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Automated Wall Painting Robot for Mixing Colors based on Mobile Application

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Abstract: The final stage, which is the building paint or the adopted design, is where most real estate developers and constructors struggle. Where extensive painting is required, which takes a lot of time, effort, and accuracy from the firm doing the work. Additionally, it might be challenging to decide on the precise color grades for the design and calculate the right amount of paint to use for the job. Where these activities are extremely expensive, and the complex implementation is accompanied by worries and skepticism. These are the motivations behind the development of painting machines that blend colors. Artificial intelligence is used in the machine's design to make it efficient and quick at what it does. High accuracy is needed when selecting the proper colors, and this machine is distinguished by its ability to select the proper color tone. The color sensor (TCS34725 RGB) determines the relevance and accuracy of the desired color by comparison with the system database with the assistance of the light sensor (STM32), which measures the degree of illumination of the chosen place. By combining basic colors, this technique saves the customer the hassle of looking at specialized stores for the level of color they require. By giving the system the codes assigned to each color, it may also blend colors. The system also has the feature of controlling the machine remotely via smart phone application by enabling bluetooth and wifi features.

Index Terms: TCS34725 RGB; STM32; Bluetooth; Wi-Fi; Artificial intelligence

1. Introduction

Urban development and final design and also the process of choosing colors is one of the most problems faced by real estate developers and contractors, and according to the Occupational Safety and Health Administration, 20.5% of worker deaths occurred in buildings under construction in 2019 [1,2,3]. in addition, there is great difficulty in choosing the right color, as well as searching for it in the local markets, and the demand from international markets takes longer until it reaches the project site. as these works cost huge amounts of money and more time amid concerns and doubts about the accuracy of implementation. Which is the main reason for choosing the painting machine with mixing colors.

Urban growth and increased costs in the use of manpower to paint and provide the appropriate colors for buildings on time. This makes it costly for property developers and property owners. Many ideas and advantages have been put forward, which have some limitations and advantages. But not in the framework of the desired results. It makes this project important which it helps reduce the time of the painting process by 30% and the amount of cost up to 50%, according to studies that have been done on many real estate developers and real estate owners. Furthermore, with the lack of a machine that combines mixing colors based on the desire of the developers and owners at the work site, as well as its ability to paint the building automatically using smart phones remotely, which makes it more important at the present time.

The main purpose of this work is to review the existing works, gaps, and inconsistencies related to the painting machine and propose a mechanism to design and implement a Painting Machine with Mixing Colors using the latest technologies and control it through smart phone applications.

The following are the outcomes of this work:

(i) To Create a smartphone application that will connect to an Arduino Mega and allow for remote operation of a painting machine.

(ii) To paint precisely, the painting machine's movement needs to be oriented using two stepper motors in four directions.

(iii) To obtain the correct color with excellent accuracy, the TCS34725 RGB Color Sensor and STM32 Light Sensor must be interfaced with the Arduino Mega.

All buildings under construction, as well as buildings that need to change the color of the paint, such as buildings, homes, schools, colleges, universities, and companies.

This paper is organized as follows: The background, aim, objectives, and applications of the project are included in the first section of the work that is being presented; the project methodology is included in the second section; literature review and theory are included in the third section; and design and analysis, which includes system analysis, requirements analysis, system design, system test plan, and the conclusion, are included in the final section.

2. Methodology

The following are some of them given that the methodology is a set of fundamental strategies for finishing the project, that it includes numerous methods for studying the project for it to be developed in a proper manner, that it helps with project control and management, and that the project's importance is divided into several categories: - Creating project specs

- Offering a workable strategy.
- Dispensing information at a specific time.
- Designing a system that is dependable, well-thought-out, and simple to manage.

The methodology that has been adapted in this work is waterfall methodology. The waterfall model will be used in this project because it is straightforward to implement, has an easy-to-understand concept, and has stages that can be finished independently of one another while the first stage is still being finished. This allows the project to be implemented correctly, successfully, and without gaps. Points can be easily added to each step as well. In contrast to the spiral model, this one is more expensive for small projects to implement, complex, and has multiple interconnected stages. Fig. 1 shows the steps implemented in waterfall methodology. The waterfall method's primary goal is to gather and clarify all requirements upfront, preventing development from going 'downhill' without the ability to make changes. Hence, this methodology facilitates to achieve the research objectives easily.

