Minor Project Report

On

3D Printed Robotic Arm Controlled by Arduino

Submitted by

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Under the guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

Madhav Institute of Technology & Science, Gwalior (M.P.), INDIA

Deemed University

(Declared under Distinct Category by Ministry of Education, Government of India)

NAAC ACCREDITED WITH A++ GRADE

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STUDENT DECLARATION

We hereby certify that the Minor Project entitled **'3D Printed Robotic Arm controlled by Arduino'** which is being submitted in the **Department of Mechanical Engineering** is a record of our own work carried out under the supervision and guidance of **Prof. Sharad Agrawal**, Department of Mechanical Engineering, Madhav Institute of Technology & Science (DU), Gwalior.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct. We have fully cited and referenced all material and results that are not original to this work.

To the best of our knowledge the material presented in this project has not been submitted to any other place (i.e. institute, university, organization) as thesis, report.

Date: 30-05-2025
Place: Gwalior

SRUTI KUMARI

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

Guided by:

Prof. Sharad Agrawal
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ACKNOWLEDGEMENT

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We are also thankful to Er. Harshdeep Sharma for his cooperation with us in facilitating the infrastructure and lab facility during our Minor Project work. We are also thankful to all our friends, those have contributed and helped us directly or indirectly in bringing this project to a successful completion. Finally, we are highly indebted to our parents, our family members, for extending every possible support with great inspiration and numerous blessings towards us.

SRUTI KUMARI

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ABSTRACT

This Minor project consists of the manufacturing of a Robotic Arm by using the Additive Manufacturing method (3D Printing), the 3D printed model of Robotic Arm is evidently controlled by the Arduino UNO connected with the Bluetooth module (BT HC-05 module) which functions across a distance as it is controlled through a mobile application by providing directions to move the arms from different points and, as to provide motion to the arm we competently used servo motors (SG90) as actuators, we have tried our best to showcase how we can manufacture a 3D Printed Robotic Arm model for the purpose of study about degree of freedoms along with the automation which is taking place in industries rapidly. Today industrial robots work in a wide range of industries, the industrial robots are developed to perform operations such as pick and place, manufacturing assembly line, welding work, metal forging, and painting operations. The constraints of available robots are in terms of structural complexity, more material in the body, over weightage, and space. To overcome the difficulties of the current scenario, technology is developing in the same direction in line with rapidly increasing human needs. The work done to meet these needs makes life easier every day, and these kinds of studies and prototypes are concentrated in robotic arm studies. Robotic arms work with an outside user or by performing predetermined commands. This model is imitatively addressed to non-industrial applications where limited payload and low precision are sufficient. We identified the need for such a product in educational, recreative and small business fields. Hence, an affordable solution is designed. Furthermore, this product can be possibly brought into the "synergetic" robotics field, unlocking a deeper interaction between man and machine remaining in the non-industrial field. By the fact that, real Cobots have very high price tags, and this forbids their use in an instructive field, then these instructive models came into field to showcase their necessity in learning and understanding.

A four degree of freedom robotic arm has been designed and implemented for the purpose of this minor project. The arm is made up of four rotary joints and an end effector, where rotary motion is provided by the servomotor. Each link has been first designed using Solid works (version 2024) and then printed by 3D printer to an extent of precision. The assembly of the parts of the robot and the motor's mechanical shapes produce the final prototype of the arm. Arduino UNO has been programmed to provide rotation to each corresponding servo motor to the slides in the designed mobile application for usage from a distance. The major goal of this project is to create a system that helps engineering students learn more about and apply the many disciplines they study. It drastically bridges the gap between AI, robotics, and 3D printing, three of the most important areas of engineering today.

Keywords: Additive Manufacturing, Arduino, Module, Actuator, Cobots, synergetic, prototypes, end effector, robotics.

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Chapter 01: Introduction

Robots and autonomous systems can get involved in a wide range of helpful endeavors throughout. Many human constraints in industrial domains can be overcome with the robotic arm, especially with the help of the distance-controlled functioning. The operations and functions of robotic arms are frequently employed in laboratories for study and various fields to decrease human error by implementing automation. Assembly lines and actions involving force control with input to its controller are among the duties handled by robotic arms [1]. As mentioned in the JOIREM, April-2024[2], the coordinated efforts of computer science, electrical engineering, and mechanical engineering lead to 3D printed automation. A robot is a machine that can be programmed by a user utilizing a programming language to carry out a certain task. The Arduino language, which is analogous to the C programming language and is based on simple processing, is utilized here. The Arduino UNO is used to write the source code, then uploaded on the Arduino board, which has a microcontroller—a tiny integrated circuit—to execute the code. A potentiometer can be used to operate a 3D printed robotic arm, giving it four degrees of freedom to move left, right, up, and down. The four servo motors in a 3D-printed robotic arm support in controlling the arm. There are numerous varieties of 3D-printed robotic arms that can be used for various tasks. A 3D-printed robotic arm is an exact replica of a human arm that has the same translation and rotational capabilities. These days, most enterprises use 3D printed robotic arms to move and pick items from one location to another. They lessen human risk and hardship, and they can be utilized in dangerous areas which are unsafe for humans to access.

