Al-Najah National University

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Graduation Project

Henna Machine

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2 Disclaimer

Salam Younis and Roaa Qino from An-Najah National University's Faculty of Engineering's Computer Engineering Department authored this study. Other than editorial adjustments, it has not been amended or rectified as a consequence of assessment, and it may contain language and content mistakes.
The opinions represented in it, as well as any results and recommendations, are exclusively those of the students Salam and Roaa. An-Najah National University assumes no responsibility or liability for the outcomes of using this study for a purpose other than what it was commissioned for.

3 Abstract

Henna has been used for ages in many parts of the world. It is a traditional art form with deep cultural importance. The Automated Henna Machine is a project that aims to honor the beauty and legacy of henna art while bringing it into the current day through technology innovation.

In order to create exact and automated henna patterns on the human hand, the proposed project intends to develop and build a unique hardware henna application machine that makes use of CNC technology and a syringe pump mechanism. Our technology aims to modernize and improve this procedure while maintaining the aesthetic element of henna application, a traditional art form that demands great accuracy and control.

The key elements of our CNC machine's design include Stepper Motors that will serve as the powerhouse behind our CNC machine also We have chosen M8 Bearing Rods for their robustness and ability to provide smooth and stable linear motion with GT2 belts which are known for their exceptional accuracy and reliability in transmitting motion ,by combining these components, we aim to create a CNC machine that excels in precision, stability, and overall performance.

Our project employs a specialized mechanism using raspberry pi camera to capture precise hand dimensions, which are then processed by a micro-controller to generate X and Y coordinates. These coordinates are seamlessly transmitted to our CNC system, which uses stepper motors and motion control software to execute the henna drawing process.

Additionally, we provide a mobile app that enables consumers to choose or alter henna patterns according to their preferences,and then easily send the design data to our CNC system for usage.

4 Introduction

Henna has been used for ages in many different regions of the world as a highly esteemed traditional art form with profound cultural value. The Automated Henna Machine idea embraces technical innovation for modern applications while paying tribute to the elegance and tradition of henna art.

4.1 General background

Henna body art has a long and storied history, originating in traditional practices. This creative medium has been handed down through the ages, capturing the richness and diversity of cultures. The Automated Henna Machine is the result of a special chance to combine this age-old craft with cutting-edge technology in the present day.

4.2 Objective

The primary objectives of the Automated Henna Machine project are multifaceted, aiming to introduce efficiency, accessibility, and creative empowerment into the traditional henna application process. These objectives include:

1-Automated Precision: Create a hardware application that uses a syringe pump mechanism and CNC technology to improve precision and control over the laborious process of drawing henna designs by hand.

2-Reduction in Application Time:Significantly reduce the time required for henna application compared to traditional methods.

3- Creative Empowerment: Offer a user-friendly mobile application to customers so they may personalize henna designs to suit their own tastes.

4.3 Significance

The Automated Henna Machine project is significant because it is revolutionizing the use of henna in traditional applications. The concept modernizes this traditional art form by cutting down on application time and simplifying the procedure. Most importantly, it removes the requirement for specialist knowledge and makes accessibility available to a larger audience. The initiative takes into account the modern needs for efficiency and personalization while maintaining the traditional significance of henna art and enabling people to exercise creative freedom. In today's ever-evolving cultural scene, the harmonic fusion of tradition and innovation guarantees that henna art will always be current, approachable, and deeply expressive.

4.4 Report Organization

In general, the structure of the report is divided into the following chapters:

The secondary chapter will begin with constraints, standards, and codes before focusing on the earlier coursework used for the project and the primary difficulties encountered.

Followed by a chapter on Literature Review, which highlights similar projects to ours.

Next, a description of each component utilized in hardware design, project flow, and the development process throughout the project will be covered in the methodology chapter.

The challenges we overcome and the successes we attained will be described in the following chapter (results and discussion).

Finally, we will conclude with some recommendations and some coming plans for future work.

