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ECE 445 Proposal
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COLOR DETECTING AUTOMATIC PAINT DISPENSER

Introduction

Problem :

Whenever a painter starts a new project they always begin by mixing their desired colors on their palette using some combination of cyan, magenta, yellow, and black. However, the painter will inevitably run out of paint, and then will need to mix the exact color that they had before. Speaking from experience, this part of the process is very frustrating and time consuming, especially for artists that are bad at mixing colors. Rather than wasting time learning color theory, or buying the color you were using straight from the tube, we will save time and money by designing a machine that can determine the pigments required to mix any color using RGB sensors, and it will also mix it for you using a combination of primary colors so that you don't have to.

Solution :

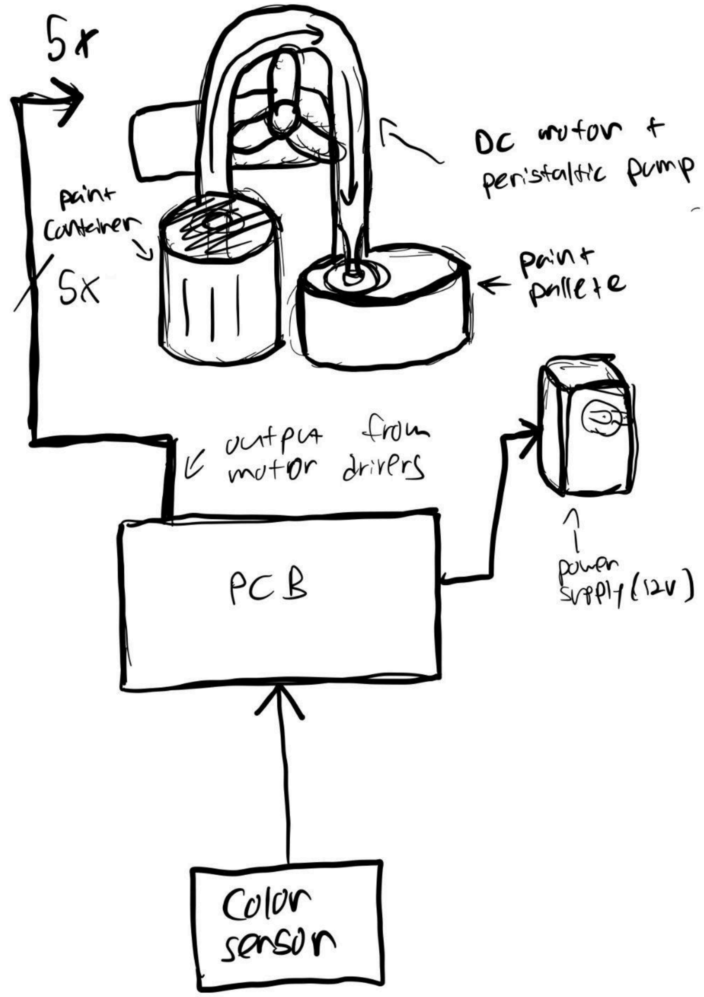
The user of the device will "scan" the desired color by using a color sensor that detects the RGB values of a surface using red, green, blue and 'clear' photodiodes. The device will send the RGB values of the color to the onboard mcu which will do some simple calculations to convert the RGB value of the color to CMYK format using conversion formulas. This is the same principle behind color printers which create color images by mixing cyan, magenta, yellow, and black. The mcu will then communicate with 5 motor drivers, each connected to a dc motor hooked up to a peristaltic pump. These will dispense the appropriate amount of white, cyan, magenta, yellow and black paint into a cup. The components will be powered by a 12 volt power supply with a voltage regulator and the final result should be a paint cup with the color that was scanned before. Ideally the person using this tool never needs to actually do any dispensing/experimenting, they can just scan a color and apply it directly on the canvas/work surface.