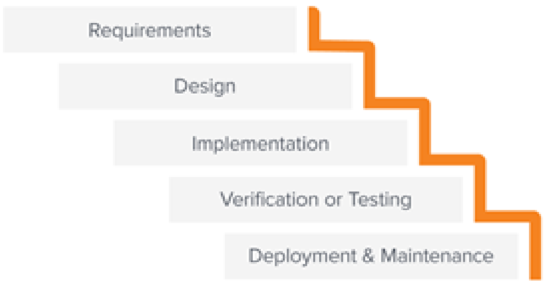


Fig. 1 Waterfall Methdology

3. Literature Review

A modular wall-painting robot (WPR) has been demonstrated in [3] and shown in Fig. 2 with a built-in remote control for use in potentially dangerous environments. The mechanical system was designed and created using materials that could be found around. The setup includes steel for the robot's frame, wood for the arm, a wastewater dispenser bottle for the paint reservoir, 12V and 24V DC electric motors, a surface pump (0.5 hp), hose, tires, and rollers, as well as a micro-controller unit, cables, and the bottom frame. When the robotic arm is in use, a pump that raises the paint at regular intervals while executing the reciprocating up and down motion feeds the roller. To automate and synchronize the setup, a programmable microcontroller was used. The robot's performance was evaluated using the conventional metric system as outstanding. The research is limited in terms of repeatability and precision during the painting process because of the arm's dexterity. More research can be done on the arm's control. The research's distinctive elements include the recycling of waste plastic water dispenser bottles as paint reservoirs, light wood for the robot's upper and lower arms, a DC motor from a wrecked Benz automobile as a programmed stepper, and waste tubeless tires from disused trolleys as tires for the WPR. Oil and gas infrastructure and equipment can be painted in small spaces using the developed method. It will reduce the amount of time needed to accomplish the task, lower labor expenses significantly, eliminate any potential health hazards, and enhance dependability, productivity, and surface finishes. The outcome of this investigation is distinctive, durable, and advantageous to the environment. It has been demonstrated that turning trash into useful robots is feasible in the era of Industry 4.0 [4,5,6].

Fig. 2. WPR

An autonomous wall painting robot [5] as shown in Fig.3 that can use a paint sprayer and a cascade lift mechanism to paint the interior walls of a room. This cascade lift system enables the paint sprayer to ascend to the required heights. Easy movement in all six directions with two degrees of freedom is made possible by the wheels with DC motors attached to the robot's base (degrees of freedom). The robot uses ultrasonic sensors to gauge its distance from the walls, adjust to them, and check to see if the sprayer has reached their tops. The master controller manages the ultrasonic sensors, wheels, and every other component of the robot. The autonomous wall-painting robot was implemented using a prototype version of the robot. The base and the cascade lift were combined to create it. Four wheels are attached to a wooden box that serves as the basis. Ultrasonic sensors are placed in the proper locations to measure the separation from the wall. The cascade lift, which is attached to the front portion of the base, has a paint sprayer holder that the paint sprayer is placed inside of. The lift was built by Cascade using aluminum profiles that were 4x4 and 2x2 in size. It consists of a single-stage lift that moves the paint sprayer up and down with the help of a DC motor attached to the top of the wooden box. The lift motor raises the sprayer by advancing the load's rope through a pulley. A second ultrasonic sensor in the sprayer's front part detects and maintains a constant distance between the robot and the front wall. The master controller for this prototype is a Raspberry Pi 3 powered by an SMPS [5-8].

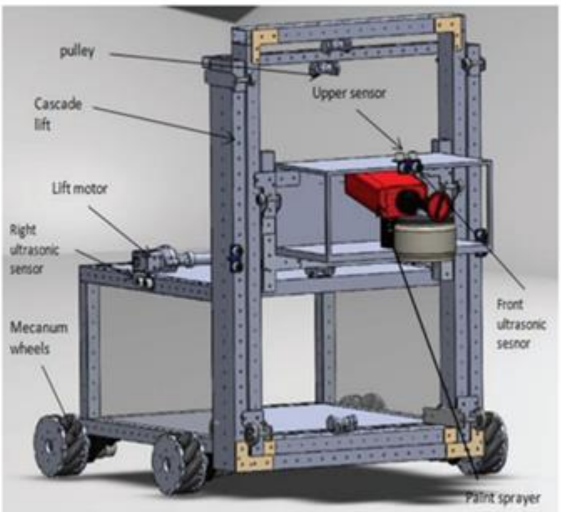


Fig. 3. Autonomous Wall Painting Robot

The development of an automatic wall painting machine prototype is described in this work. The prototype is controlled by the user's input of the wall's dimensions and paint color via a camera embedded Raspberry Pi 2 module. The Raspberry Pi Module gathers the wall image and utilizes image processing tools to calculate the dimensions, which it then transmits through Bluetooth transfer to the base painter system. The mechanical design comprises of a 2-D plotter with a painting joint connected to a line-by-line moving DCV (Directional Control Valve) spray paint. Two Nema 17 stepper motors power the plotter, which is managed by an STM32 slave controller that gets the dimensions from a Bluetooth module. Everything in the system is powered by a double shaft Nema 23 stepper motor [9,10,11].

