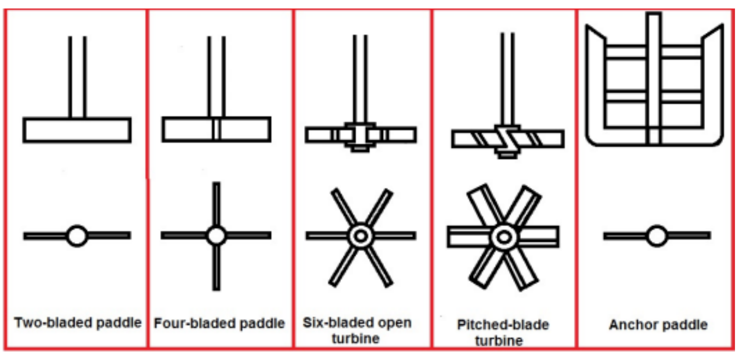


Figure 3.5: Various types of paddle agitators(13)

4.Color Sensor

A complete color detector, the Color Sensor It is made up of four white LEDs and a TAOS TCS3200 RGB sensor chip. It has a limited range of the nearly infinite visible color spectrum that it can detect and measure[20].

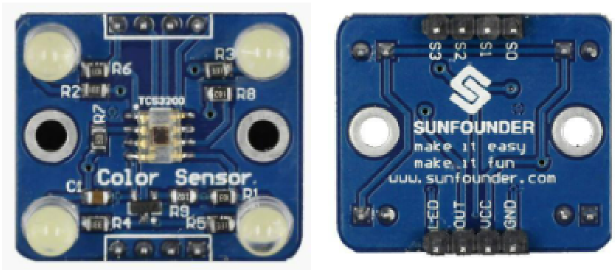


Figure 3.6: Color Sensor(20)

The chromatic light that an object reflects in the white light (sunlight) after absorbing the rest is what gives it the color that we can see. The color white is an amalgamation of all the visible colors, including red (R), yellow (Y), green (G), blue (B), and purple (P). According to the three primary color theories, any color can be created by combining red, green, and blue in a specific ratio.As a result, by knowing the ratio, you can determine what color the tested object is. When a color filter is chosen for the TCS3200[20], it only lets one primary color through while blocking the other two. By analyzing the values of the three primary colors' light intensities, we can ascertain the color of the light reflected to the TCS3200. Red, green, blue, and clear without a filter are the four different types of filters available for the TCS3200 sensor[20]. According to the module's pin S2 and S3's high and low values (see the table 3.2), the filter is chosen:

Table 3.2: different types of filters

S2	S3	Photo Diode Type
L	L	Red
L	H	Blue
H	L	Clear (no filter)
H	H	Green

A programmable converter found in the module converts color light to frequency. The RGB color component of the light reflected by the object passes through the filter selected for the TAOS TCS3200[20] RGB chip to produce square waves, which are then generated by the oscillator built into the device. The relationship between wave frequency and light intensity is direct: the higher the frequency, the brighter the light. Additionally, the OUT pin on the sensor module has a frequency that is proportional to the oscillator's frequency; the ratio is dependent on the high and low of pins S0 and S1.The schematic diagram of the module is as figure[20]:

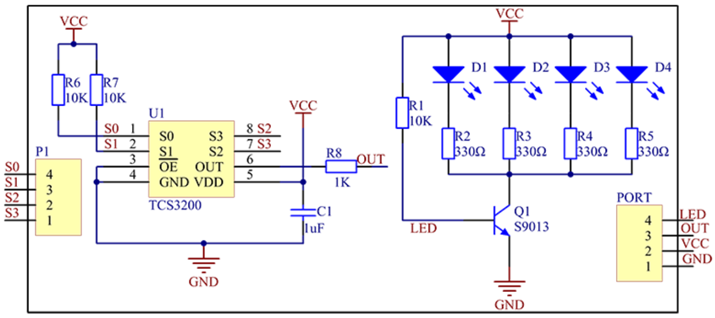
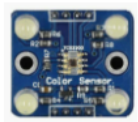


Figure 3.7: The schematic diagram of TCS 3200 (20)

After contrasting the TCS3200 sensor with a group of sensors that share the same operating principle, The table 3.3 represents the differences:

Table 3.3 : Comparison between different color Sensors

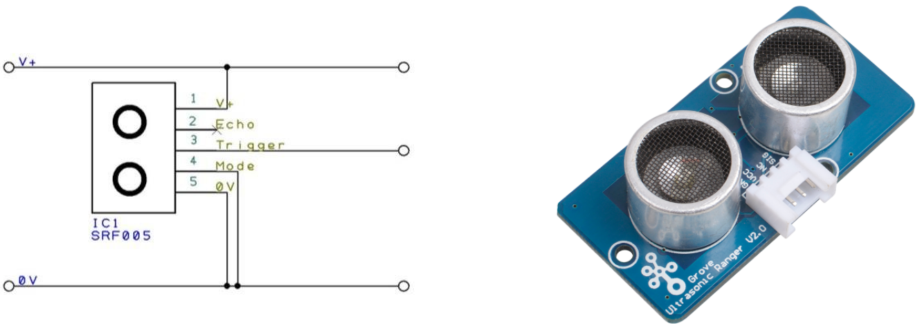
Category	**AS73211** 	**TCS3200** 	**TCS3400** 
Description	Industrial-grade XYZ color sensor with high sensitivity and dynamic range	Programmable color light-to-frequency converter	Color light-to-digital converter with 5th IR channel Vdd I²C
Supply voltage	2.7 - 3.6	2.7- 5.5	2.7 - 3.6
Interface	fast I²C	Frequency	I²C Bus (1.8V, VDD)
Color sensor Chanel	XYZ tri-stimulus CIE 1931/standard observer	RGBC	RGBC and IR
Temperature Range	-40 to 125	-40 to 70	-40 to 70
Package	QFN16	D, pin count 8	6-pin FN

In contrast, the TCS3200 sensor was selected for our project based on Table

3.3 since it is simple to find and purchase and because it reads RGB.

5.Ultrasonic Sensor

An ultrasonic sensor is a device that measures the distance of an object by using sound waves. It emits high-frequency sound waves and then listens for their echo to determine the distance of an object. Ultrasonic sensors are commonly used in robotics, automation, and automotive industries It is shown in the figure [3.8].



(a) Schematic Ultrasonic Sensor Reading

(b) Ultrasonic Sensor

Figure 3.8: Ultrasonic Sensor

The ultrasonic sensor is used to measure the distance between the sensor and the paint level in the tank. The program calculates the distance between the paint level and the sensor and then determines the required amount of paint to be added from white to achieve the desired color in the tank.

6. 12V Peristaltic DIY Aquarium Chemical Dosing Pump Tube Head

Due to the inner rotor's small size, a small 12V water pump requires a small amount of 12V DC voltage. It has one water outlet, one outlet, and one inlet. With a voltage of 12 volts, this water pump is referred to as a small water pump. We will have four of these pumps, each of which will be connected to one of the four primary colors. These pumps are connected to the controller, which establishes the necessary ratios for each of the four colors.The pump is seen in the figure[24].

Figure 3.9: 12V Peristaltic DIY Aquarium Chemical Dosing Pump Tube Head

The four primary colors will be connected to the pumps as follows :

- Pump 1 is connected to the color CYAN.
- Pump 2 is connected to the color MAGENTA.
- Pump 3 is connected to the color YELLOW.
- Pump 4 is connected to the color KEY.

7.Relay

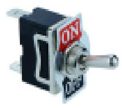
A switch that is electrically controlled is known as a "relay." A set of working contact terminals and a set of input terminals for one or more control signals make up this device. The switch may have any number of contacts in various contact configurations, such as make contacts, break contacts, or combinations of both. Relays are used when multiple circuits need to be controlled by a single signal or when a circuit needs its own, low-power signal. In order to refresh the signal coming in from one circuit by transmitting it on another circuit, relays were first used in long-distance telegraph circuits. Early computers and telephone exchanges made extensive use of relays to carry out logical operations.

the Relay is shown by the figure[22] :

Figure 3.10: Relay(22)

Table 3.5 shows the differences between switch and relay :

Table 3.5 : Comparison between switch and relay

Switch 	Relay 
An electromechanical switch is a tool used to establish or terminate circuits.	A relay is an electromechanical component that is used to create or destroy circuits.
Switches can be mechanically operated.	Relays can be electronically controlled.
By switching circuits on and off, it regulates the flow of current.	It opens or closes contacts to control high-power circuits with low power signals.
The contacts can be opened or closed using it.	It serves to safeguard the system against harm.
A switch makes a direct contact or connection.	It is a remote control switch
It works slower than a relay because a physical object is required to make the changes.	It operates faster
Using a manual switch to operate fans and lights in a home is an example.	Using a turn ON/OFF Air Conditioner and LDR street light (Automatic) is an example

The relay[22] will act as a connecting component between the ESP8266 and additional components like the mixer and pump. It will also function as a key, making it one of the most important parts of the project that cannot be overlooked.

3.2.2 material components

We will go over specific components that were difficult to include in the hardware and software.

- The materials used to build the mixing tank and the liquids to be combined must be compatible. For the majority of mixing experiments, being able to observe what is occurring within the mixing tank is quite helpful. Additionally,a clear cylindrical bowl[19] with a capacity of roughly 1000ml will be used as a mixing tank to facilitate cleaning after each coating mixing operation.The tank doesn't fade with time and continues to be shiny.