An industrial arm has four joints, which are comparable to the shoulder, elbow, and wrist of a human arm. Usually, a stationary foundation structure is used to mount the shoulder alternatively as compared to a flexible body. With four degrees of freedom, this kind of robot can turn in four distinct directions. In contrast, a human arm has seven degrees of freedom. As an illustration, our arm's function is to move our hands from one location to another. Like this, a pick and place robotic arm's function is to transport an object from one location to another. Industrial robots are made to do precise tasks repeatedly in a controlled setting. We studied about its control system which is Arduino in JETIR June 2020[3] that, python programming is used to program the Arduino UNO microcontroller to provide servo motor control. As a result, the servo motor input circuit is the only circuit construction required to do the needed actions using components found on the Arduino. Apart from the circuit that houses the servo motor inputs, the robot arm's mechanical section is depicted using the Solid Works program and the circuit's dimensions. Robot arms have been specified for the mechanical component. And as for the controller or power source, Bluetooth is the foundation of our project. These days, Bluetooth is a popular technology. Numerous international corporations are working on it and offering their clients services. Many residences, hotels, and flats, among other establishments, are completely automated using Bluetooth. It is used in 3D printed robotic arms to gather, exchange, or transfer data so that the robots can respond accordingly [2].

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[1] Hussein Mohammed Ali, Yasir Hashim, Ghadah Alaadden Al-Sakkal (IJECE) Vol. 12, No. 2, April 2022, pp. 1411~1418

[2] Prof. Sunil Madhukar Mahajan, Ghrushnesh Aniruddha Bhandari, Rushabh Vijay Ghatborikar, Saurabh Pandey, Prathamesh Balasaheb Aher, (JOIREM) Volume: 20 Issue: 4 | April-2024

[3] Rajashekar K, Hanumantha Reddy, Ruksar Begum T K, Shaheena Begum, Syeda Ziya Fathima, Saba Kauser, (JETIR) June 2020, Volume 7, Issue 6

Chapter 02: Methodology

- **Proposed Work**

Developing a robotic arm that can replicate the motion of a human hand is the aim of this methodology. The SG90 servo motor, which has a torque of 1.8 kg/cm, is used to control the 3D-printed robotic arm. The voltage range at which the servo motor runs is 4.8 to 6 volts. Through the design and production of unique items or gadgets, 3D printer technology has made major strides possible in several industries. A potentiometer is used to measure the angle of the human hand. The potentiometer can function as a rotatory encoder because it has a respectable resolution. The Arduino Uno, which serves as the system's brain, and the Sg90 servo motor, which moves the arm, make up the hand. The servo motor works on the PWM signal. A 3D-printed robotic arm is an exact replica of a human arm that has the same translation and rotational capabilities. This block diagram shows every component that is connected to every other component. Here, four servo motors—which are utilized for translation and rotational motions as well as a battery-powered power source are linked to an Arduino board, along with four more potentiometers.[2] [4]

Fig.01: Block Diagram of Working

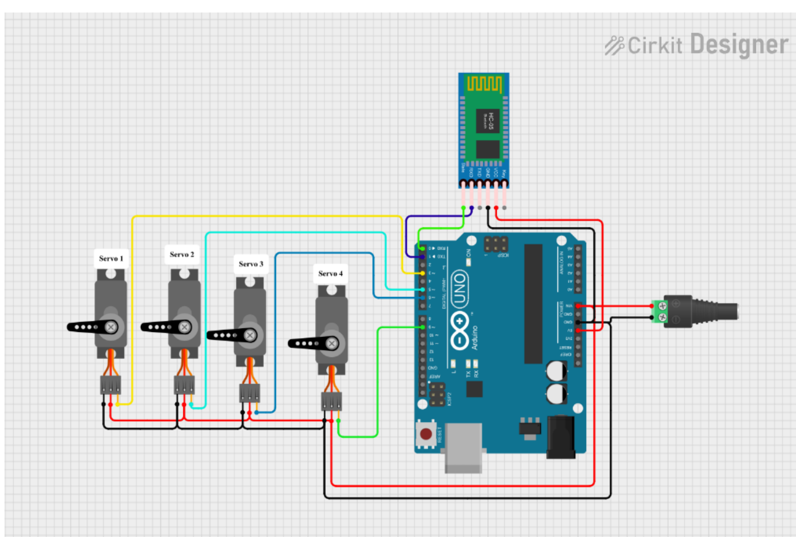

Fig.02: Circuit Diagram of connected components [5]

[4] Himanshu Lohakare, Trupti Chainde, Prajwal Jadhav, Khumesh Rahangdale, Devshri Wanjari, Prof. Avinash Ikhar, International Journal of Research Publication and Reviews, Vol 5, no 3, pp 4247-4252 March 2024

[5] https://docs.cirkitdesigner.com/project/published/47ecb005-3f25-4ab1-b795-76e3fc1c67a8/arduino-uno-controlled-servo-array-with-bluetooth-connectivity

- **3D Printed Robotic Arm**

A mechanical arm that serves the same purpose as a human arm is called a 3D printed robotic arm. It is incredibly beneficial and lessens the need for human labor. It is highly helpful for intricate and risky painting tasks including grabbing, spinning, and welding (tungsten welding). Consider waste management and toilet seat cleaning, where we teach a robot's hand to perform tasks that a human used to perform without realizing it. It is also guaranteeing cleanliness in this way. This is crucial for tasks requiring precision, reliability, and repeatability.