Fig. 4. AGWallP

The camera module is attached to the Raspberry Pi 3 module. The user specifies the color to be painted on the wall, which is also the subject of the photograph. The foundation wall painting system, where steppers and spray systems work in tandem, is another component where electronics are used. An IoT (Internet of Things) system with Raspberry Pi units on either side of the setup was considered before utilizing the Bluetooth technology. The systems would be connected via a shared network, but this proved to be too expensive and beyond the scope of the project's goal. Finally, it was decided to build up a Bluetooth connection between the distant user and the painting system. The slave controller STM32F103C8T6, a 32-bit cortex-M3 microcontroller, is incorporated in the base painting station, as is the Bluetooth module HC-05 transceiver. The main rationale for selecting the controller was to obtain a less expensive but more powerful controller. Furthermore, because the STM32 controller has a huge online support community, it is easy to troubleshoot and debug any faults that occur during programming [12-15].

The detailed computer-aided design (CAD) model of a fully working wall painting robot for interior finishes is shown in this study. In addition to beautiful wall drawings, the RoboPainter can paint full-scale wall-ceiling murals. A DOF spray painting arm is installed on a DOF differentially driven mobile base in these degrees of freedom (DOF) mobile robot system. In comparison to previous literature, the design proposed achieves numerous accomplishments in terms of overall robot mass and painting pace. To enable for further improvement in terms of robot motion control, detailed dynamic model parameters are supplied. Fig. 5 shows robo painter

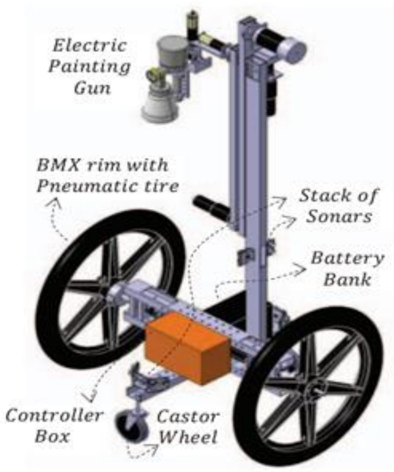


Fig. 5. RoboPainter

The designed technical data for the RoboPainter is a DOF mobile painting robot. A spray painting pistol is at the end of the painting arm. Thanks to the arm tip's generic fixation assembly, a variety of commercially available painting guns can be mounted to it; for example, see for sprayers that use 220 volte mains electricity and for those that use 110 volte mains electricity. It was designed with the intention of using off-the-shelf components to reduce development time and allow for easy, quick component replacement in the event of failure. RoboPainter's joints are controlled by ESCON servo controllers and Maxon DC-geared motors, all of which are equipped with position encoders. Despite the painting arm's considerable reach (1.29 m), its lateral motion is limited to the breadth of two paint strips in either direction from the robot centerline. The wall is separated into two pieces during the motion planning phase of the spray-gun path: the core and the outline sections. In the core section painting, the maximum permissible painting workspace per fixed mobile base post. The goal of such a constraint is twofold. By reducing the volume of space occupied by the robot structure, it improves human-robot safety. In an average of 10 seconds, the painting arm can deliver a strip of paint measuring 0.25 m wide by 2.45 m high.