5 Constraints, Standards and Earlier coursework

5.1 Standards

Respecting pertinent technical standards is essential to the construction and design of the Automated Henna Machine in order to guarantee compatibility, functionality, and safety. In this project, the following guidelines and requirements are taken into account:

- CNC Standards: To guarantee compatibility with current CNC technology, the design takes into account standards pertaining to Computer Numerical Control (CNC) systems. Adherence to industry standards for CNC ensures accuracy in both motion control and machining operations.
- Electrical Standards: The safety and dependability of the electrical parts utilized in the CNC machine are guaranteed by adherence to electrical standards, such as those established by the Institute of Electrical and Electronics Engineers (IEEE). This covers electromagnetic compatibility, power distribution, and wiring standards.
- Mechanical Standards: The project complies with standards for mechanical engineering,The choice of materials, structural integrity, and adherence to accepted standards for mechanical components are all taken into account.

5.2 Constraints

- Dealing with python language.
- The lack of knowledge of dealing with Raspberry Pi.
- The parts are sensitive and spoil quickly.
- The project must operate within budget limitations.

5.3 Earlier coursework

We are required to take a few courses that are essential for advancing our expertise and completing this project.

- PIC and Arduino Lab.
- wireless course.
- Arduino course.
- Online Raspberry Pi course.
- Online python course .

6 LITERATURE REVIEW

Around the world, henna has a deep cultural and historical importance. Traditionally, henna is applied to the skin by trained workers who use needles or cones to create complex patterns. This age-old artistic expression, which represents creativity and identity, has its roots in traditional rites and celebrations.

For many years, the most common way to apply henna has been by hand, this process requires accuracy and skill. An increasing number of people are interested in incorporating automation into traditional art forms as technology develops. In line with this trend, the Automated Henna Machine project uses CNC technology to update the henna application procedure.

Several industries have witnessed success with the incorporation of CNC technology into artistic pursuits. CNC machines provide a high degree of accuracy and control since they are driven by stepper motors and accurate mechanical parts. The Automated Henna Machine's design features—which include Stepper Motors, M8 Bearing Rods, and GT2 belts—showcase a dedication to attaining accuracy, dependability, and overall performance.

Beyond just hardware, the project includes a customized mechanism that captures hand dimensions precisely with a Raspberry Pi camera. Including a smartphone app improves user engagement. This is in line with current developments , which place a strong emphasis on user-friendly interfaces and seamless data transfer.

7 Methodology

7.1 Hardware parts :

7.1.1 Overview

Here we will talk about hardware components we used :

- Arduino Uno.
- Raspberry Pi 4 model B .
- RASPBERRY Pi camera module.
- Stepper motors.
- Connecting wires.
- Sg90 servo motor.
- IR sensor.
- Battery.
- a4988 stepper motor driver.
- Linear bearing rod M8 x 350mm.
- GT2 Pulley 16 teeth.
- GT2 belt.

7.1.2 Description

In this section we will talk about each of the hardware components used:

1. Controllers

   - Arduino Uno

     The Arduino Uno features 14 digital input/output pins and 6 analog input pins. The number of bins typically refers to the number of digital pins available for connecting and controlling devices, while the analog input pins are used for interfacing with sensors and reading analog signals.

     it facilitates precise control over the intricate movements of the CNC system, ensuring the accurate application of henna patterns[1]

Figure 1: Arduino Uno

   - Raspberry Pi 4 model B

     The newest model under the Raspberry Pi name in the computer category is the Raspberry Pi 4 Model B. Multimedia performance, memory, and connectivity have all considerably improved, as has the processing speed. These enhancements are observed in comparison to the previous generation's Raspberry Pi 3 model B+.: [2]

     It is noteworthy that, in terms of end-user experience, the new Raspberry Pi 4 Model B's performance is on par with an entry-level x86 machine. Some of the most important features of the most recent Raspberry Pi computer are as follows:

     (a) a powerful 64-bit quad-core processor.

(b) There are two micro-HDMI ports that support up to two 4K resolution displays.

(c) Up to 4Kp60 video decoding in hardware

(d) RAM in the amount of 4 GB

The Raspberry Pi 4 Model B, equipped with a camera module, captures hand dimensions for the Henna Machine. Using specialized algorithms, it processes the data to generate precise X and Y coordinates, facilitating accurate Gcode creation for the CNC system.