Types of Robotic Arms Made using 3D Printing: -

- Cartesian Robot: Used for arc and machine tool operations.
- Cylindrical Robot: It is primarily utilized for spot welding, machine tool handling, and assembly tasks. This is a robot that has axes that resemble a cylindrical frame of reference.
- Spherical Robots: These are primarily utilized in gas welding, arc welding, machine tools, fettling machines, and spot welding.
- Articulated robots: These can be as basic as two-joint constructions or as complex as ten or more interactive pair systems. Electric motors are one of the tools used to manage them.
- Parallel Robot: A parallel manipulator is a device that supports a platform or end effector by means of several computer-controlled serial chains. Six linear actuators make up the most basic parallel manipulator, most likely. Stewart Platform or Goff-Stewart Platform were the names of the engineers who initially created and utilized the apparatus.
- SCARA Robot: Selective Compliance Assembly Robot Arm is what SCARA stands for. It can adjust to XY-holes inside the axes since its arm is flexible on the XY-axis and securely positioned within the Z-axis.

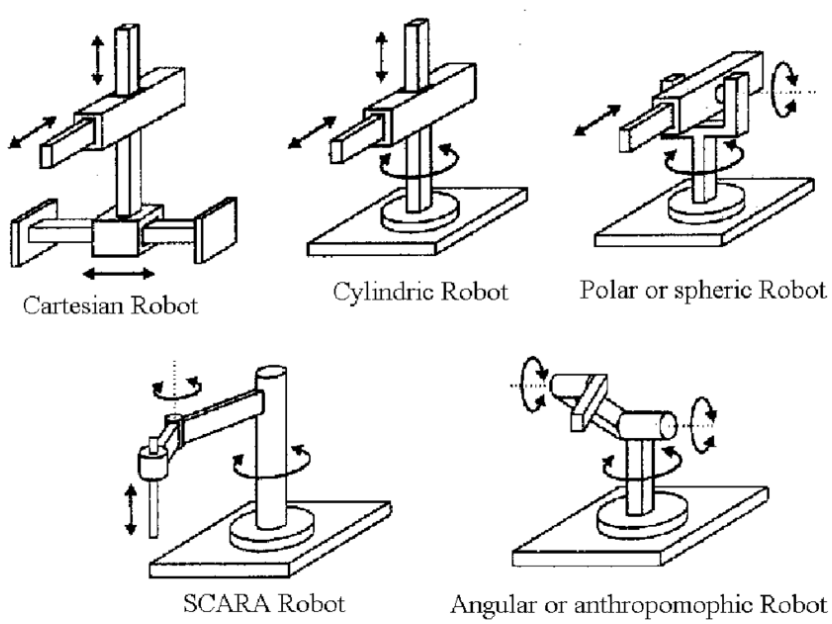

Fig.03: Types of Robotic arms[6]

[6] https://www.researchgate.net/figure/Common-robot-arm-configurations_fig1_244270445

- **Design and Implementation**

As described in the IJECE Vol. 12, No. 2, April 2022[1], the design and installation of a robotic arm controlled by an Arduino over Bluetooth are described below, along with the arm's features, orientation, speed, and extension. Calculating the angles for the robotic arm's location requires an understanding of its geometry. It is crucial to understand the lengths of each link as well as the arm's beginning and ending locations in the work area, which are then compared to the robotic arm's base or another point. The two types of kinematics used to describe this motion are forward and reverse. Singularity is the state in which the robot's genesis point in three-dimensional space is (0,0) and cannot be reached.

To manage its location and wrist position, the robotic arm's extension must be able to reach items outside of its base. For the given tools to carry objects, the orientation needs to be exact in terms of speed. Fig.04 depicts the general robotic arm design used in this paper. This graphic shows the motors and joints along with all their mechanical components and how they move in response to commands from the Arduino platform. With six servo motors, this system offers six degrees of freedom (DOFs), and the Arduino controls each motor separately. The process of designing the robotic arm's mechanical components is crucial and significant.

The robotic arm's mechanical components must be shaped by the way the motors support both the items and their own weights. Software is needed to design the robotic arm's mechanical components as well as a 3D printer that forms the mechanical components as needed. The components of the robotic arm were made using the open-source Solid Works 3D printer modeling program. The following specifications were used to create the robotic arm's components: one nozzle, 0.4 mm nozzle diameter, 0.05 to 0.40 mm layering pitch, 10 to 200 mm/s modeling speed, and automatic filament supply to nozzle. Additionally, the 3D printer interface made use of USB 2.0, Ethernet, Wi-Fi, or USB memory.