Table 1. Comparision of existing approaches

Reference	Concepts, approach, methods, and analysis,	Inconsistencies, gaps, contradictions, differences	Improvements
[3]	The bottom of the paint reservoir has a pipe network added to let paint flow out onto the roller. The robotic arm's top and lower arms are connected by a joint. A junction is built into one end of the lower arm, which is attached to a motor pinned to the bottom frame, and a motor is inserted into the other end, where the upper arm is attached. This arrangement makes sure that the paint is distributed evenly as it flows from the reservoir onto the roller.	- There is no barrier or object collision prevention feature. - It takes longer to change the color or look for it in the market because the painting procedure is done in a tank.	- Including an ultrasonic device to gauge the distance to any adjacent objects to avoid collisions or to change the device's course. - It utilizes the ability to change the color of the paint while combining colors using a unique formula, which saves time and resources.
[5]	The cascade lift and the base merged. Four wheels are attached to a wooden box that serves as the basis. To calculate the distance from the wall, ultrasonic sensors are placed in the proper locations. A DC motor helps the hoist move the paint sprayer while pushing it up and down. The master controller for this prototype is a Raspberry Pi 3 powered by an SMPS.	The mechanical construction employed is heavy and bulky, requiring more energy to operate and costing more money. It lacks the ability to travel in different directions and the challenge of moving to cover the entire wall.	- Using a fiber-based structure results in a lighter product with lower energy and manufacturing costs. - It moves easily in 6 distinct directions—up, down, forward, backward, left, and right—using a motor that is controlled by the phone.
[7]	The user's input of the wall's dimensions and paint color using a Raspberry Pi 2 module with a built-in camera. The Raspberry Pi calculates the dimensions using its image processing capabilities before Bluetooth those results to a device. A 2-D plotter with a painting joint and a DCV spray paint that moves line by line from one location to another make up the mechanical structure. The is run by an STM32 slave controller and is powered by two stepper motors.	Using a camera to capture the color of the wall and connecting it to the Raspberry using Bluetooth because it is difficult to accurately assess the color due to the site's lighting, the camera's accuracy, and the angle of capture	Using the light sensor and the color determination sensor, which transmits analog signals to the Arduino and compares them gradually to a database that contains more than 250 colors to determine the color with high accuracy and display it on a phone application by sending data via Wi-Fi and Bluetooth.
[7]	The painting arm's tip is a spray-painting gun. ESCON servo controllers and Maxon DC-geared motors control the joints of the Rob Painter. The wall is divided into two areas during the motion planning stage of the spray-gun path: the core and the outline sections. The painting arm can provide a strip of paint 0.25 m wide by 2.45 m high in an average of 10 seconds.	Because there are just three wheels being used to move the device, there are some limitations to its mobility, which affects the accuracy of the coating because it cannot move smoothly.	The use of four wheels aids in the device's equilibrium and aids in drawing the wall by calculating the site's area using an unique equation while movement.

4. Design and Analysis

Details on the proposed system are included in this part, along with information on the painting machine with color-mixing capabilities using a mobile application. The project's planned system is shown in the schematic design, while the many project components covered in this part are shown in Fig. 6.

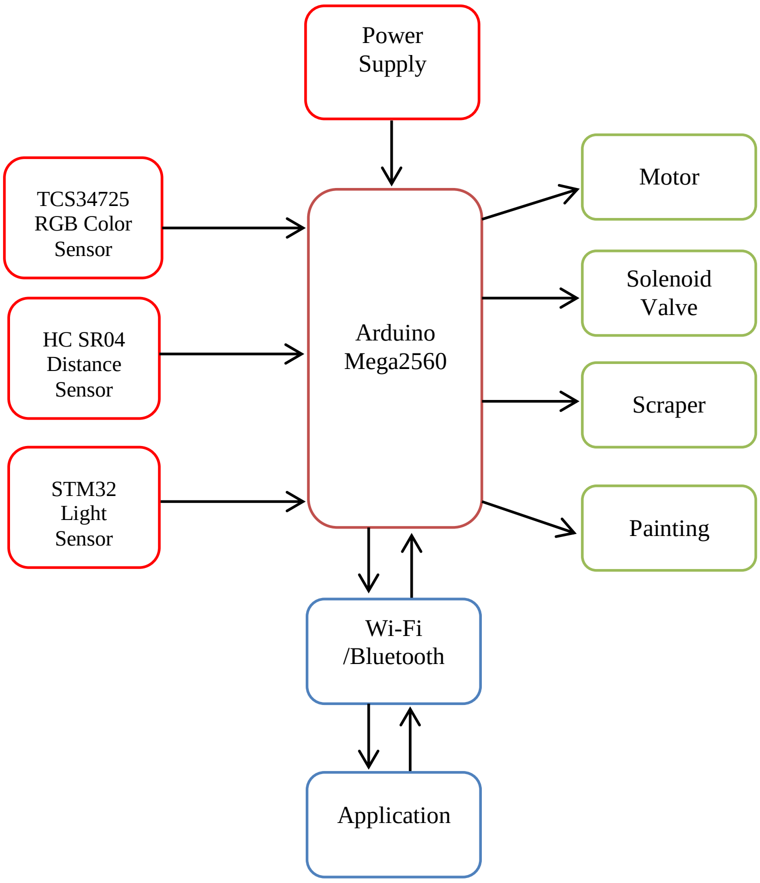


Fig. 6. Block diagram of the proposed work

Functions

Power Supply: is an equipment that changes ac power into dc output. to run the electrical circuit that powers all the project's machinery.