Figure 2: Raspberry-pi-4

2. Sensors

- IR sensor
  Photodiodes and infrared (IR) LEDs make up the infrared (IR) sensors. The IR photodiode is referred to as a receiver, while the IR LED is referred to as a photoemitter. Infrared light from the LED strikes the surface and returns to the photodiode as a reflection. Following that, the photodiode generates an output voltage that is high for bright surfaces and low for dark surfaces, according to the surface's reflectance.

  The Henna Machine's IR sensor measures the hand's height by using infrared light. The sensor measures the distance by examining the light's reflection, which allows for precise changes for the best possible henna application.

Figure 3: IR sensor

3. Motors

   - Stepper Motors The Henna Machine's CNC technology is driven by stepper motors, which translate electrical pulses into precisely timed rotations. The precise, stable, and intricate henna application procedure can be attained by using these motors, which offer incremental steps to ensure precise positioning of the henna applicator.

Figure 4: Stepper Motor

   - Servo Motors The Henna Machine's servo motor regulate the CNC pin's vertical movement, accurately modifying its location for complex henna applications. These motors provide angular precision, which makes it possible for the device to precisely move the pin up and down, improving the henna design's overall control and details.

Figure 5: Servo Motor

4. others:

   - a4988 stepper motor driver.
     The Henna Machine's A4988 stepper motor driver converts digital inputs into exact steps to govern and control the movement of stepper motors. By controlling the electrical pulses that power the stepper motors, this driver improves the precision and stability of the CNC system and guarantees a smooth and controlled application of henna.[3]

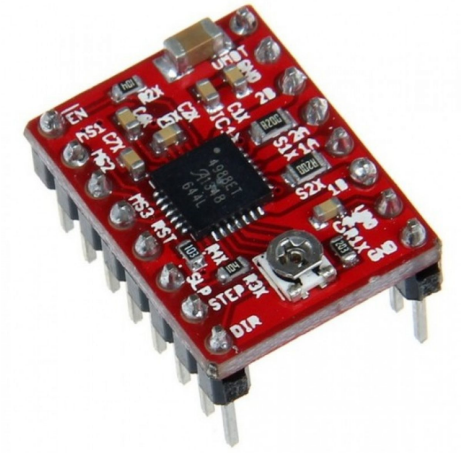

Figure 6: a4988 stepper motor driver.

- RASPBERRY PI CAMERA MODULE V2

  The 8 megapixel Sony IMX219 image sensor and fixed focus lens on the Raspberry Pi Camera Module v2 are custom-made add-on boards for the Raspberry Pi. It can support video up to 1080p30, 720p60, and 640x480p60/90 pixels as well as static images up to 3280 x 2464 pixels. This version 2 offers a quantum leap in terms of image clarity, color purity, and low-light performance—it's not just a simple resolution increase.[4]

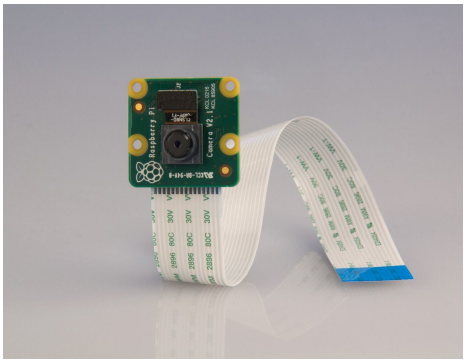

Figure 7: RASPBERRY PI CAMERA MODULE V2

- Battery.

  The Henna Machine's battery functions as a transportable power source, providing energy for mobility and independence. This vital part gives the device the electricity it needs to function, guaranteeing simplicity and adaptability when applying henna in a variety of environments.

Figure 8: Battery.

- Connecting wires.
  The Henna Machine's connecting wires create electrical routes that enable power distribution and communication between many components. These cables guarantee smooth communication, enabling the several units to function as a unit for the accurate and regulated automation of henna application.

Figure 9: Connecting wires.

- Linear bearing rod M8 x y 350mm.
  The Henna Machine's M8 x 350mm linear bearing rod provides a sturdy and reliable guide for regulated linear motion. When used in tandem with GT2 belts and stepper motors, it guarantees accurate and seamless movement of the CNC system, improving the precision and stability of the henna application procedure.