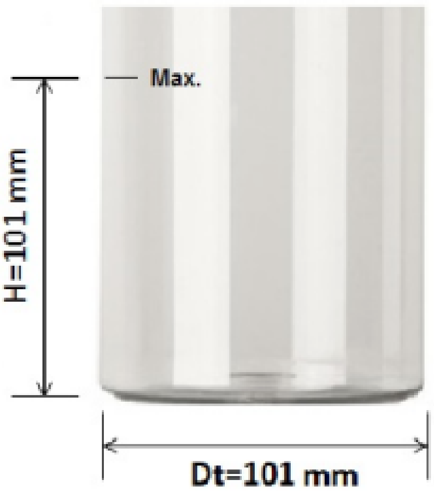


Figure 3.11: cylindrical Bowl(13)

- In five clear tanks[19], the unfinished paint colors CYAN, MAGENTA, YELLOW, and KEY were kept. These tanks are constructed of plastic, and the lowest part of them is conical to let the raw paint flow smoothly through them. Approximately 800 ml of liquid is stored in each tank.Where figure[19] represents the tank:

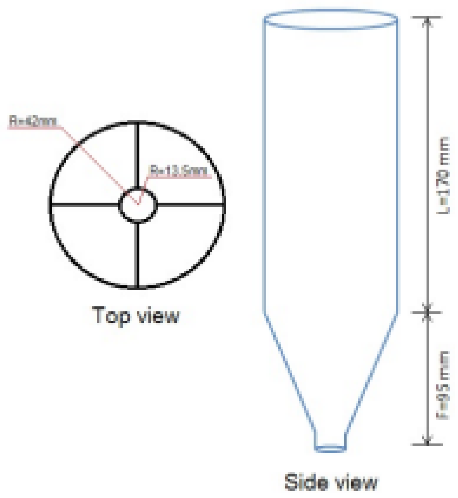


Figure 3.12: clear tanks(13)

3.2.3 System software components

MIT App Inventor was selected as the development platform for creating the application due to its compatibility with the project's component usage and its ability to deliver accurate outcomes and optimal performance. After conducting thorough research on various programming languages, we concluded that MIT App Inventor is the most suitable choice. For system programming and component integration, we decided to utilize the C language. We also carefully selected the appropriate protocol to establish a connection between the application and the system. This comprehensive approach ensures a seamless integration of components and efficient functionality throughout the project.

1.Mobile application Language :

The application was developed using App Inventor and establishes a connection with the machine through MQTT.

App Inventor is a web-based development environment that allows users to create mobile applications for Android devices. It is designed to simplify the process of app development by providing a visual, drag-and-drop interface along with a simple programming language.

With App Inventor, users can create fully functional mobile apps without the need for extensive programming knowledge. The platform utilizes a blocks-based programming approach, where users can select and arrange blocks of code to define the behavior of their app. This visual programming interface makes it easier for beginners to understand and create complex functionality.

App Inventor provides a wide range of components and features that can be added to an app, including buttons, text boxes, sensors, media playback, location services, and more. Users can customize the appearance and behavior of these components through the blocks-based interface.

The platform also offers built-in support for connecting apps to various services and APIs, such as web APIs, databases, and IoT devices. Users can integrate their apps with these external resources using pre-built blocks or by defining their own custom blocks.

App Inventor supports real-time testing of apps using a companion app called "MIT AI2 Companion." This allows users to preview and interact with their apps directly on their Android devices as they build and modify them in the web interface.

Once an app is complete, App Inventor provides options to package and export the app as an Android APK file, which can be installed and distributed on Android devices.

2.Complete System Programming Language:

In order for the system to work as a whole, it was necessary to take into account the languages through which we wanted to connect the system's components. After conducting research, learning the appropriate language, and comparing it to other languages, it was found that the C language, also known as the "C language," was the best suitable language for programming the system's components to get the best performance. one of the most frequently spoken languages today.

These are the languages:

- **C Programming Language** : Statements, functions, and variables are all included in the C programming language. The C programming language can be easily expanded, making it flexible for adding new features. To start, C is a procedural programming language that supports pointers. The programming language C is made up of statements, functions, and variables[23]. Programming in C is flexible and can quickly adopt new features.What potential does C have?

    1. Reduced code development time.
    2. Similar to Native App Performance.
    3. It has a total of 32 keywords.
    4. Simple Platform-Specific Logic Implementation.

- **C++ Programming Language** :is an object-oriented programming language that can identify both classes and objects. It is a flexible programming language with many potential applications. It can make games, browsers, and operating systems, among other things. It offers a variety of programming paradigms, including functional, procedural, object-oriented, etc. C++ is consequently robust and flexible. C++ is an old but still functional language. It is frequently used to create highly skilled gaming software and powerful applications[23].What potential does C++ have?

    1. It allows for the overloading of functions.
    2. C++ is built from the ground up.
    3. It has a total of 52 keywords.

4. Channels Cin and cout are also commonly used in C++ to conduct input and output actions.
5. C++ supports the new memory allocation operator.

- **Python Programming Language** :is a powerful programming language that has automatic dynamic typing, the capability to dynamically bind different operations. Beginner programmers frequently use Python due to its straightforward syntax, well-organized packages, and plug-ins. Python's design philosophy makes extensive use of whitespace, which makes its code simpler to read. Its object-oriented programming methodology ensures that programmers will receive assistance in writing clear, logical code for both complicated and straightforward applications[23].Python's Features Include:
  1. The ability to connect to a database system.
  2. Python is used to develop server-side web applications.
  3. It can perform difficult math and be used for quick prototyping.
  4. It is a high-level language with GUI programming capabilities.
- **Java Programming Language** :is a popular programming language that was first made available in 1995. It is object-oriented, secure, and safe. More than 3 billion devices use Java, which is owned by Oracle. The safest software can be developed using it, including embedded systems, desktop and mobile apps, web applications (using the Spring Boot framework), and massive data processing. Unreferenced objects don't need to be removed because Java has a feature called Automatic Garbage Collection[23].What potential does Java have?
  1. APIs are provided for practically every job.
  2. Java supports all three concepts: encapsulation, abstraction, and inheritance.
  3. Opposed to other programming languages, it has a powerful exception handling and a type-checking system.
  4. Java has a straightforward syntax.

Differences Between C, C++, Python, and Java in table 3.7 :

Table 3.7 :Comparison Between C, C++, Python, and Java

c	c++	java	python
Compiled Language	Compiled Programming language	Compiled Programming Language	Interpreted Programming Language
Operator overloading is not supported.	Operator overload is supported.	Operator overloading is not supported.	Operator overload is supported.
A small number of libraries are available.	Has a small number of library patrons	Many concepts, such as UX, are supported by the library.	It includes a sizable library collection that makes it possible to use it for applications in data science, AI, and other fields.
similar to C++ in speed	The programming language C++ compiles quickly.	Compared to the C++ compiler, the Java program compiler is a little slower.	When an interpreter is used, execution is delayed.
Platform-specific	Platform dependent	Platform-unaffected	Platform independent
Syntax rules are strictly followed.	Syntax rules are strictly followed.	Syntax rules are strictly followed.	It isn't necessary to use semicolon ';'

Based on the previous table, we determined that the C programming language would be best suited for our project. We will be able to program the different project components to come together as a working system by using it to connect the project's various components.

3.Protocols:

A protocol is simply a set of guidelines that computers follow in order to interact with one another and the outside world in predictable, deterministic ways. Simply put, messaging protocols outline a methodical way for applications to exchange data payloads. They also describe the data routing, message prioritization, and implementation-specific message processing processes. Some messaging protocols go much further than others in defining security concepts and assisting implementers in achieving the availability and scale of the messaging layer in a uniform and standardized manner. The MQTT protocol serves as an example of a messaging protocol.types of protocol:

- **Message Queuing Telemetry Transport (MQTT)** :MQTT is a popular IoT communication protocol that has a straightforward publish/subscribe messaging transport. It is a protocol that makes it easier for different machines to exchange data, and it has become one of the most important ones on the Internet. All devices communicate through a broker or server. The broker can be set up on a PC, MAC, Linux system, or even on a small computer. Two of the most famous brokers available on the market these days are HIVEMQ and Mosquito. Client devices can accept information from the broker, receive information from the broker, or subscribe to specific topics. Additionally, they can publish particular messages to the broker. Through the broker, all devices communicate with one another[10].

- **Advanced Message Queuing Protocol (AMQP)** :AMQP is a messaging protocol that connects businesses and applications. Although it wasn't designed specifically for IOT applications, this protocol has many uses in the Internet of Things and is efficient at communicating messages.

  It connects the system, provides the system with the necessary information, and transmits that information forward in order to accomplish the necessary goals. AMQP connects across a range of technologies, systems, times, and locations[18].