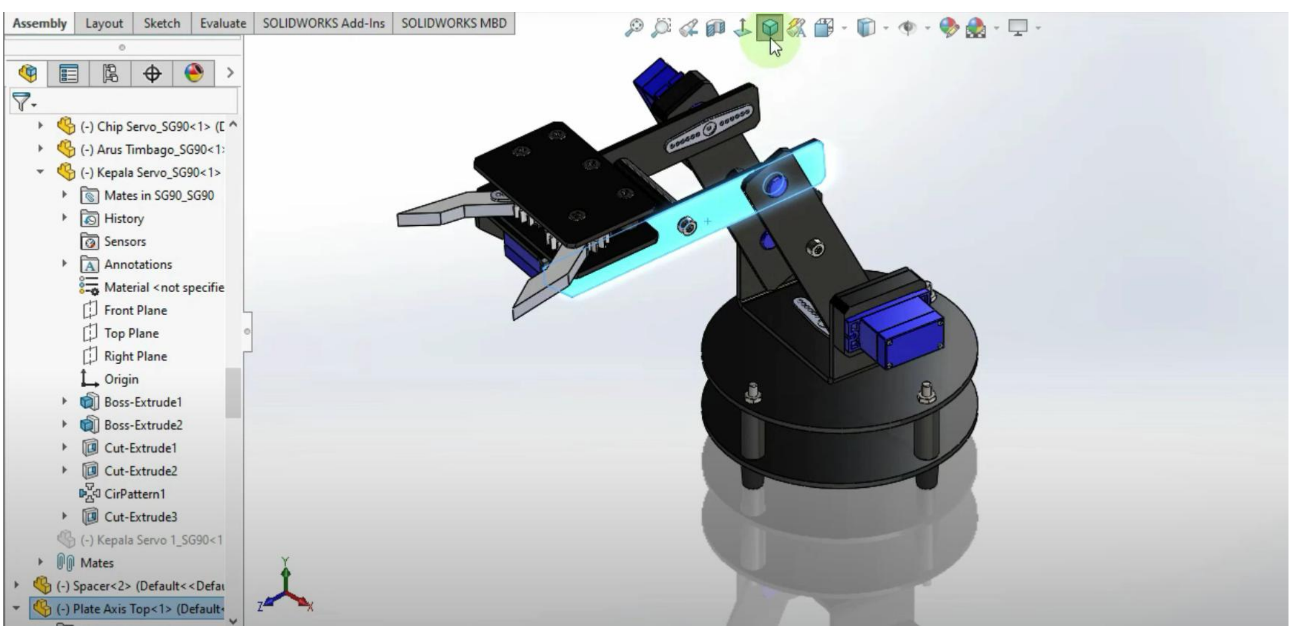

Fig. 04: Design of Robotic Arm in SolidWorks

- **3D Printing**

Here, we employed a 3D printing method known as Fusion Deposit modeling. The build input material for FDM technology is thermoplastic filaments, which are liquified and resolidified into the required shape in accordance with the specified CAD model. It is highlighted in a thesis [7], that one practical method for creating the structural elements of an inexpensive four-degree-of-freedom robot is through 3D printing. Consumer 3D printers are reasonably priced and ensure high-quality manufacturing. The open-source community and safety need to be examined in greater detail. In terms of safety, cooperative jobs become highly intriguing because no heavy-duty work would ever be done on such a device. In a university practical robotics lab, for instance, it would be feasible to communicate with the robot as it is carrying out a task. As a result, the robot will be designed with the possibility of human interaction in mind. Impact detection and back drivability are crucial features that require careful consideration.

There are two spools in an FDM printer: one for the construction material and the correspondingly for the support material. According to the IRJMETS, Volume:05/Issue:12/December-2023[8], these following are the primary processes in the fused deposition modeling 3D printing process:

Step 1: The liquefier head uses heat to liquefy the solid construction material filament that has already been loaded after the CAD data has been entered.

Step 2: Using the extrusion nozzle, which travels in all directions specified by the CAD data, this molten liquid plastic is fed onto the foam construction platform as a layer. The liquid/semi-solid layers are added one on top of the other repeated. Support structures are employed in designs that have overhangs or other elements that could bend or warp. Depending on the preference, the support material may be the same as the build material or any different material.

Step 3: After the building is finished, any support structures that were utilized are eliminated.