We would use fluid acrylics for this due to being extremely versatile and easy to work with and also easy to pump. The peristaltic pumps work by pumping a fluid from one reservoir through a silicon tube to another location. When pumping, the most important detail is the proportion of paint pumped as that will lead to the correct color. We plan to experiment with the pumps initially and calculate the dc motor time for the amount of paint pumped. We would then use the ratio we calculate in the microcontroller to get the adequate amount of time each specific motor needs to be turned on for each motor. The way a peristaltic pump works is that there is a roller that pinches a tube with the paint so it can dispense the paint. When the rotation stops, there is no drip or paint loss since the roller is still pinching the tube. In addition, the roller will dispense a fixed volume of paint each rotation.

There are 6 formulas used to convert RGB to CMYK (the model used in printers. Really these values are just proportions, suppose C is 0.5 and we want 100mL of white paint in the mixture, the amount of Cyan paint needed is 100mL of White * 0.5 = 50mL. We run the motor for x amount of time at some specific settings and see how much x mL of liquid gets dispensed. If the process ends up being too difficult with our acrylics then we will switch to a paint that is more watery.

- $R' = R/255$
- $G' = G/255$
- $B' = B/255$
- $K = 1-\max(R', G', B')$
- $C = (1-R'-K) / (1-K)$
- $M = (1-G'-K) / (1-K)$
- $Y = (1-B'-K) / (1-K)$

Visual Aid :

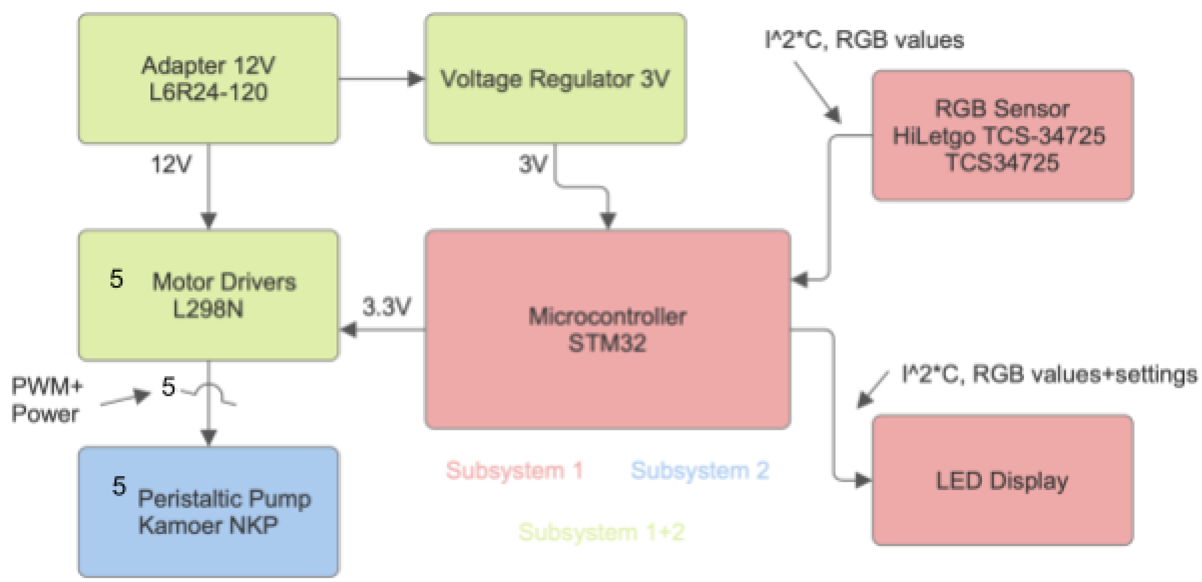

5x
DC motor +
peristaltic pump
paint
container
5x
paint
pallete
output from
motor drivers
power
supply (12V)
PCB
Color
sensor

High-level requirements list :