TCS34725 RGB Color Sensor: This sensor functions to recognize and distinguish between colors, translate them into a code, and transmit them to the controller.

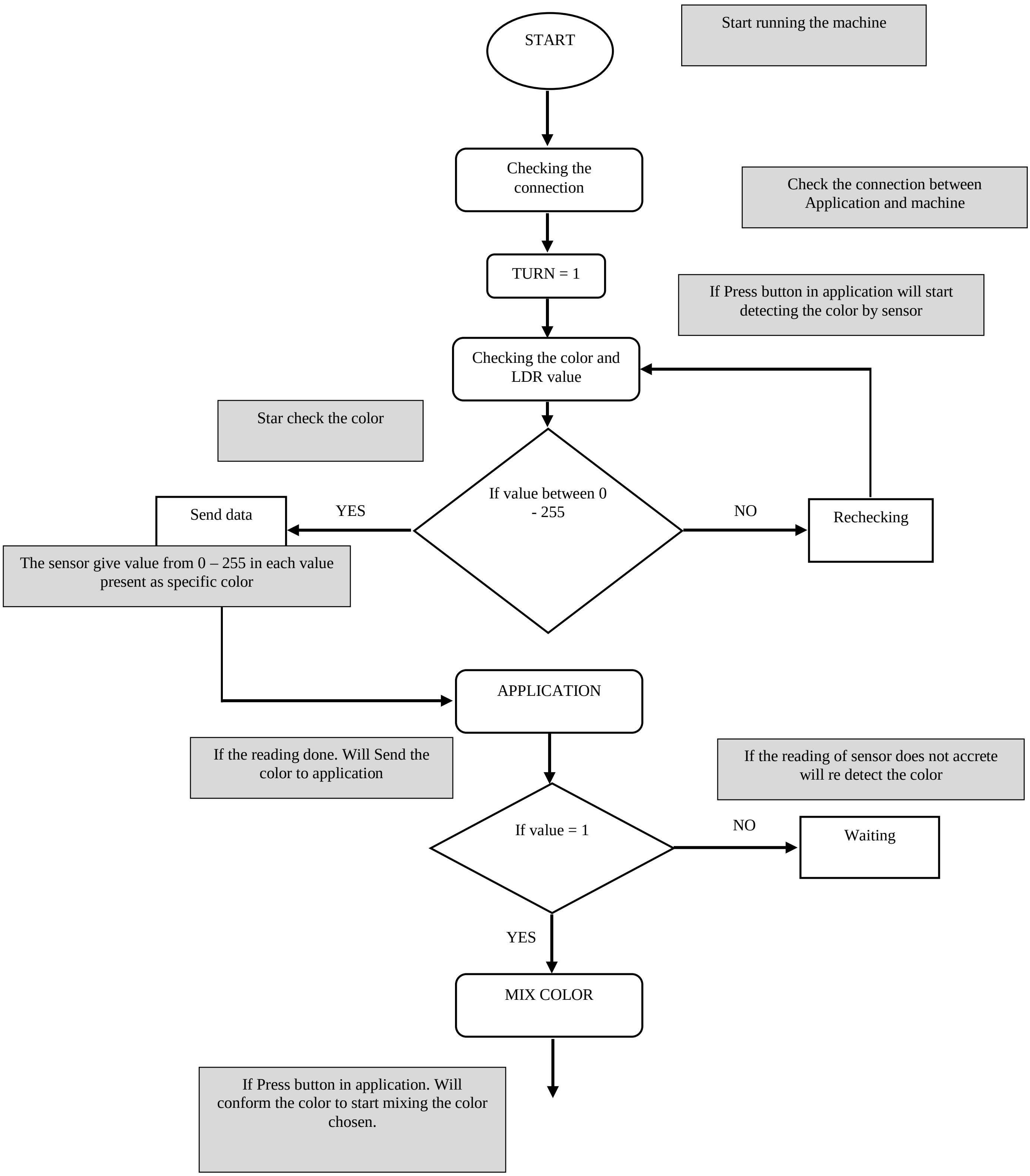
HC SR04 Distance Sensor: works to establish the separation between any item and the project to avoid any collisions.