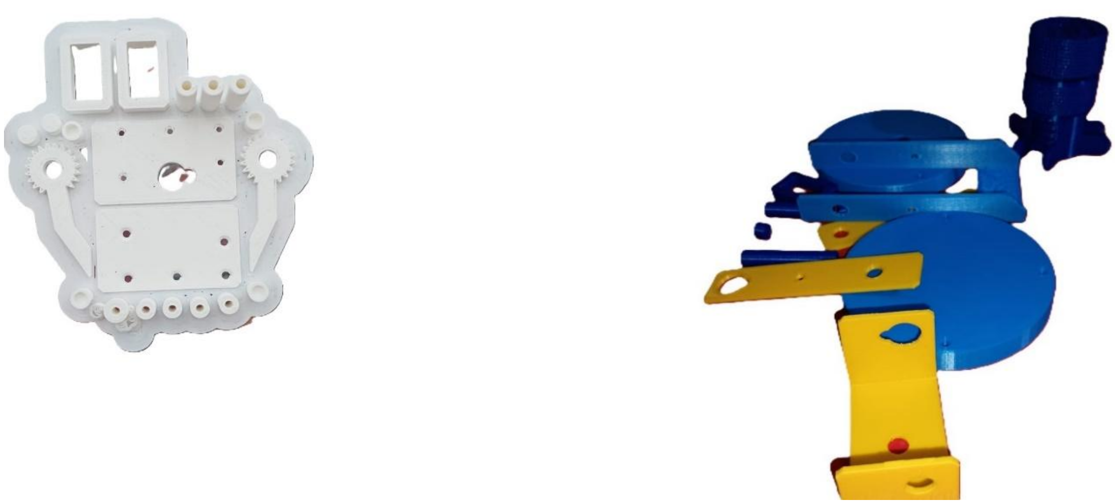

Fig. 05: 3D printed components of Robotic Arm

[7] Lorenzo Ferrari, Luca Berton, 2020-2021 (Laurea Magistrale in Mechanical Engineering - Ingegneria Meccanica)

[8] Sathyanarayana V, Chethan S, Mahesha KK, International Research Journal of Modernization in Engineering Technology and Science, Volume:05/Issue:12/December-2023

- **Hardware and Software Used [3][4]**

MATERIAL

PLA 3D printer filament, which is stronger and less expensive, is used to make the frame that the hand will move on. Polylactic Acid, or PLA for short, is a recyclable thermoplastic polyester. The PLA is ideal for 3D-printed structures since it doesn't require high-temperature printing.

Arduino UNO

This open-source microcontroller is based on microchips; however, microcontrollers of the PIC type are typically employed in software and programming domains. Arduino.cc is the company behind the ATmega328P microprocessor. The board has sets of analog and digital input/output pins that can be connected to different circuits and expansion boards. It is built on earlier wiring and processing projects using Arduino. Processing is designed for users who are not programmers. Programming language is used to create Arduino wire.

HC-05 Bluetooth

This module allows communication with any Bluetooth-enabled device or between two microcontrollers, such as Arduino. This module exchanges at a 9600 baud rate with the aid of USART. There are two modes of operation for the HC-05: AT command mode, which allows you to modify the default device setting, and data mode, which allows you to send and receive data from other Bluetooth devices.

L298N Motor Driver

This dual H-bridge motor driver enables simultaneous direction and speed control of two dc motors. The module is capable of driving DC motors with voltages ranging from 5 to 35 volts, with a maximum current of 2 amps. Two motors can be driven by the driver module.

Servo motors

Servo motors identify a mechanism's operating error, give feedback, and fix problems. Servo motors are the type of motors that can carry out our desired commands. Even at extremely low or extremely high speeds, they may function steadily. The little size can be used to obtain the enormous moment. Control systems that require quick operation, excessive axis movement, condition control, and other features use servo motors. The final control component of a machine is a servo motor. Servo motors are extremely sensitive devices that work with electronic or programmable circuitry.

Arduino IDE (software)

Integrated Development Environment (IDE) for Arduino: It is a software program that gathers all the necessary tools for writing, compiling, and uploading code to your Arduino board in one location. Writing code, or sketches, for Arduino boards is the main function of the Arduino IDE. Your project will come to life once you upload the code you've written to the Arduino board using the IDE. Anyone can contribute to and enhance the Arduino IDE's code because it is publicly available. A built-in library called Wiring is included with the Arduino IDE and offers standard functions for communicating with sensors, actuators, and other parts.

- **Code**

```
#include <Servo.h>

// Create Servo objects
Servo base, shoulder, elbow, gripper;

// Define pins
const int basePin = 3;
const int shoulderPin = 5;
const int elbowPin = 6;
const int gripperPin = 9;

// Angle variable
int angle = 0;

void setup() {
  base.attach(basePin);
  shoulder.attach(shoulderPin);
  elbow.attach(elbowPin);
  gripper.attach(gripperPin);

  Serial.begin(9600);
  Serial.println("Robotic Arm Ready.");
  Serial.println("Select part: B (Base), S (Shoulder), E (Elbow), G (Gripper)");
}

void loop() {
  if (Serial.available()) {
    char cmd = Serial.read();

    switch (cmd) {
      case 'B':
        Serial.println("Moving Base...");
        moveServo(base, 0, 180);
        break;

      case 'S':
        Serial.println("Moving Shoulder...");
        moveServo(shoulder, 0, 180);
        break;

      case 'E':
        Serial.println("Moving Elbow...");
        moveServo(elbow, 0, 360);
        break;

      case 'G':
        Serial.println("Operating Gripper...");
        moveServo(gripper, 0, 90);  // Gripper only needs 0° to 90°
        break;

      default:
        Serial.println("Invalid command. Use B, S, E, or G.");
        break;
    }

    Serial.println("Ready for next command: B, S, E, or G");
  }
}

// Sweep servo from min to max and back
```

```
void moveServo(Servo &servo, int minAngle, int maxAngle)

{
  for (angle = minAngle; angle <= maxAngle; angle += 5)

{
    servo.write(angle);
    delay(20);
  }
  for (angle = maxAngle; angle >= minAngle; angle -= 5)

{
    servo.write(angle);
    delay(20);
  }
```