- **Constrained Application Protocol (CoAP)** :There are numerous crucial IoT communication protocols, and this is one more. IoT hardware is designed to work with limited devices, nodes, and networks. CoAP is a connection less protocol because it uses UDP and runs on it. It is a restful, effective protocol with a 4-byte header. It uses a simple protocol[10].
  The CoAP adheres to the request-response protocol, in which each request necessitates a specific response. The GET, POST, and PUT methods are supported by CoAP. These methods are handled asynchronously by CoAP using UDP[10]. The CoAP is designed in a way that makes using the HTTP interface simple and also makes it simple to use with networks and nodes that have limited resources.the comparison of protocols in the table 3.8 :

Table 3.8 :comparison of protocols

Criteria	MQTT	AMQP	COAP
Year	1999	2003	2010
Architecture	Client/Broker	Client/Broker or Client/Server	Client/Server or Client/Broker
Semantics/ Methods	Connect, publish, opt-out, close, disconnect, and then subscribe.	Consume, deliver, publish, get, select, acknowledge, delete, nack, recover, reject, open, and close.	Get, Post, Put, and Delete.
Quality of Service (QoS)/ Reliability	Qos 0 - at most once Qos 1 - at least once Qos 2 - exactly once	Settle format (similar to at most once) Or Unsettle format (similar to at least once)	Confirmable massage (similar to at most once) Or Non-confirmable massage (similar to at least once)
Transport Protocol	TCP	TCP,SCTP	TCP,SCTP

The MQTT protocol[10][18] will be used for this project because it is made for low-power, low-bandwidth devices. We will use it directly as a link between the application and the system to make the application part of the system. It makes use of a lightweight publish/subscribe messaging protocol, allowing any other device to subscribe to a specific topic.

3.3 Block Diagram

The system's connections, how it functions as a unit, and the connections between its components are shown in the figure[3.13] diagram.

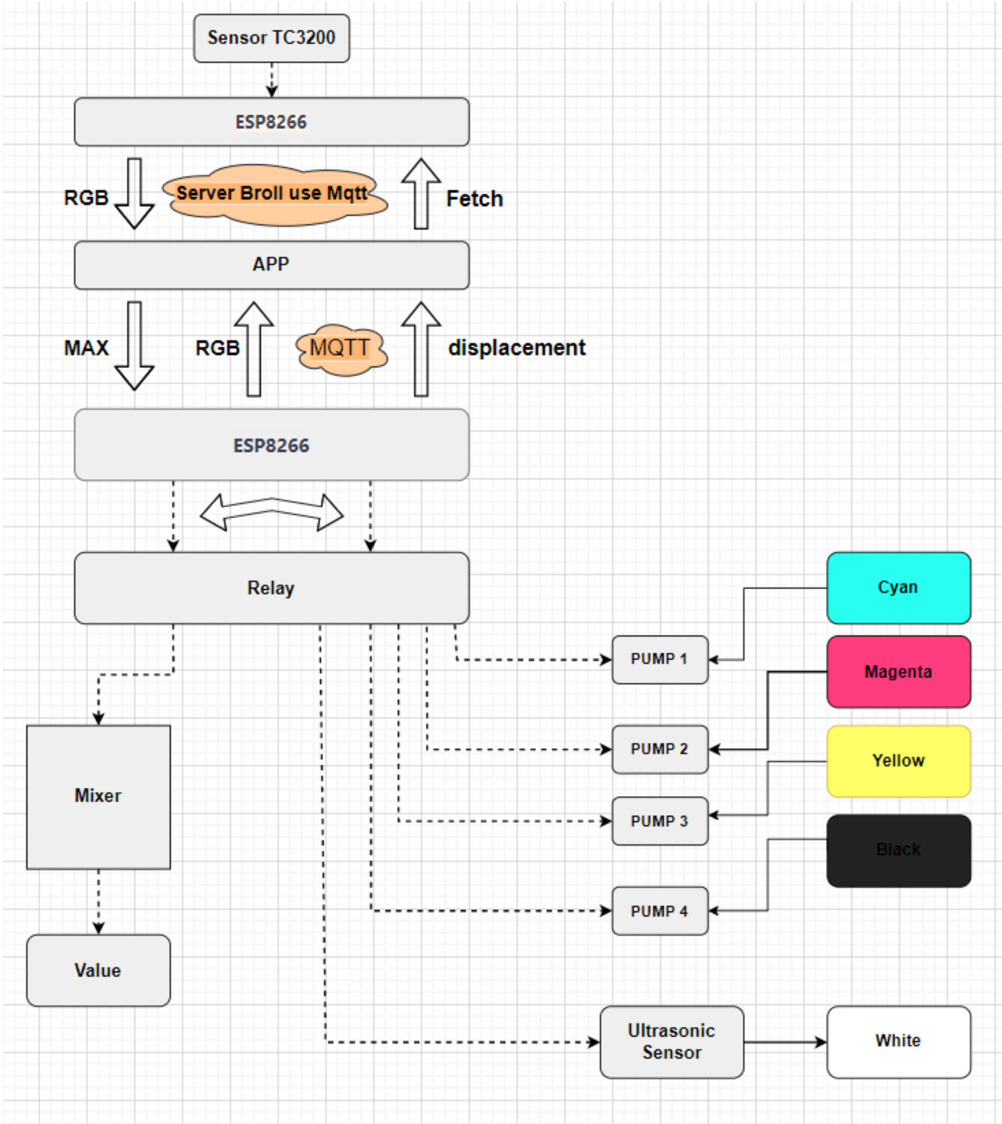


Figure 3.13: Block Diagram

The figure shows the elements of the system as well as their interactions and the overall operation of the system. The two ways to obtain the value involve a sensor or an application connected to the ESP8266[21] via the MQTT protocol[10]. The ESP8266 is then connected to the relay that links the elements to one another. Some, which serves as a key and is linked to the pumps responsible for pumping the value of each color a, a, The sensor reading value must also be visible in the application in order to verify that the sensor reading value is what we want to produce and reduce the error rate.

3.4 Flow Charts

A diagram that demonstrates the operation of a system, computer algorithm, or process is called a flowchart. They are frequently used in many different disciplines to examine, organize, enhance, and convey frequently complicated processes in simple, understandable diagrams.

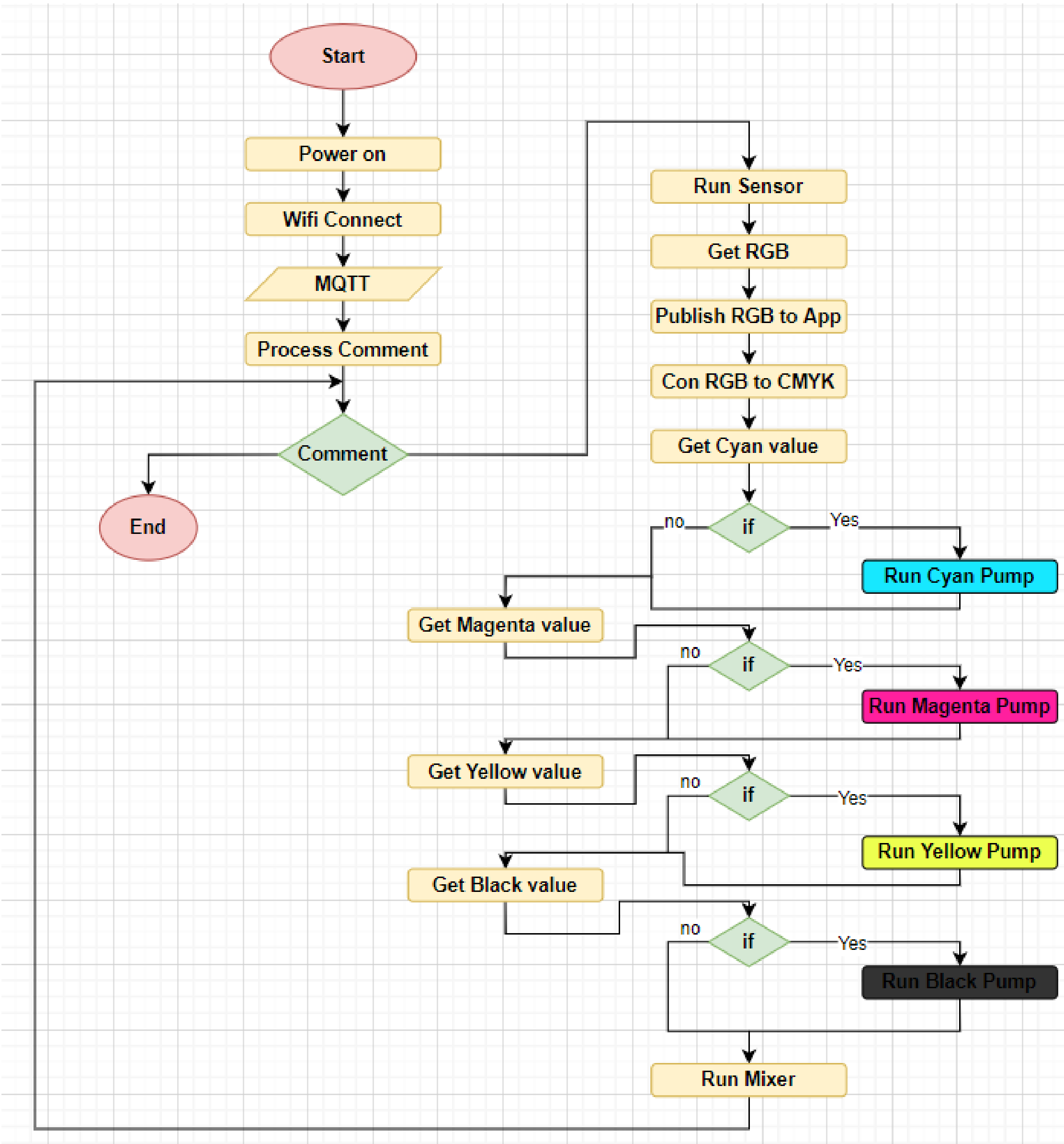


Figure 3.14: Flowcharts

3.5 Cricut Diagram

A schematic diagram is a simple form of two-dimensional circuit representation that shows how various electrical components are connected and function. The schematic symbols that are used to represent the components on a schematic diagram must be understood by a PCB designer. The figure[3.15] shows the overall system layout and the connections between the various components:

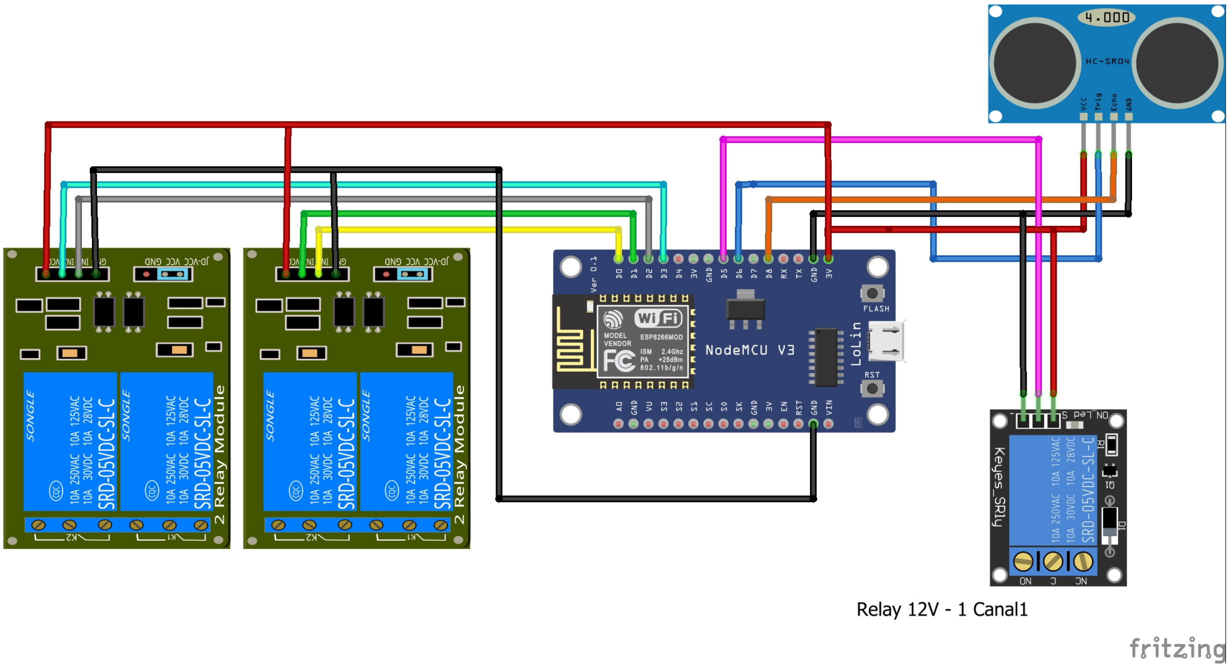


Figure 3.15: circuit Diagram To Machine

This design represents the connection between the parts without the sensor. Since the sensor communicates with the machine through Wi-Fi, this specific component is responsible for establishing the connection to:

- The Ultrasonic sensor is connected to the ESP2866 module.
- The relay module communicates with the ESP2866.
- Each pump is connected to its respective relay.
- The ESP2866 module is powered by adapters.
- The ESP2866 module communicates with the sensor via Wi-Fi using the MQTT protocol.

In addition to the existing design figure[3.16], the TCS3200 sensor is connected to the ESP2866 module. This connection allows the ESP2866 to receive data from the TCS3200 sensor and utilize it within the application or transmit it to other devices through the established MQTT connection.

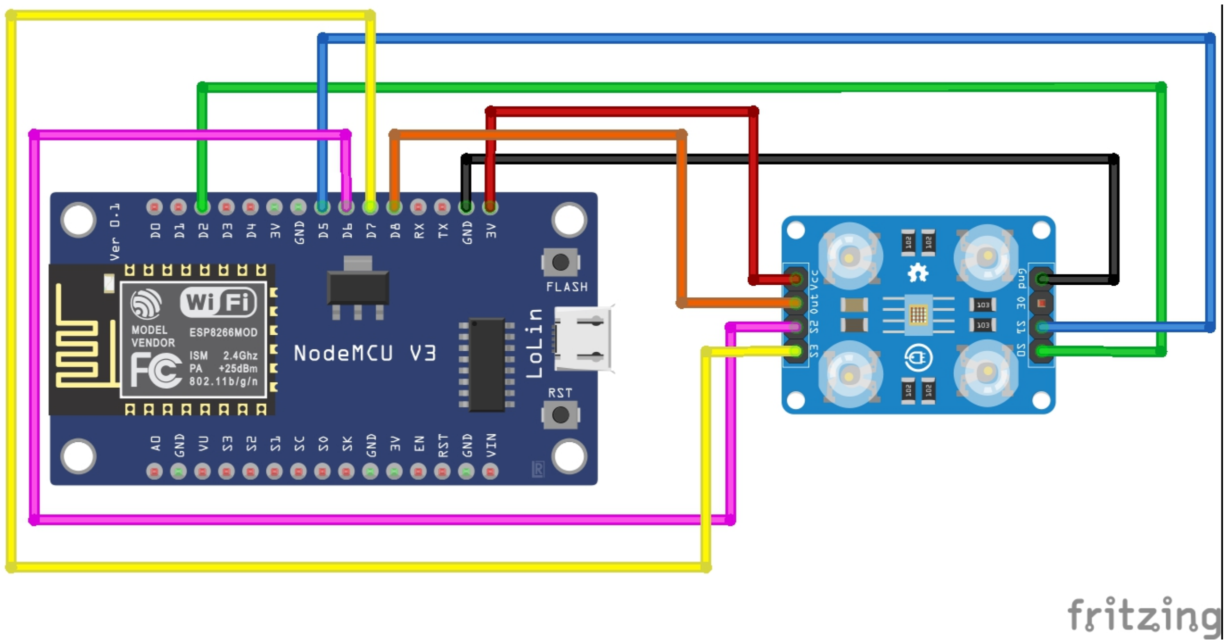


Figure 3.16: circuit Diagram To Color Sensor TCS3200

3.6 Summary

The project's inspiration came from a desire to help people who use paint save time and effort by offering potential solutions. After careful planning, we created the required machine and its functionality using its components and programming. At the end of Chapter 3, we were able to describe the machine's operation and the procedure. A decision on the parts to use and how to connect them was also made after visiting painting facilities and parts stores. Finally, a number of tasks were completed during the development of this bot, including:

1. Identify the parts categories that are appropriate for our project.
2. Create a plan for the project's construction process.
3. Being aware of the ideal initial setup for connecting the circuit in the model.

Chapter 4

Implementation

4.1 Overview

This chapter explains the implementation part for the hardware components and the software.It dives into more details about the project's overall different hardware components and software modules.

4.2 Hardware Implementation

In this section, we will describe the hardware components used in our project and how they are connected.

4.2.1 Machine Hardware Implementation

In this section, we will describe the Machine without TCS3200 sensor used in our project and how it is connected.

(a) Front view of the machine **(b)** Rear view of the machine

Figure 4.1: Machine Sensor Implementation

The following hardware components were utilized for implementing this machine:

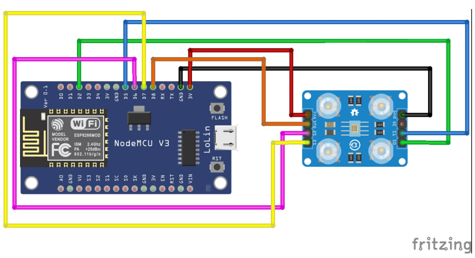
1. An ESP8266 development board .
2. Four relays to control the pumps, one relay to control the mixer, and an ultrasonic distance sensor.
3. A power supply that can provide enough power to the ESP8266 and the relays .
4. A compatible MQTT broker that the ESP8266 can connect to.

For machine implementation, you can follow these steps:

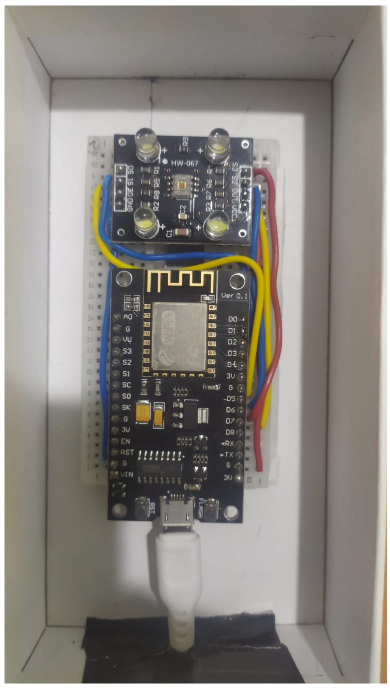
1. We connected the ESP8266 to your computer using a USB cable.
2. We connected An ultrasonic sensor to the ESP8266 board.
3. We connected relays module to the ESP8266 board.
4. We connected pumps to the relays module.

4.2.2 TCS3200 Hardware Implementation

In this section, we will describe the TCS3200 Sensor used in our project and how it is connected.



(a) Before Implementation



(b) After Implementation

Figure 4.2: TCS3200 Sensor Implementation

For TCS3200 implementation, you can follow these steps:

1. We gathered all the required components, including the ESP8266 board, TCS3200 color sensor, wires, breadboard, and power supply.

2. We connected the TCS3200 color sensor to the ESP8266 board according to the wiring diagram in the code as shown in image [4.1].

3. We connected the ESP8266 board to the power supply as shown in image [4.1].

4. We Turned on the power supply and verify that the ESP8266 board and TCS3200 color sensor are working properly.

4.3 Software Implementation

This section explains how the software program integrates the instrument and sensor and establishes communication between them using MQTT. It also describes the implementation of the machine through the code.