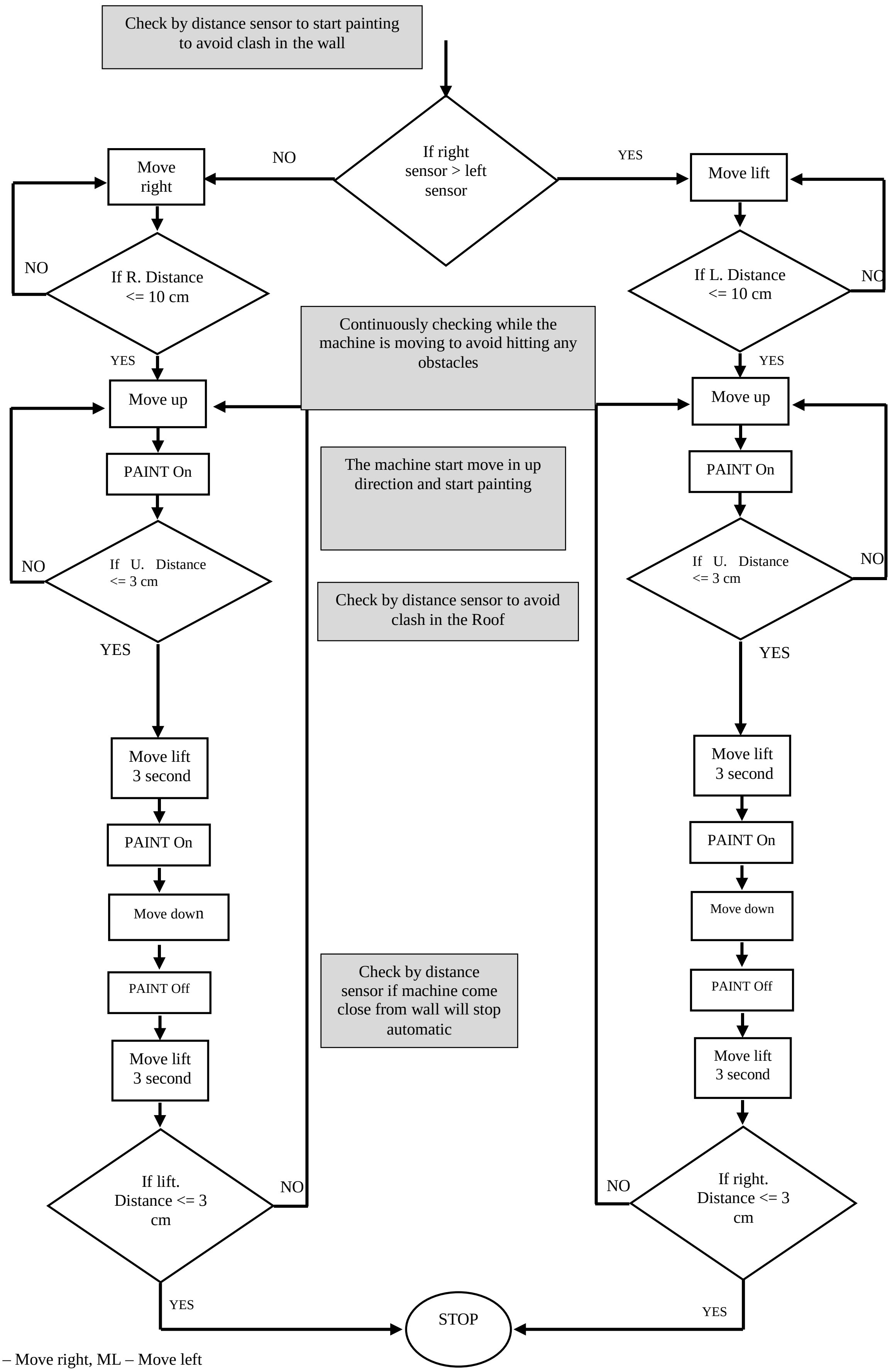
STM32 Light Sensor: It is useful to be aware of the site's lighting intensity to determine the proper level of color.

Application: An application in smart phones that works to receive data and compare it to Database. establishes the proper volume, pace, workplace, and project management. and use Wi-Fi and Bluetooth to transmit data to the controller.

Scraper: a device for removing the uneven wall layer to obtain a dye devoid of flaws and fissures.

Flowchart: The connection between the program and the machine is checked. Next, a sensor reads the colors (depends on the value from 0 - 255). After that, the color is confirmed, and the data is sent to the program. The color is confirmed by pressing a button in the program. To complete the process of mixing colors to obtain the chosen colors. the machine moves according to the side to be painted, considering the presence of a sensor that prevents it from colliding with the wall, the paint starts, and the machine moves from the top to the bottom, then to the right or left (according to the specified direction) in a small degree and moves again down to the top and so on. Fig.7 shows the flowchart of the proposed work.