Figure 10: Linear bearing rod M8 x y 350mm.

- GT2 Pulley 16 teeth.
  Together with GT2 belts and stepper motors, the 16-toothed GT2 Pulley in the Henna Machine offers mechanical power transfer. This pulley makes controlled rotation easier, which improves the CNC system's accuracy .

Figure 11: GT2 Pulley 16 teeth.

- GT2 belt.
  To achieve controlled linear motion, the stepper motor and GT2 pulley are connected by the GT2 belt, which functions as a transmission component in the Henna Machine.

Figure 12: GT2 belt.

7.1.3 Hardware Development

1-The first step in building our two-dimensional CNC machine was to transfer our paper idea design into a solid, physical structure. After getting ideas from already-existing CNC drawing machine designs, we decided to take a different approach and spent time building a custom frame that would serve as the foundation for our machine.

2-In order to regulate the motions of the CNC machine along the X and Y axes, stepper motors were carefully positioned on the frame. Accurate placement and a tight fit were essential for efficient functioning.[5][6]

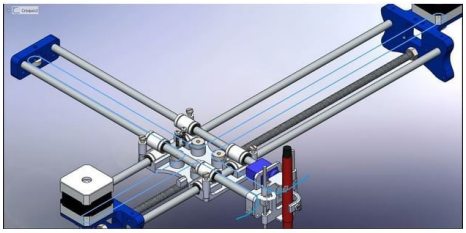

Figure 13: The CNC design plan

3-The design used linear bearing rods (M8) to provide steady linear motion in both the X and Y axes. Achieving smooth and precise motions required precise rod alignment.

4-To convert rotating movements into accurate linear motion, stepper motor shafts were fitted with GT2 pulleys (16 teeth) and GT2 belts. The precise placement of the CNC machine was guaranteed by this design.

5-A4988 stepper motor drivers were linked to the stepper motors. These drivers provide a dependable and adaptable driving power by managing the current and the stepper motors' motions.

6-The Arduino Uno, which served as the main controller, was fixed firmly atop the frame. For coordinated control, wire connections were made between the Arduino Uno, A4988 drivers, stepper motors , and IR sensor .

7- in addition to the dual stepper motors responsible for the X and Y axes, a third stepper motor was introduced to oversee the intricate control of the liquid dispensing system (syringe pump mechanism).

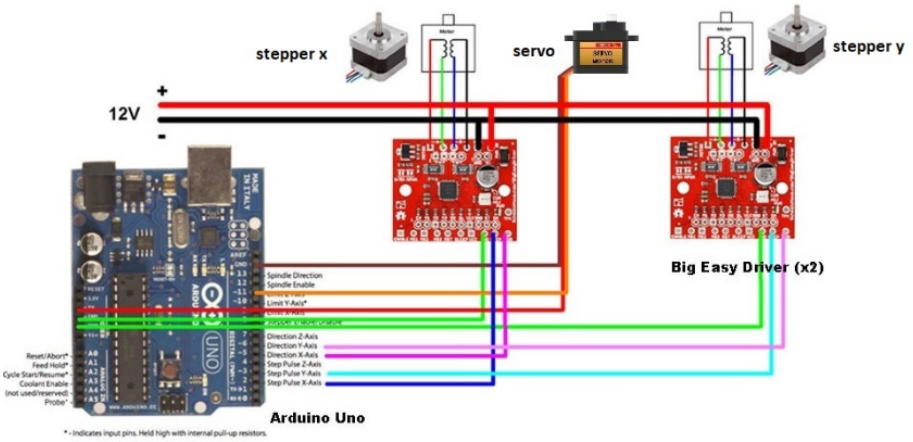

Figure 14: The Arduino Uno Connections .