4.3.1 Operating System

We utilized the Windows operating system to develop the software for the project and installed the Arduino IDE. By downloading and installing the Arduino IDE.

4.3.2 Installing Needed Packages

we downloaded and used a set of libraries that were necessary for our project. Here is a list of the libraries we used.

- **ESP8266WiFi.h** : This package provides pre-written code for connecting the ESP8266 Wi-Fi module to a Wi-Fi network.

- **PubSubClient.h** : This package provides pre-written code for publishing and subscribing to MQTT topics.

- **Wire.h** : This package provides pre-written code for communicating with devices over I2C protocol.

```
#include <ESP8266WiFi.h>
WiFiClient WIFI_CLIENT;
#include <PubSubClient.h>
PubSubClient MQTT_CLIENT;
#include <Wire.h>
```

Figure 4.3: Installing Needed Packages.

4.3.3 Machine Software Implementation

Based on the code, we implemented a software for a paint machine using an ESP8266 board, relays, pumps, sensor ultrasonico and mixer.

We developed the code for the paint mixing machine by following these steps:

1. We included the required libraries, including ESP8266 WiFi, PubSubClient, and Wire.
2. We initialized constants to represent the pins utilized by various components such as the relays, ultrasonic sensor, and other devices.
3. We set up the WiFi network credentials and defined the MQTT broker information.
4. We created an MQTT client and connected it to the broker.
5. We implemented a callback function that handles incoming messages on subscribed topics.
6. We created a function to convert RGB color values to CMYK.
7. We Implemented a function to read distance from the ultrasonic sensor.
8. In the main loop, we checked the status of the WiFi and MQTT connections, and reconnected them if necessary.
9. When the topic "prepare_primary_colors" is received, we extract the RGB color values and convert them to CMYK.
10. When the "do_mixing" topic is received, it toggle the mixing state of the machine.

11. During each iteration of the loop, the machine reads the distance from the ultrasonic sensor and publishes it to the MQTT broker.

12. We controlled the relays to mix and pump the paint based on the mixing state and CMYK values.

4.3.4 TCS3200 Software Implementation

Based on the code, we implemented a a TCS3200 color sensor using an ESP8266 board . The software connects to a MQTT broker, subscribes to a topic to fetch RGB color values from the sensor, and publishes the RGB color values to another place. Here are the steps to implement the software:

1. Install the required libraries:

   - ESP8266WiFi.
   - PubSubClient.
   - Wire.

2. Define the pins of the TCS3200 color sensor:

   - S0.
   - S1.
   - S2.
   - S3.
   - SensorOut.

```
#include <ESP8266WiFi.h> // ESP8266
WiFiClient WIFI_CLIENT;
#include <PubSubClient.h>
PubSubClient MQTT_CLIENT;

#include <Wire.h>

/* TCS3200 */
#define S0 4 // D2
#define S1 14 // D5
#define S2 12 // D6
#define S3 13 // D7
#define sensorOut 15 // D8
```

Figure 4.4: step 1 and step 2.

3. Connect to Wi-Fi network using the ESP8266WiFi library. Define the SSID and password of the Wi-Fi network.

4. Connect to the MQTT broker using the PubSubClient library. Define the server and port of the MQTT broker.

```
/* WiFi */
const char* ssid = "PAINT-MACHINE"; // Enter your WiFi name
const char* password = "100100100"; // Enter WiFi password

/* MQTT */
const char* mqtt_server = "broker.hivemq.com";
const int mqtt_port = 1883;
```

Figure 4.5: step 3 and step 4.

5. Implement the **'reconnect()'** function to try to connect to the MQTT broker.

   void reconnect(): This function is used to reconnect the MQTT broker. It sets up the connection with the broker, subscribes to the necessary topics, and waits for three seconds to try again if the connection is not established.

```
void reconnect()
{
    MQTT_CLIENT.setServer("broker.hivemq.com", 1883);
    MQTT_CLIENT.setClient(WIFI_CLIENT);

    while (!MQTT_CLIENT.connected()) {
        Serial.println("Trying to connect with Broker MQTT.");

        MQTT_CLIENT.connect("ppu_smart_paint_machine_esp_color_2023");

        MQTT_CLIENT.subscribe("PPU/smart_paint_machine/fetch_rgb_from_sens

        delay(3000);
    }

    Serial.println("connected MQTT.");
}
```

Figure 4.6: step 5.

6. Implement the **'callback()'** function to handle incoming messages.

   void callback(char* topic, byte* payload, unsigned int length): This function is called when the device receives a message from the MQTT broker. It converts the message payload to a string and stores it in the message variable.The function also sets the fetch_rgb_from_sensor flag to "yes" if the topic is "PPU/smart_paint_machine/fetch_rgb_from_sensor".

```
String message = "";
String fetch_rgb_from_sensor = "no";

void callback(char* topic, byte* payload, unsigned int length) {
  String stopic = String(topic);

  Serial.print("Message received: ");
  Serial.print(topic);
  Serial.print("   ");
  message = "";
  for (int i = 0; i < length; i++) {
    message += (char) payload[i];
  }
  Serial.println(message);

  if (stopic == "PPU/smart_paint_machine/fetch_rgb_from_sensor") {
    fetch_rgb_from_sensor = "yes";
  }
}
```

Figure 4.7: step 6.

7. In the **setup()** function, set the callback function and connect to the MQTT broker.

   void setup(): This function is called once when the device starts up. It initializes the serial communication, sets up the TCS3200 sensor, connects to the WiFi network, and sets up the MQTT client.

8. In the **loop()** function, check if the MQTT client is connected. If not, try to reconnect.

   void loop(): This function is called repeatedly while the device is running. It checks the MQTT broker connection, checks the fetch_rgb_from_sensor flag, reads the RGB values from the TCS3200 sensor, publishes the RGB values to the MQTT broker, and waits for one second.

9. If the **fetch_rgb_from_sensor** variable is set to "yes", read the RGB color values from the TCS3200 sensor and publish them to the MQTT broker.

10. Call the **MQTT_CLIENT.loop()** function to check for incoming messages.

11. We Added delays to the code for proper functioning..

4.4 MQTT Protocol Implementation

MQTT is a lightweight open messaging protocol that provides resource-constrained network clients with a simple way to distribute telemetry information in low bandwidth environments. The protocol, which employs a publish/subscribe communication pattern, is used for machine-to-machine (M2M) communication[15].

MQTT is utilized as the central link between the application, sensor, and machine components, providing the most efficient and effective connectivity between them. In the figure[4.8], the creation of MQTT within the application is accomplished using MIT App Inventor. This integration ensures seamless communication and data exchange among the different elements, enhancing the overall functionality and performance of the system.

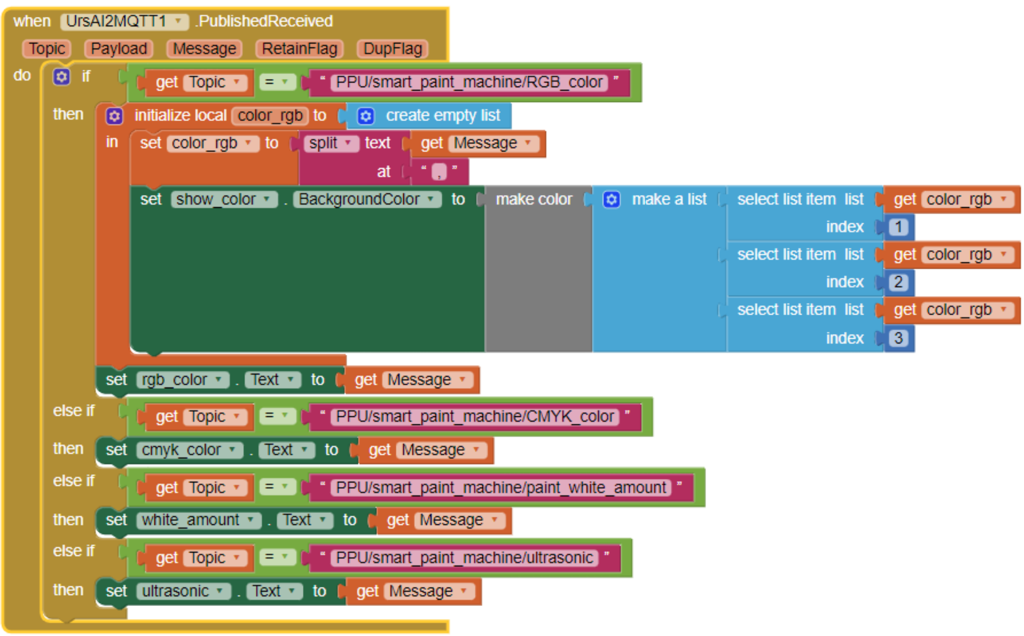


Figure 4.8: Connect MQTT In Mobile App.

The library mqtt-client is a plugin that Responsible for exchanging data between the application and the robot so that it achieves effectiveness and ease of dealing.

The library provider is a plugin that easy to use package which is basically a wrapper around the Inherited widgets that makes it easier to use and manage. It provides a state management technique that is used for managing a piece of data around the application[15].

4.5 Mobile Application Implementation

In this section, we will provide an explanation of the application developed using the MIT App Inventor language. We will showcase the application's pages and provide insight into their functionality.