- Our first high level requirement is the color sensor accuracy, so how well it can detect the color that is provided. This is necessary to evaluate in order to ensure that the color detection is right so that we can dispense the desired color that was inputted. Our color sensor must be able to capture the precise RGB values of the inputted color for the overall project to work correctly.
  - The color sensor must have an accuracy of ±5% when detecting the RGB values of a surface. This means that when comparing the detected RGB values to a reference color, the deviation in each of the RGB values (R, G, and B) should not exceed 5% of the original input value. For example, if the sensor detects a color with RGB values (200, 150, 100), the acceptable margin of error would be within 5%, resulting in values between (190-210), (143-158), and (95-105) respectively.
- Our second high level requirement is motor precision, so that they can dispense the correct amount of paint to make the required color. We need to ensure that the motors respond correctly and are able to accurately dispense the paint so that we have the right ratio of colors to generate the desired color that was inputted.
- Our third high level requirement is overall accuracy of the colors, so how accurate the resulting color is compared to the original color that was inputted. We have to make sure that the project works correctly by putting the resulting color that was dispensed back into the RGB sensor and verifying that it matches the original color that was inputted. We will repeat this process multiple times to ensure consistency and accuracy.

Design

Block Diagram:



Subsystem 1 (Color Classifier) :

Materials:

- HiLetgo TCS-34725 TCS34725 RGB Light Color Sensor Colour Recognition Module RGB Color Sensor with IR filter and White LED for Arduino
- STM32 Series MCU
- 5 x L298N Motor Drive Controller Board DC Dual H-Bridge
- Custom pcb for Microcontroller management
- Standard button

- 12 volt power supply (L6R24-120)

The Color Classifier subsystem will have all the logic for the design. It will have a pcb that contains input from a color sensor and a microcontroller to process the input from the color sensor. This will all happen when a button is pressed and a high signal is sent. The motor drivers are also placed on the PCB to interface with the microcontroller to receive the processed signals once the color is processed. We will use a 12 volt power supply in order to power this system. A voltage regulator circuit will be used in order to get the voltage to the 3 volts needed for the microcontroller.

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- $R' = R/255$
- $G' = G/255$
- $B' = B/255$
- $K = 1-\max(R', G', B')$
- $C = (1-R'-K) / (1-K)$
- $M = (1-G'-K) / (1-K)$

- ❖ $Y = (1-B'-K) / (1-K)$

Next, the volume of paint for each primary color (cyan, magenta, yellow, black, and white) is determined based on these proportions. For example, if the desired volume is 100 mL, the amount of cyan paint would be:

Cyan Paint=100×C

This calculation is repeated for magenta, yellow, black, and white. If the cyan component C=0.5, then the system will dispense 50 mL of cyan paint.

Subsystem Requirement:

The high-level requirement for our subsystem is the accuracy of the color sensor, specifically its ability to detect and capture the exact RGB values of the provided color. Ensuring precise color detection is critical because the entire system depends on converting the scanned color into the correct proportions of cyan, magenta, yellow, black, and white for paint mixing. If the sensor inaccurately reads the color, the resulting mixture will not match the intended shade. Accurate color detection is essential for achieving the desired outcome.

- ➢ The color sensor must have an accuracy of ±5% when detecting the RGB values, so the detected RGB values to a reference color, the deviation in each of the RGB values (R, G, and B) should not exceed 5% of the original input value.

Subsystem 2 (Paint Dispenser) :

Materials:

- 5 x Low flow peristaltic pump 12V dc Kamoer NKP
- Custom 3d printed casing for holding pumps
  - Printing at idea lab / material to be used: PLA
- Wires for connections
- 3d printed reservoirs for paint
- 12 volt power supply (same one as Color Classifier subsystem)
- Silicon tubing for peristaltic pump + caps for ends of tubes

The Paint Dispenser will receive signals from color classifiers in order to pump the correct materials. The motors will drive the peristaltic pumps to pump the paint from the paint reservoirs into a central location centered around the 3d printed pump holder. The artist can put their palette in this area and mix around their colors once every paint needed for that color is dispensed.

To control the paint dispenser motors, we will use PWM to regulate the speed of the motors, which is directly proportional to the paint flow rate. The PWM duty cycle will determine how fast each motor rotates, and this can be adjusted dynamically based on the volume of paint required.

The motor speed is calculated based on the pump's flow rate, which can be measured experimentally (e.g., 10 mL per second at 100% duty cycle). To dispense the correct amount of paint, we will adjust the motor run time t as follows:

$$t = (\text{Desired Volume}/\text{Flow Rate}) \times \text{Duty Cycle}$$

For instance, if the desired volume is 50 mL and the flow rate is 10 mL per second at 100% duty cycle, the motor would need to run for 5 seconds.