- **Assembly**

Most of the components of Robotic arm are 3D-printed which is fixable and easily assembled with a requirable force without breaking a part, along with it we required some Nut & Bolts to fix some of the components altogether.

Assembly Process
Step 01: Preparing the base by fixing them (top & bottom base) with nut & bolts by passing them through holders.
Step 02: Fit the plate axis bottom with Servo 1 and tighten them, only free it to move rotationally.
Step 03: Attach Servo 2 with plate axis middle and fit them together using holder to improve its mobility.
Step 04: Fit plate axis top with plate axis middle and Servo 3 and tighten it with the holder.
Step 05: At last, put gripper on top of the plate axis top and attach Servo 4 with the gripper. Then, ensure its motion throughout.

- **Testing**

We made the decision to check to see if the 3D printed parts' measurements and accuracy matched those of the intended parts exactly. Additionally, we have tested the C++ code used to control the servo motors with an Arduino. Because one error could cause the entire coding to go out of line, these programs are extremely intricate and can be quite challenging to complete. Testing the codes is therefore a crucial and significant undertaking. It is also crucial to test the several wire connections on the bread board, from the motors to the Arduino and power supply, since a single incorrect connection could cause the Arduino to overload and malfunction.
After that, we tested the Arduino's codes to see if the app we created related to the Arduino and codes. We can conclude that the testing was successful because the motors and Arduino appeared to be operating fine and flawlessly.

Chapter 03: Advantages & Limitations

- **Advantages**
  - 3D printing significantly reduces production costs by using affordable materials.
  - It can be light in weight depending on its material, which improvises its mobility.
  - Optimization and modification of designs can be done easily for any specific task.
  - Through Robotic Arm, it is easier to monitor and manage things.
  - As a result of this accuracy, product quality, speed, and efficiency all elevated.
  - It is now feasible to move items from one location to another.
  - Increment in the production level.
  - When operating, it is safer than a human.
  - Enhance the working conditions in factories.
  - Automatic grounding of high voltage system.
  - Retrieving suspicious objects without endangering humans. (such as digging channel)

- **Limitations**
  - Mostly 3D printers use plastic-based materials that may not be as strong or durable.
  - Requirement of continuous power supply.
  - Posing problems with heavy-duty tasks due to their material strength leads them to less suitable for industrial applications.
  - Lacking security and privacy.
  - 3D Printed robotic arms are not creative and innovative.
  - Experts are needed to handle it, and fear of job loss increases.

Chapter 04: Applications

A 3D-printed robotic arm can be used across a wide range of fields, offering flexibility and innovation. 3D printed robotic arms have diverse applications, ranging from industrial automation to personalized healthcare. They are used in manufacturing for assembly, welding, and painting, as well as in the construction industry for large-scale 3D printing of structures. Additionally, they are utilized in research and development for prototyping and custom robotic solutions and there are more applications such as used for minor surgeries, to dislodge the hazardous objects without affecting humans, picking and placing of objects from one place to another place, useful for analysis and testing in lab.
Following is the detailed analysis of its applications:

Prosthetics & Assistive Devices
Customizable, affordable prosthetic arms can be designed for individuals, providing mobility and functionality tailored to their needs.

Industrial Automation
3D-printed robotic arms help with lightweight automated tasks such as assembly, packaging, and material handling in factories.

Medical & Surgical Assistance
In healthcare, robotic arms assist with surgeries, rehabilitation exercises, and precise drug administration.

Education & Research
Universities and research labs use 3D-printed robotic arms for experimentation, robotics training, and engineering projects.

Space Exploration
Lightweight, customizable robotic arms can support astronauts in tasks requiring delicate operations in space.

Agriculture & Farming
Automated robotic arms can perform farming tasks like sorting produce, planting seeds, or managing irrigation.

Art & Creativity
Some artists and designers use robotic arms for precision-based art, including 3D sculpting, painting, and assembly of creative structures.