A brief overview of how the application works:

At the outset, the application comprises a login page, which plays a crucial role in our project. Since the color reading machine can only respond to one user at a time, it becomes disabled when multiple users try to access it simultaneously. The second page features two buttons: one for selecting a value via the sensor and the other for navigating to a page that provides two input options. The first method involves selecting a color by moving a point to the desired color, while the second method uses the camera to identify the desired color. Both pages feature a "start" button that sends the chosen value to the machine to initiate color production.

Once the selection process is completed, the color value is sent via the MQTT protocol, which establishes a connection between the application and the machine.

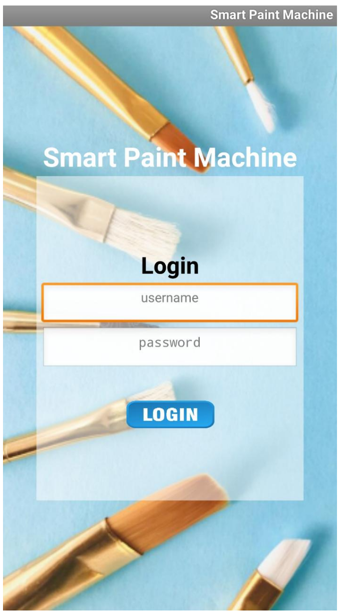


Figure 4.9: Page for selecting the method of color input.

This page serves as the login page where users can log in using their name and password, provided that their computer is already registered in the database. To ensure that the machine is used by only one user, we have not enabled the account creation process.

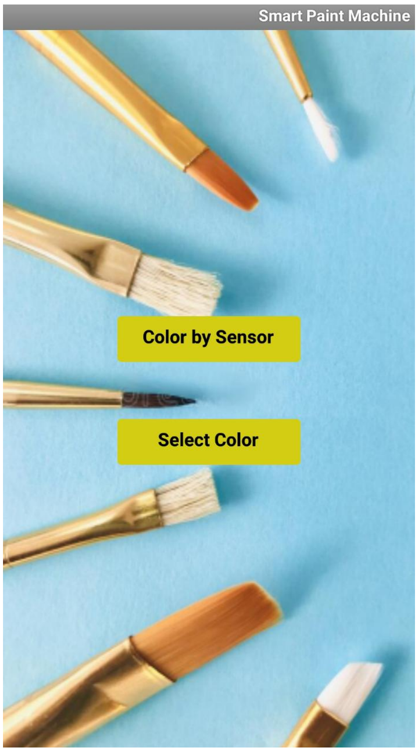


Figure 4.10: Select Page

The page contains two buttons. The first button allows the user to go to a color selection page using the sensor. The second button allows the user to go to a color selection page a color through the camera or manual selection.

In order for the reading to be completed, pressure must be placed on the image of the sensor, and so the reading is requested from the sensor. When the sensor is directed to the color, the value of the color appears with its analysis into the three main colors.

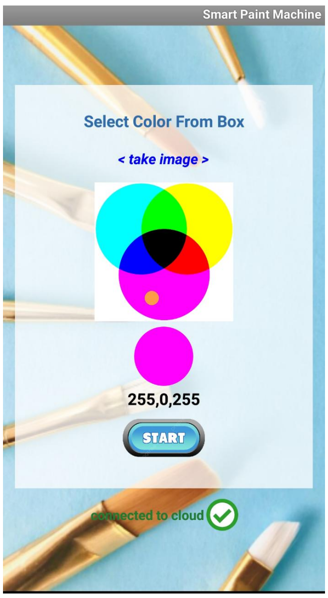
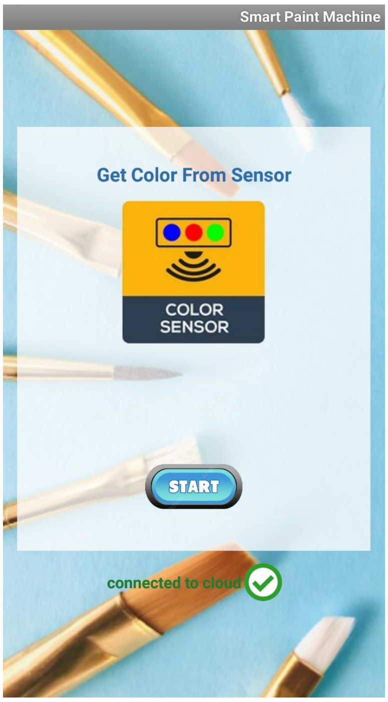
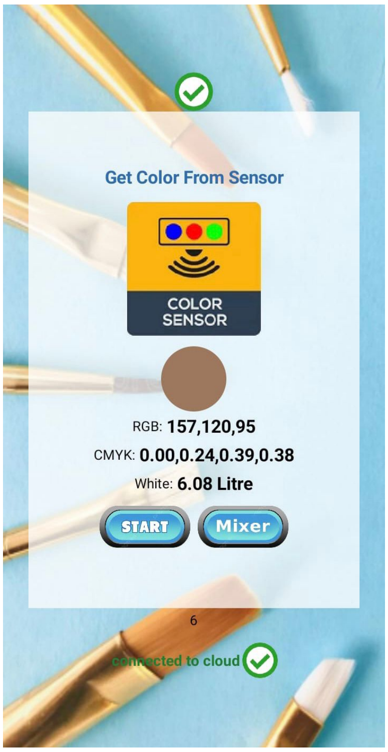


Figure 4.12: Manual Selection



(a) Before Reading



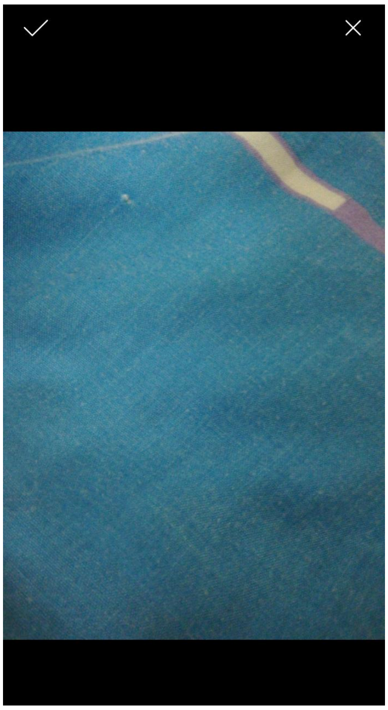
(b) After Reading

Figure 4.11: Sensor Color Page

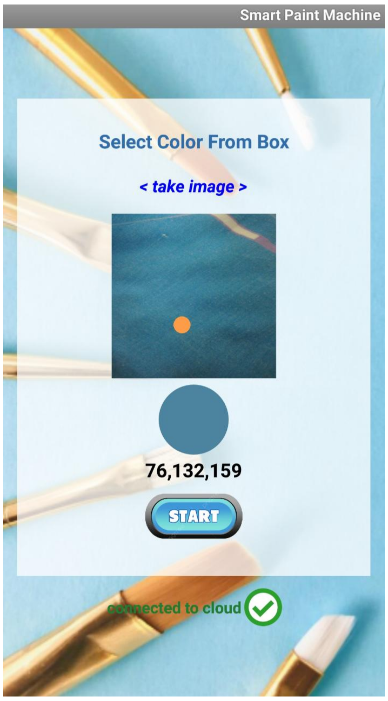
In the figure[4.11], the color selection is performed using the sensor.

This page allows the user to select the desired color using the camera. After the user chooses the camera option, the camera app is opened, and the user can point the camera to the color they want to select. Once the user has selected the picture, it is displayed on the screen. Then, they can choose the desired color by moving the orange ball to the color they want from the picture. The chosen color's value is then displayed on the screen, and the user can proceed to the next step.

When the user selects a color using any of the available color selection methods, the chosen color's value is sent to the machine via MQTT by clicking on the "start" button that is present on all color selection pages.



(a) Before Reading



(b) After Reading

Figure 4.13: Page for Selecting Colors via Camera

4.6 Implementation Issues

We encountered several problems when starting the practical part of the project, and we did our best to overcome these problems. Some of these problems include:

- The first problem we discovered was that the sensor could only read the color in a dark place. We came up with a solution, which was to attach the sensor to a dark box that is connected to the machine.
- There was also a problem with the sensor's accuracy, as it couldn't read all colors. We reached out to several sources and companies to get a better sensor, but what we had was the best available. We took a supplementary step to reinforce the sensor by using the camera of the phone to capture colors with high accuracy.
- Initially, we used large pumps, but their performance was somewhat unstable due to their strength and speed, which was more than what we needed. We used smaller pumps to give us stability and better efficiency for the project.
- As we progressed with the work and started experimenting, a problem arose with the pumps and the paint. After completing the processing cycle and mixing the paint, traces of the paint remained in the pump. We looked

for an alternative, which was a specific type of pump, but due to the time constraints and material limitations, we turned to another solution, which was to perform a washing cycle for the pumps after each cycle.

- It is worth noting that the lighting of the phone has an impact on the intensity of colors.

Chapter 5

Validation, Testing, and Results.

5.1 Overview

This chapter illustrates the testing process of the overall system, its components, and software. We test all the parts to ensure that all the functions work as expected and without errors.

5.2 Hardware Testing

We conducted a series of tests on the device using the Ultrasonic sensor to measure the distance and calculate the required amount of white pigment for a given color. The application then transmits the color information via MQTT. The machine precisely operates the pumps for a specific period to dispense the appropriate quantities of each dye. Finally, the device receives an MQTT response to activate the mixer. These steps ensure precise color mixing and accurate control of the machine's pumps and mixers, as well as their timing. The accompanying figures display the readings for these results.