We will also experiment with the optimal PWM duty cycle to ensure motor precision, likely operating in the 70-90% range for the best control without stalling or losing efficiency.

A low-flow peristaltic pump works by squeezing a flexible silicon tube with rollers, creating positive displacement that pushes the paint through the tube without any backflow. The rollers are attached to a rotating mechanism powered by a DC motor, which controls the flow rate.

Each rotation of the pump moves a fixed volume of fluid, which means the total volume dispensed is proportional to the number of rotations. This provides precision in controlling the amount of paint, and we will calibrate the system to determine the volume per rotation. This will be done by measuring how much paint is dispensed after each pump rotation under different conditions.

Subsystem requirement:

The second high-level requirement is motor precision, which is essential for dispensing the correct amount of paint to achieve the desired color. The DC motors must respond accurately to the calculated ratios, ensuring each primary color (cyan, magenta, yellow, black, and white) is dispensed in the right proportions. If the motors fail to dispense the exact amounts, the resulting color will deviate from what was inputted. Precise motor control is crucial to maintaining consistency in color mixing and ensuring that the final paint matches the user's expectations.

- ➢ If the motor dispenses 50 mL at 100% duty cycle, a 5% decrease in duty cycle could reduce the volume to 47.5 mL, which is still within acceptable error for most use cases. Since we have 5 motors and the error for each motor will add up, we expect <1% error per each motor in order to have < 5% total error.

Tolerance Analysis:

Motor Speed Tolerance: The flow rate of the peristaltic pump is affected by motor speed, which is controlled by PWM. Small variations in PWM can cause deviations in the volume dispensed. For instance, a 5% deviation in the PWM signal may result in ±5% variation in the amount of paint dispensed. If the motor dispenses 50 mL at 100% duty cycle, a 5% decrease in duty cycle could reduce the volume to 47.5 mL, which is still within acceptable error for most use cases. Since we have 5 motors and the error for each motor will add up, we expect <1% error per each motor in order to have < 5% total error. We will experimentally calibrate the system to find the optimal range for the PWM duty cycle to minimize this error.

Color Detection Tolerance: As mentioned earlier, the color sensor has a tolerance of ±5% in detecting RGB values. This tolerance means that slight variations in the detected color could result in small discrepancies in the final mixed paint color. For example, if the desired cyan component is 0.5, a 5% sensor error could lead to a value between 0.475 and 0.525, resulting in a variation of ±2.5 mL for a 100 mL mix. We will conduct repeated trials to determine if this tolerance level affects the overall paint mixing process.

By calibrating the system and considering these tolerances, we can ensure that the color mixing process remains accurate and consistent within an acceptable range of error.

Ethics And Safety

There are several ethical and safety concerns that need to be addressed. In terms of ethics, a primary concern is transparency by fully informing the users about the true capabilities and limitations of the color detecting automatic paint dispenser. For example, the limitation of the RGB to CMYK color conversion process is something that must be addressed as there can be scenarios where the inputted color and the resulting color do not match properly. According to the IEEE Code of Ethics, statements made about the accuracy of a product must have evidence of extensive testing and validation so that users are not misled. ACM's ethical guideline also highlights the importance of developing technology in the consumer's best interests while following proper design practices and techniques. Safety is also a big concern, given that there are electrical, mechanical, and chemical components in our project. The 12 volt power supply could pose risks such as short circuits or shocks if not insulated. Complying with the IEEE

Safety Standards and following their instructions regarding grounding and electronic protection will allow us to prevent any accidents. Precautions should be taken to prevent chemicals and paints from touching the user's skin and ventilation to prevent inhalation of harmful particles. Mechanical parts like dc motors and peristaltic pumps could pose physical risks if not properly enclosed. Improper disposal of paint waste could cause environmental harm, so it's essential to follow EPA guidelines for chemical disposal and ensure the project minimizes waste and contamination.