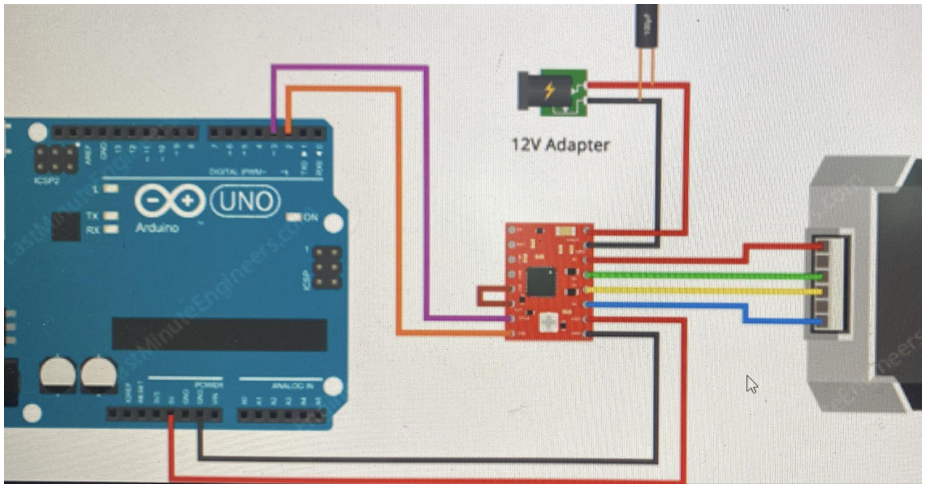

Figure 15: The Stepper motor with the driver Connection .

8- We used the Arduino's GRBL library to precisely control the stepper motors

of the CNC machine, guaranteeing exact motions while drawing.additionally a smooth link was created between the Arduino and Raspberry Pi to facilitate effective coordination and communication between the core controllers.

9-After that ,we used the Raspberry Pi camera connection, high-resolution pictures of the user's hand for measurements .

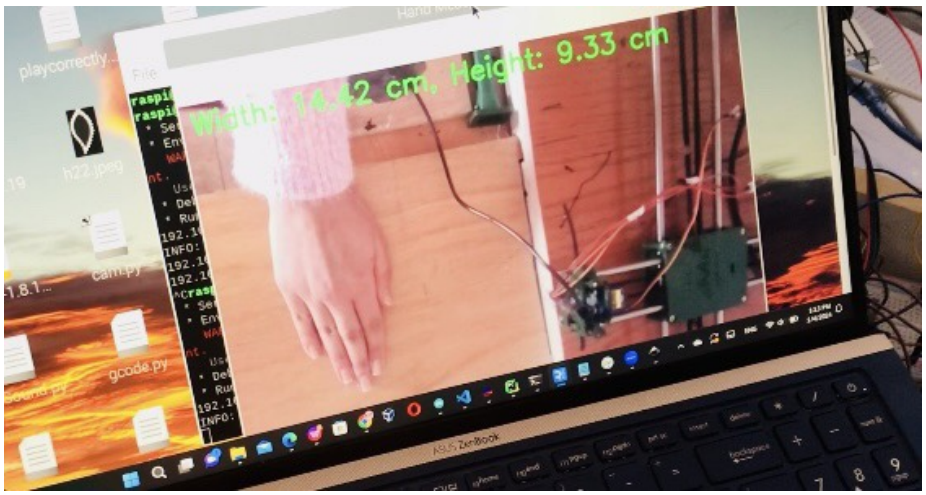

Figure 16: measured hand dimensions.

10-We created a Raspberry Pi Python code application to produce G-code based on measured hand dimensions. The movements and drawing patterns of the CNC machine were controlled by this G-code.

11- we created a mobile application that lets users submit pictures or patterns for henna .and Integrated features that let users turn on the camera to take exact measurements of their hands. and then we put instructions into practice to launch the serial communication and begin the CNC machine's drawing operation.

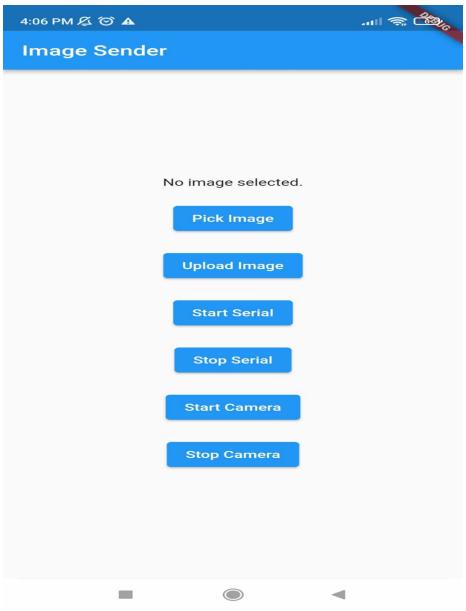

Figure 17: Mobile application.