Figure 5.1: Hardware testing for the machine - 1

Figure 5.2: Hardware testing for the machine - 2

Figure 5.3: Hardware testing for the machine - 3

Figure 5.4: Hardware testing for the machine - 4

Figure 5.5: Hardware testing for the machine - 5

- **Distance** : These are the results of measuring the distance between the dyes inside the tank and the sensor using the Ultrasonic sensor. The measured distance is then used to calculate the precise amount of white pigment required to achieve the desired color.
- **Message received** : These results correspond to the commands received from the application via MQTT. These commands include the color value and the mixer operation.
- **Scale_amount** : These results also include the time it takes for the pumps to operate.
- **m-relay - y-relay** : "These results show the performance of each of the four pumps.

5.3 Software Testing

In this section, we conducted tests on the application and the MQTT protocol.

5.3.1 Mobile Application Testing

We conducted a test to verify the accuracy of the TCS3200 sensor's readings and the conversion of its RGB color values to CMYK, along with the use of the Ultrasonic sensor. Additionally, we confirmed the correct display of the sensor results in the application, as illustrated in the accompanying figure [5.6].

Figure 5.6: Mobile Application Testing

- **RGB** : The RGB shows the color value read by the sensor.
- **CMYK** : The CMYK shows the RGB value converted to CMYK using the sensor.
- **White** : The Ultrasonic sensor provides a reading that represents the necessary amount of white dye to be added to achieve the desired color, as shown in the figure [5.6].

5.3.2 MQTT Protocol Testing

We conducted a test to verify the proper functioning of the MQTT protocol by selecting a specific color through the application and transmitting the result via MQTT, which was then displayed on the MQTT server. As shown in the figure [5.7][5.8], The application sends these results to the ESP for execution, with MQTT acting as an intermediate link between the two. This process ensures that the color is accurately transmitted over MQTT to the appropriate destination.

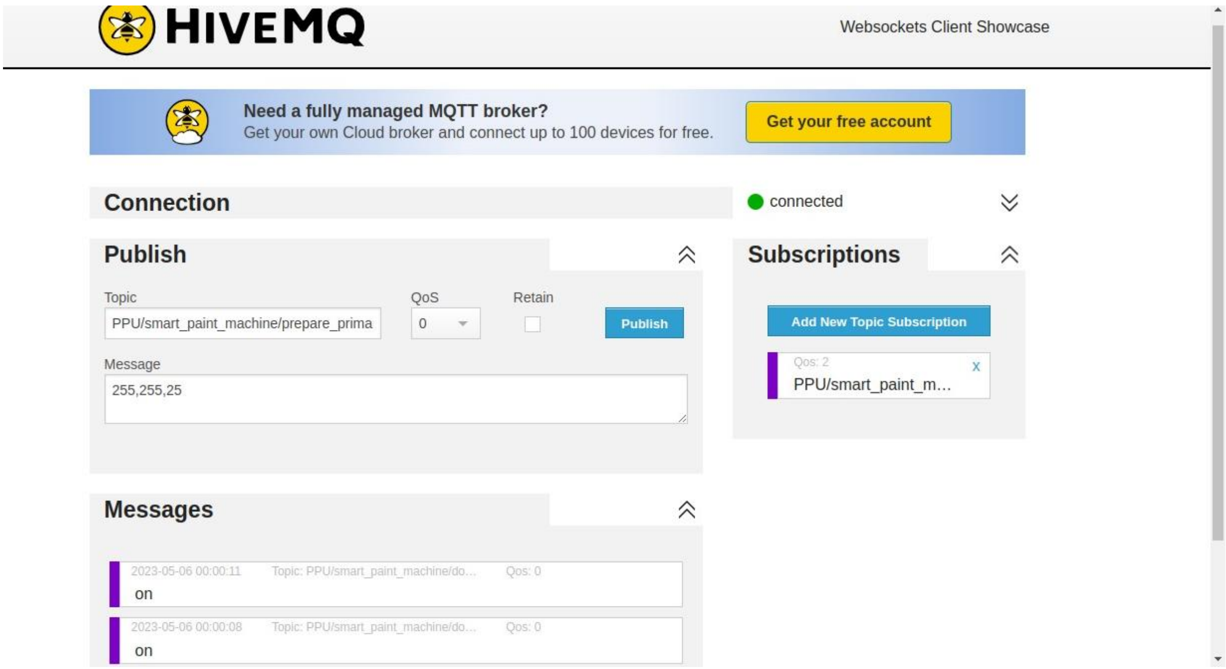


Figure 5.7: MQTT Testing - 1

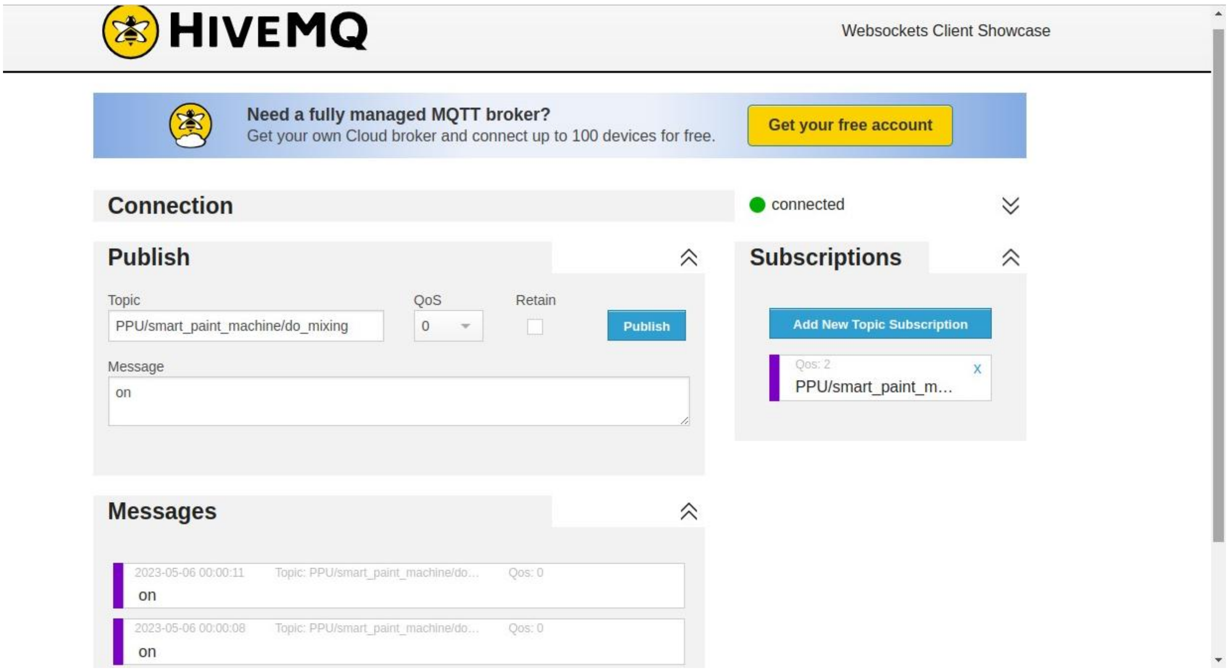


Figure 5.8: MQTT Testing - 2

5.3.3 Machine Testing

These are the results achieved by each component: hardware, software, and MQTT:

Hardware : Refers to the physical components used in the project, such as electronic devices, sensors, and connections. The hardware collects and transmits or receives data, facilitating communication with other components.

Software : Refers to the programs or source code developed to control and interact with the hardware. The software provides the necessary instructions and logic for the hardware to perform specific tasks or functions.

MQTT : is a communication protocol used for transmitting messages between devices or applications. It plays a vital role in facilitating the exchange of data and messages between the hardware, software, and other devices or systems. MQTT enables efficient and reliable communication, ensuring the seamless flow of information.

Together, the hardware, software, and MQTT work collaboratively to achieve the desired functionality and results in the project. The hardware collects data, the software processes and controls the data, and MQTT facilitates communication and message exchange between different components or systems.

Comprehensive testing was performed on the entire project, covering all components and functions. The test results, as depicted in the accompanying images, provide an accurate representation of the project's overall performance and behavior.