Chapter 05: Results and Discussion

Experimental results show that the system can accurately convert hand motions into comparable robotic arm movements. Tests of the proposed robotic arm have been carried out based on movement speed, force, and balance, demonstrating the arm's ability to manage weight, force, and balance appropriately. After examining it, the mobile application demonstrated that it functions flawlessly. Initially, upon turning on, all the robotic arm's motors move straight to the home position based on a signal received from the mobile application. Various hand angles result in unique arm motions, demonstrating the system's diversity and adaptability. The system's efficiency and user-friendly interface make it suited for various industrial applications, such as assembly, pick-and-place, and quality control. Each component is assembled via 3D printing. Initial testing revealed that the robot's functionality requires to be improved upon. The robotic arm swings to record the home position rapidly and dynamically. Since the function servo.read() in the Servo.h library, which moves the motors, can only return the last entered angle value, the issue resulted from not knowing the joints' current positions. Each servo motor's current angle value was determined by disassembling the motors and connecting them properly. The current angle values can be determined by connecting the soldered wires to the microcontroller's analogue inputs and then scaling using the map () function. As all the components are necessary for the model but crucial role is played by servos as Each servo is essential for the other servo connecting points that shape a hand so that the arm remains steady and may be used to pick and position objects efficiently, and as a result, we set up the servo structure that enables us to pick and arrange devices or objects. After the jaw is fitted so that we can easily pick up the goods with its assistance, all of the connections are secured, and a 3D printed robotic arm is ready to attach to Arduino pins. Based on the project's test results, the Arduino-controlled robotic arm can accomplish a lot of work considering its size and movement speed. It is simple to handle, convenient to use, and may be unscrewed to move or fastened to a stationary location where the job is required. Somewhere else. In the end, robot technology is only getting started, whether it is used in businesses or in our daily lives. Robots can save a significant amount of time, cut costs, and provide several other advantages.

One significant advancement in the field of robotics is the creation of artificial robotic hands using 3D technology. The development of a personalized and useful robotic arm that nearly mimics the size and form of a genuine hand has been made possible by this technology, which can significantly enhance the user's capacity to carry out daily tasks.

The ability to create lightweight, long-lasting, and user-friendly prosthetics is one advantage of employing 3D technology. But there are drawbacks to employing 3D technology as well, like the availability of appropriate printing materials and the requirement for certain software and knowledge to design and print a robotic arm.