12- The transmission between the Raspberry Pi and Arduino was made possible by establishing serial connectivity. we arranged the communication channel so that the Raspberry Pi and Arduino could exchange G-code instructions for accurate CNC machine operation.

13-Stepper motors on the CNC machine were coordinated in accordance with the G-code instructions that were received, guaranteeing precise and elaborate henna designs on the user's hand.added an additional degree of control for the henna application process by integrating a third stepper motor to operate the syringe pump mechanism.

Figure 18: syringe pump.

Figure 19: syringe pump.

14- included an infrared sensor to measure the user's hand's distance from the drawing pin,this measurement is then converted into degrees to enable accurate operation of the connected servo motor.

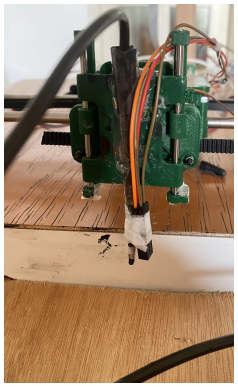

Figure 20: IR sensor.

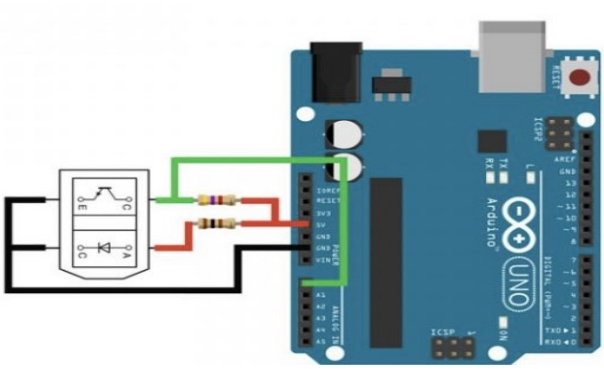

Figure 21: IR sensor connection.

7.1.4 Overall Design

The final result for the Henna Machine as shown in figure.

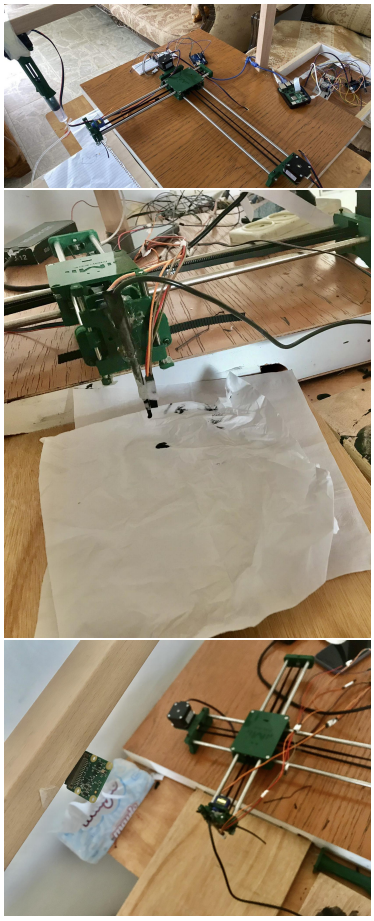

Figure 22: The final result for Henna machine.