Figure 5.9: Testing of Machine - 1

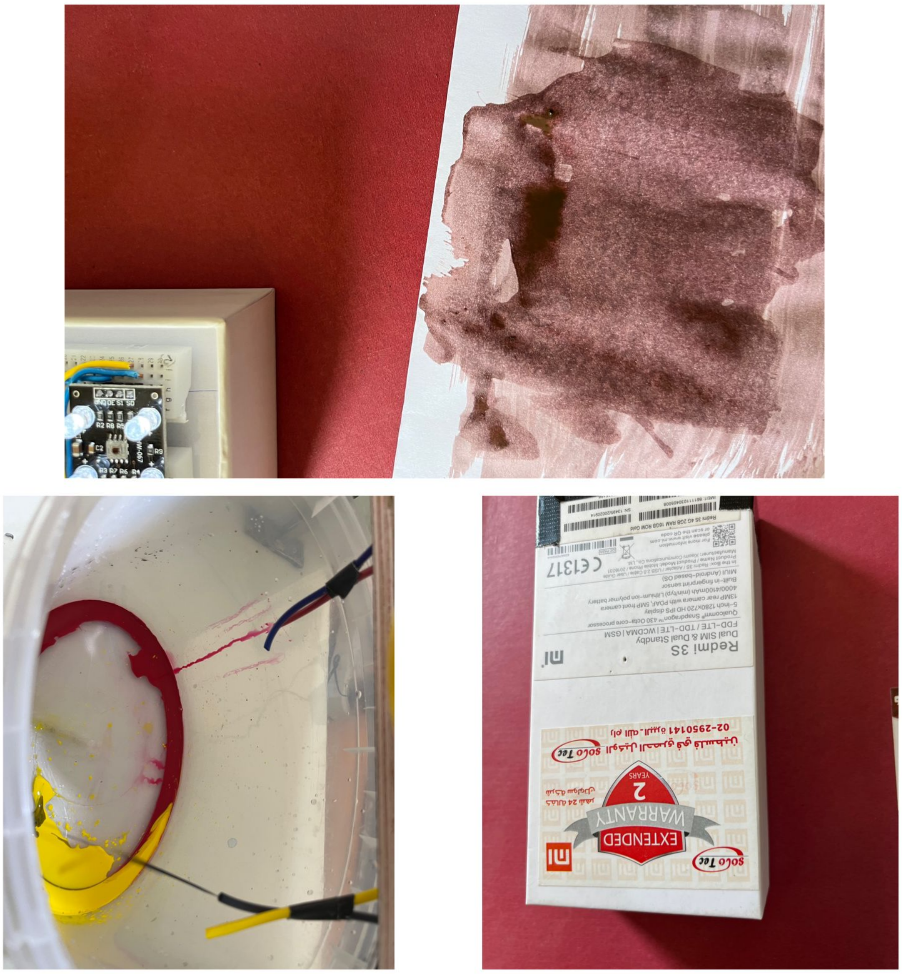


Figure 5.10: Testing of Machine - 2

5.4 System Validation

Once all project components were connected to both the hardware and software elements and integrated with MQTT, we proceeded to validate its operational mechanism and determine if it adhered to the optimal approach. This verification process was crucial in ensuring the desired outcomes and performance. Ultimately, the effectiveness of the project's functionality will be assessed and demonstrated during the presentation, providing an opportunity to evaluate the results achieved.

Chapter 6

Conclusions and Future Work

6.1 Conclusion

Our project aims to simplify the color mixing process and provide a straightforward way for users to achieve their desired color. We have successfully developed a machine that accurately determines the required color through an application. The color sensor readings appear on the application, and we linked it to the machine using the MQTT protocol. The machine then uses relays to mix the precise proportions of the primary colors specified by the ESP8266. Once the desired color is achieved, the machine completes the mixing process.

To improve machine performance within our budget, we made strategic component substitutions to achieve the highest possible level of accuracy.

6.2 Future Work

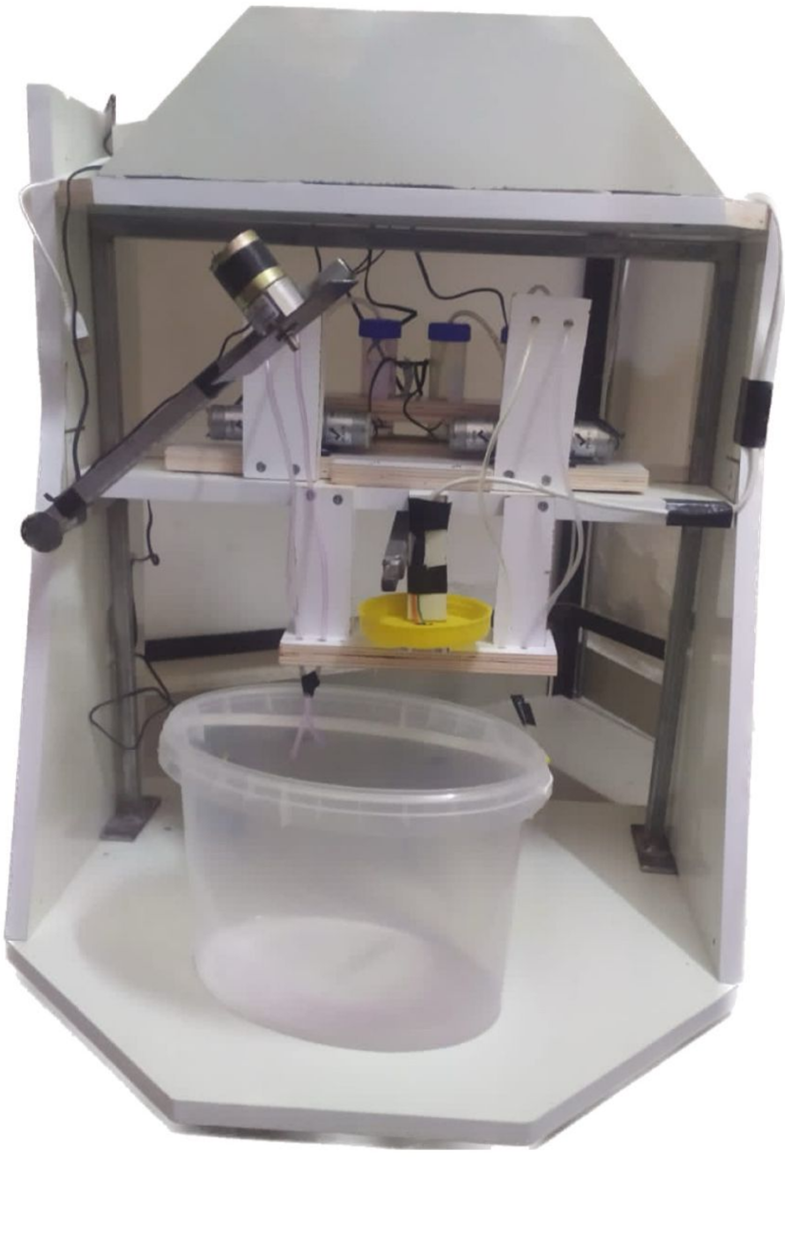
There are several features that can be added to this project to improve and enhance the machine. The following are some examples:

- Directing the machine towards a specific object and determining the required quantity by calculating the area.
- Using artificial intelligence to determine the most optimal ratios of primary colors and ensure higher accuracy.

- Expanding the scope of work and deploying a customer-specific application so that the customer can request a certain color with a specific quantity and receive a notification once the request is fulfilled.
- Providing the feature of reading the contents of the machine's application and interacting with it using voice to assist people with special needs.

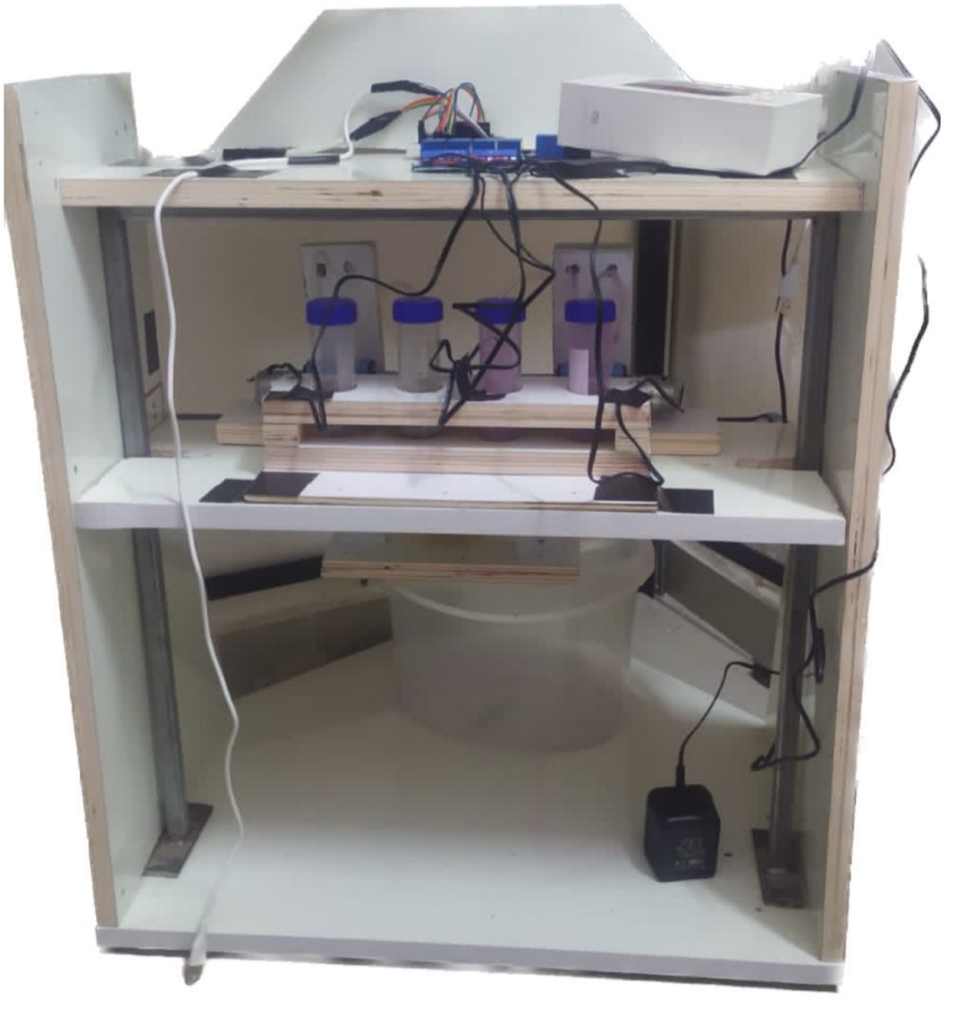
Appendix A

Front view of the machine



Appendix B

Rear view of the machine



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