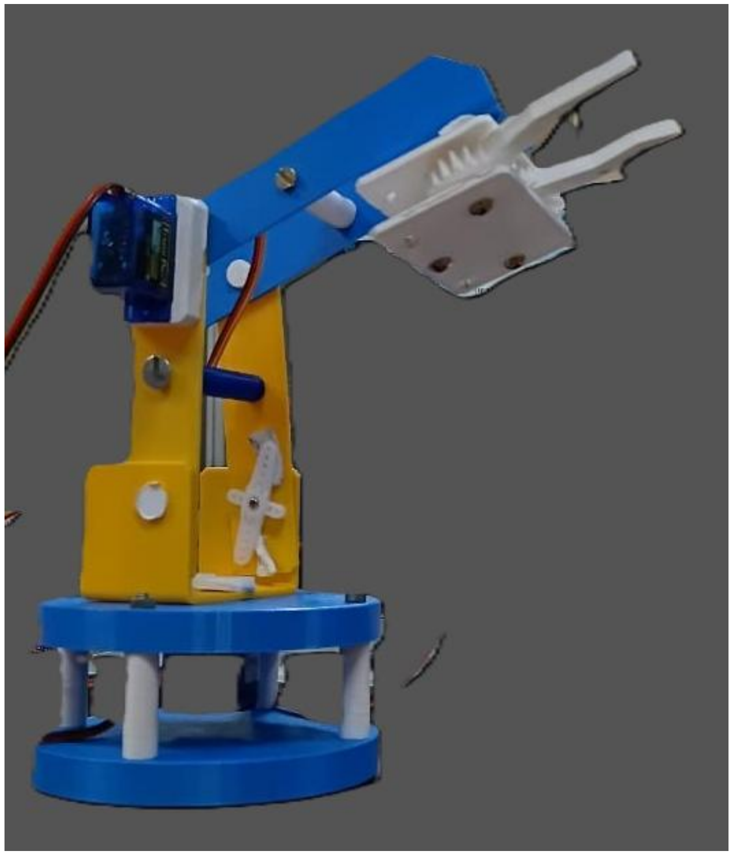

Fig. 06: Assembled Robotic Arm

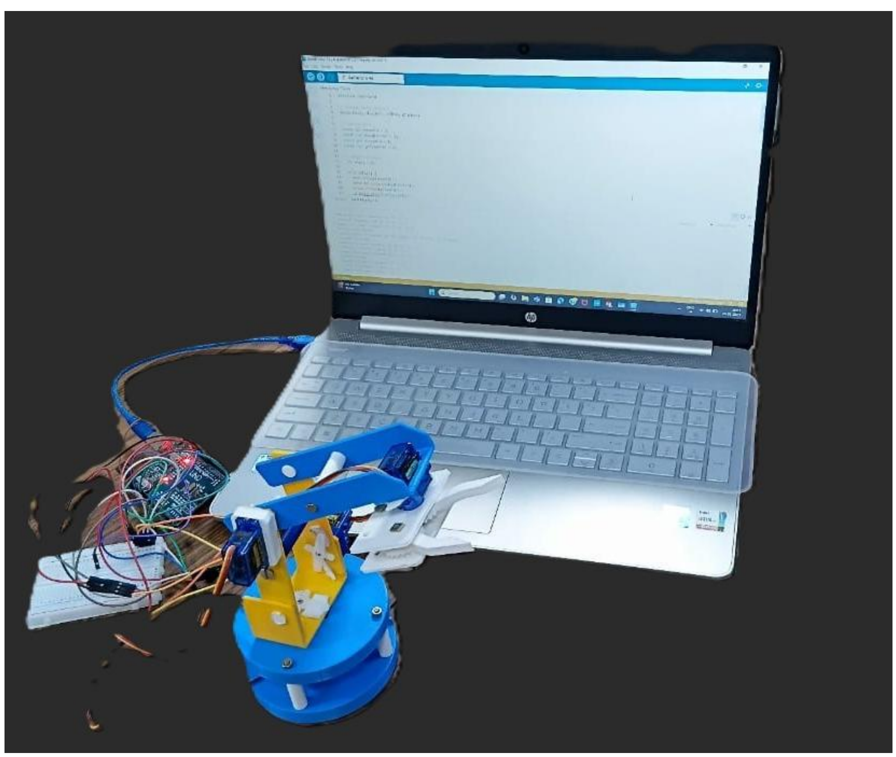

Fig. 07: Controlled and tested by Arduino IDE

Chapter 06: Conclusion

The objective of this project is to create a mobile application that will safely control a robotic arm that is entirely controlled by the Arduino platform. This robotic arm can be employed in a wide range of sectors or in hazardous environments. Each servo motor can rotate thanks to Arduino's programming, matching the sliders in the mobile application that was made to be used remotely. The testing of the finished design has revealed that it performs its function as intended.[1]

Developing technology for new developments and breakthroughs in the manufacturing and production sectors is 3D printing. 3D printing will be able to produce prototypes in large quantities. We shall manufacture our own products without the help of expert workers. 3D printing will reduce waste and time reduction, economical. This proposed project provides an overview of how to use a servo motor to create robotic arm joints and control them with an Arduino UNO and Bluetooth module used for heavy-duty industrial applications as well.

A combination of an intuitive and user-friendly control interface, the system's accuracy, versatility, and industry significance, along with its intuitive nature, makes it a transformative solution for maximizing human-robot collaboration and fostering innovation in industrial automation. This improves human-robot interaction in a variety of applications, including manufacturing, healthcare, and education. Future research might concentrate on gesture optimization, recognition algorithms, extending the movements that are supported, and investigating sophisticated control techniques for increasingly difficult jobs.[4] [8]

The automation is the reason we are successful in this project. [9][10] The Arduino should be used to monitor and control the project. Using a potentiometer and four degrees of freedom, the 3D-printed robotic arm controller can rotate 180 degrees. In addition to acknowledging the instructions, this project accounts for the activity and is capable of painting. It can minimize human labor by constantly and continuously painting the same scene.[2]

Finally, it is ensured that our future is going towards advancements and automation by the help of various machines and technologies throughout the world. As per the humans, they will adapt it and make it able to use in a manner of safety and growth in each and every field of science and engineering including social and economic fields.

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[9] Harvard Business Review, "Automation: Science Fiction or Business Fact?" Harv. Bus. Rev., vol. Analytics, p. 8, 2014

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Chapter 07: Future Scope

Future is set to transform various industries by the implementation of 3D-printed robotic arms, from manufacturing products in an industry and for healthcare to manufacturing light weighted components for space exploration and sustainability. As nowadays, technology is advancing these robotic arms are becoming more feasible, customizable and cost-effective, enabling greater accessibility and efficiency for humans. If we consider industrial automation, various industries are integrating these AI-driven robotic arms for precision tasks in various fields like automotive, aerospace, and construction, leading it to reduced production costs and enhanced productivity.

Additionally, customization is a major advantage, as 3D printing allows manufacturers to design robotic arms tailored for specific tasks, eliminating the constraints of traditional designs. The field of medical prosthetics is also benefiting, with affordable, patient-specific robotic limbs being developed to improve mobility and quality of life. In space exploration, organizations like NASA are experimenting with 3D-printed robotic arms that can be produced on-site, reducing payload weight and increasing adaptability in unpredictable environments. Moreover, with a growing focus on sustainability, researchers are developing eco-friendly materials such as biodegradable polymers and carbon fiber composites to make robotic arms more environmentally friendly. Artificial intelligence and machine learning will further enhance the precision and autonomy of these systems, making them smarter, more efficient, and self-learning.
This also includes:[2]

- If the 3D-printed robotic arm is out of sight, we can utilize infrared sensors to automatically detect and avoid obstructions.

- A 3D-printed robotic arm with gesture control is possible with MEMS technology.

- Hand gesture sensors can be used in place of a potentiometer.

- A human who has lost a hand in an accident can utilize a 3D printed robotic arm as an artificial arm.

- 3D-printed robotic arms can be utilized for procedures and surgery in the medical field.

- In addition, variations and greater adaptability to add or change any component in accordance with preferences are frequently implemented to improve its use, expand its field of application, and make it more versatile or universal.

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