7.2 Codes and techniques:

7.2.1 Python Code For Sending Commands From The Mobile App

- Flask Setup: The code builds a web server using the Flask framework. It outlines three routes: File uploads are managed by /upload; serial communication is managed by /serialcontrol; and camera control is managed by /cameracontrol.
- Serial Communication Control: Requests to initiate or terminate serial communication are handled by the /serialcontrol route. In order to deliver a file to Arduino, it first establishes a serial connection, launches a new thread (serialthread), and sets serialrunning to True. It sets serialrunning to False when it stops.
- Camera Control:
  Requests to start or stop the camera are handled by the /cameracontrol route. It first calls the measure hand size function and sets camerarunning to True. It sets camerarunning to False when it stops.
- Camera Measurement: The function measure hand size obtains video frames directly from the camera. It processes hand landmarks, determines the width and height of the hand, and projects measures into the video feed using the MediaPipe library. Unless the user hits 'q' or camerarunning is set to False, the loop keeps going.
- File Upload: /upload route handles file uploads, saving the file to the specified directory.
- Send File to Arduino: send file to arduino function reads a file line by line and sends it to the Arduino via a serial connection. It waits for an acknowledgment from the CNC machine after each line.
- Wait for Acknowledgment: wait for acknowledgment function waits for an acknowledgment from the CNC machine before proceeding.
- Main Execution: In the Python script, the `if __name__ == '__main__':` block starts the Flask app to run the server on host '0.0.0.0' and port 5000.

7.2.2 Python Code for Generating G-code

- Set Desired Width and Height from the camera.
- Load an Image: Reads the image file in grayscale using OpenCV.
- Resize and Threshold the Image:
  - Resizes the image to the desired width and height.
  - Applies thresholding to create a binary image.
- Find Contours:
  Detects contours in the binary image using OpenCV's 'findContours' function.
- Initialize G-code:
  - Sets the initial G-code, positioning the CNC machine at the origin ('G0 X0 Y0').
- Define Feed Rate, Z Height, and Servo Parameters.
- Generate G-code from Contours:
  - Generates G-code commands based on the detected contours.
  - For each contour:
  - Iterates through contour points, creating G-code for X, Y coordinates.
  - Controls the servo angle based on the point's position within the contour, adjusting servo commands.

8 Result and Discussion:

The Automated Henna Machine project has brought together state-of-the-art CNC technology with traditional henna artistry in a seamless way. An amazing system created to respect the history of henna while innovating its use has been created through the combination of carefully chosen hardware components.

The CNC machine was first built by carefully designing and assembling a unique frame that used linear bearing rods (M8) to provide steady linear motion. With the use of GT2 pulleys and belts and stepper motors positioned carefully along the X and Y axes, it was possible to achieve the exact and controlled movement needed for complex henna designs. The stability of the CNC system was enhanced by the incorporation of a4988 stepper motor drivers, which offered dependable control over the system's movements.

The Arduino Uno, serving as the CNC machine's central controller, was essential in coordinating its complex movements. Its many analog and digital pins allowed for a high degree of control and guaranteed the accuracy required by the henna application craft. By taking exact hand measurements and producing matching coordinates for the CNC system, the Raspberry Pi 4 Model B and a camera module brought a sophisticated layer to the system.

The addition of sensors, like the infrared sensor, made the henna application procedure more flexible. The technology was able to improve overall precision by dynamically adjusting to differences in hand location by measuring the user's hand height. Intricate detailing in henna designs was ensured by the additional layer of control provided by servo motors, which controlled the CNC pin's vertical movement.

The creation of a mobile application, which enabled pattern submissions and hand measurements, improved user participation even further. The coordinated movements and precise application of henna were made possible by the connectivity between the Raspberry Pi and Arduino, which enabled the execution of G-code instructions. The system as a whole demonstrated a user-centric design methodology, offering a customized and delightful experience.

9 Conclusion and recommendations:

The journey of building the Automated Henna Machine has been a transformative experience, not only because of the amazing technology advancement but also because of the priceless talents that have been acquired. We learned a great deal about CNC technology and cultural preservation during this project, knowledge that goes far beyond the realm of hardware and programming.

We developed a variety of talents after constructing this robot, from technical mastery to sharp problem-solving abilities. Our precision engineering talents were refined by the complex design and assembly of the CNC machine, which demanded exacting attention to detail. Our grasp of sensor integration, real-time data processing, and microcontroller programming has increased as a result of our work with the Arduino Uno and Raspberry Pi 4 Model B.

10 Future work

When the line follower and human follower were being developed, the majority of the beneficial features were discovered, and many of them were put into practice. Some of these, however, are not able to be included due to time limits and other reasons. In conclusion, the following are the development features:

- Machine Learning Integration .
- Refine the mobile app interface for improved user interaction.
- Color selection .
- payment system .

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