START
Start running the machine
Checking the connection
Check the connection between Application and machine
TURN = 1
If Press button in application will start detecting the color by sensor
Checking the color and LDR value
Star check the color
If value between 0 - 255
YES
NO
Send data
Rechecking
The sensor give value from 0 – 255 in each value present as specific color
APPLICATION
If the reading done. Will Send the color to application
If the reading of sensor does not accrete will re detect the color
If value = 1
NO
Waiting
YES
MIX COLOR
If Press button in application. Will conform the color to start mixing the color chosen.



MR – Move right, ML – Move left

Fig. 7. Proposed flowchart

5. Circuit Design

The section is divided into three subsections. First section discusses about the schematic diagram. The second section will be discussing about the test points and finally, developing test plans will be discussed.

A. Schematic diagram of the proposed work

Fig. 8 shows the schematic diagram of the proposed work. The circuit simulation is done in proteus software tool as shown in Fig. 12 where the painting colours are assumed as red, white, blue, green, black .

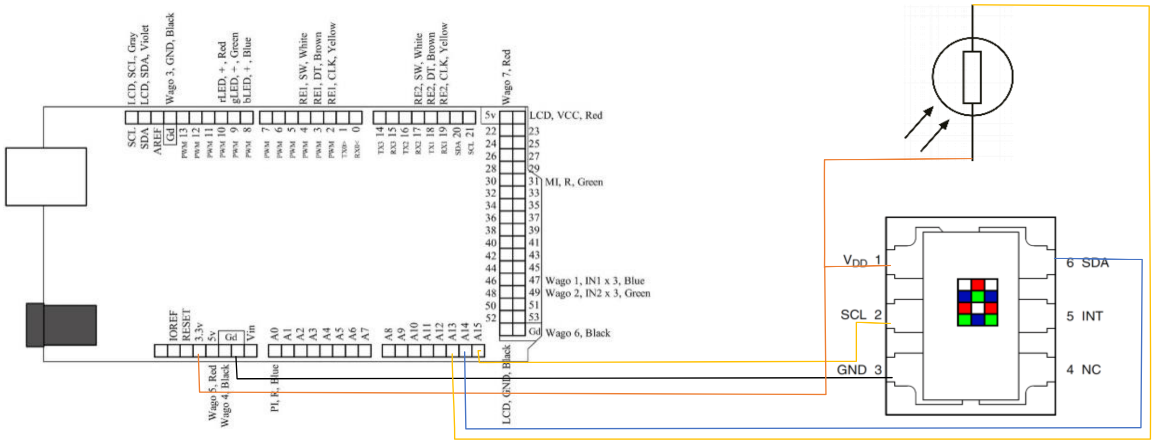


Fig. 8. Schematic diagram of the proposed work

1- The color sensor and the light sensor use the Arduino, which contains a database for each color, to decide the proper color by passing analog signals and numbers to it. After that, the controller uses Wi-Fi to transmit the data to the mobile application for the customer to view. He can choose the proper color through it if he knows the color code or needs to seek a change.

Fig. 9. Color Code

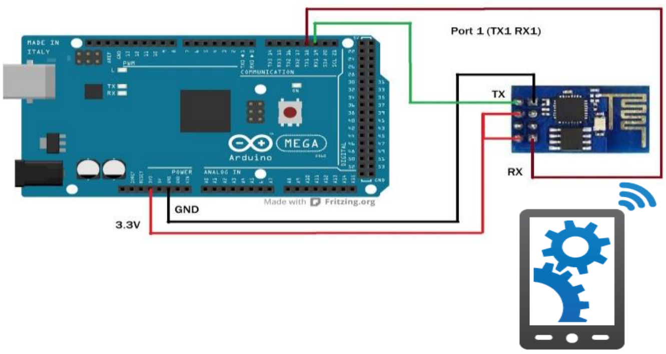


Fig. 10. Circuit Diagram

2- Following the method for determining color. It is controlled by a smartphone app, and data is sent to the Arduino through Bluetooth or Wi-Fi. Using the solenoid valve, which regulates the output of the quantities of colors to obtain the desired color, to begin the process of combining the fundamental colors based on the color selected. Additionally, based on the region, directing the motors and the machine's movement in the right, left, up, and down directions.

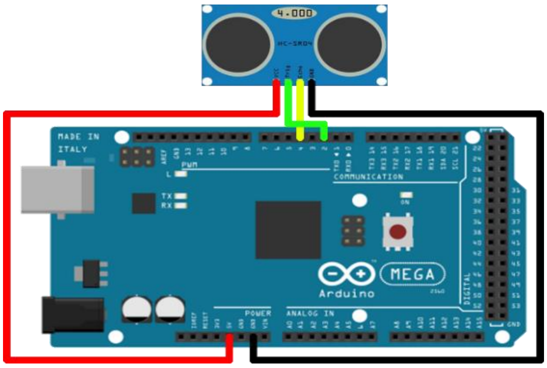


Fig. 11. Circuit diagram 2

3. Check for any objects that can stop the machine from moving or functioning properly by using the distance sensor (). by measuring the distance between the machine and a wall or other object and transferring data from the sensor to the Arduino. It operates to promptly stop the machine or reverse its direction of movement depending on the location if any object is found nearby.

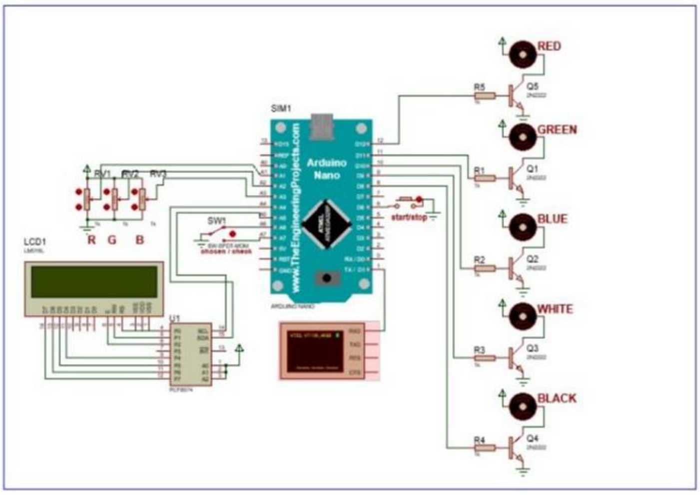


Fig. 12. Automated wall painting robot circuit simulation in proteus

B. Identifying Test Points

The test requires two parts:

Part One: Software

Arduino programming: A special program is used for the Arduino (Arduino IDE) to program it to receive signals from the sensors, process them and output them in different ways based on the code.

Programming an application: that receives, sends, and processes data and connected to Arduino via Bluetooth and Wi-Fi.

- Check the operation of the program and its connection.
- Checking the code in line with the goals set for the project.
- Test receiving and sending data to the Arduino.

Part Two: Hardware

Connect all devices to the Arduino through specific ports based on the code used, connect them correctly, and experience the operation of each device to ensure that the project works accurately.

- Test the inputs and outputs of the Arduino according to the project.
- Connect the devices to the Arduino and feed them to the appropriate source.
- Determining measurements and calculations based on signals from sensors to ensure accurate implementation.

C. Developing Test Plans

The testing phase of the project necessitates the use of tools such as the test Arduino program and the requirement to build the software. The check program makes program measurements to the three sensors in addition, internet connection piece (ESP8266) makes the app and requires Wi-Fi hotspot.

Input Project:

- Measurement of the LDR sensor alone.
- Measurement of the TCS34725 sensor alone.
- Measurement of the HC SR04 sensor alone.
- Power Supply for each device.

Output Project:

- Supporting devices with a power source to obtain higher efficiency of the device.
- Check the project with a high-speed internet connection. Addressing the delay in sending and receiving data.

6. Conclusion

Most real estate developers and contractors struggle at the end stage, which is the building paint or the adopted design. Where large areas are painted and require high accuracy, great effort and a longer time from the executing company. Also, the difficulty of choosing the specific color grades for the design and knowing the appropriate amount of paint for the project. Where it costs huge amounts of money for these works, amid fears and doubts about the elaborate implementation. These are the reasons behind making painting machine with mixing colors. The machine is designed to be fast and proficient in its work using artificial intelligence. The process of choosing the right colors requires high accuracy, and this machine is characterized by the feature of choosing the appropriate color tone. The robot was developed to meet the desire for a quicker, less strenuous painting process. The system is automated using an Arduino microcontroller, which is programmable. The production process will be substantially simplified as a result. Additionally, it would end human involvement in operations, removing the risks and hazards associated with painting. Finally, because of the system's high level of precision, the created robot will speed up production while enhancing surface smoothness. And make it easier to choose the appropriate hue. The proposed robot might play a significant role in humans if it were to be scaled up and dared to go where people cannot. It can be managed using a phone app. Finally, metrics for correct setup evaluation were used to put the built robot to the test. The research can be extended by connecting ultrasonic sensors that can be used as a powerful technique for obstacle identification and avoidance.

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