Dual Arm Robot

for

ELEMENTS OF MECHATRONICS SYSTEMS (21MHC101P)

Submitted by

D.D.S.M.Harshavardhan(RA2311038010020)
Vuyyuru Shanmukha Reddy(RA2311038010017)
Boppana Sai Abhiram(RA2311038010011)

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BONAFIDE CERTIFICATE

Certified that this project report titled "***Title of the project***" is the bonafide work of **D.D.S.M.Harshavardhan (RA2311038010020), Vuyyuru Shanmukha Reddy (RA2311038010017), and Boppana Sai Abhiram (RA2311038010011)** who carried out the project work under our supervision. Certified further, project work reported here is for fulfilling the outcomes of the project based subject **ELEMENTS OF MECHATRONICS SYSTEMS (21MHC101P).**

SIGNATURE	SIGNATURE
Dr.V.Krithika M.Tech, Ph.D., Faculty In charge, Dept. of Mechatronics Engineering	**Dr. G. MURALI, M.E., Ph.D.** Professor and Head of the Department Dept. of Mechatronics Engineering

Signature of the Internal Examiner1

Signature of the Internal Examiner 2

ABSTRACT

This document describes the design of a dual arm robot based on the teensy microcontroller. The small size of the robot and the simplicity of its components make it suitable for its easy reproduction and programming. Dual-arm robots are expected to perform work in a dynamic environment. One of the most basic tasks that a dual-arm robot does is pick-and-place work. However, this work is more complicated when there are several objects in the robot's workspace. Additionally, it is likely to take a long time to finish the work as the number of objects increases. Therefore, we propose a method using a combination of two approaches to achieve efficient pick-and-place performance by a dual-arm robot to minimize its operation time. First, we use mixed integer linear programming (MILP) for the pick-and-place work to determine which arm should move an object and in which order these objects should be moved while considering the dual-arm robot's operation range. Second, we plan the path using the rapidly exploring random tree so that the arms do not collide, enabling the robot to perform efficient pick-and-place work based on the MILP planning solution. The effectiveness of the proposed method is confirmed by simulations and experiments using an actual dual-arm robot.

In Conclusion, we focused on the pick-and-place work of a dual-arm robot and proposed a motion planning method that minimizes the time taken to finish the work. Compared to the conventional method, which determines which arm moves an object only using the object positions, the proposed method in the simulation results plans a path that considers the dual-arm robot's operation range and minimizes the maximum path length of the arms. It was confirmed that the proposed method minimized the time taken to finish the pick-and-place work. It was also confirmed that the path planning using the RRT enabled the dual-arm robot to execute the pick-and-place work without collisions between the arms.

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We extend our gratitude to few of the Lab Assistants and Lab heads for helping us with information of few components used in our project.

The success and final outcome of this project required a lot of guidance and assistance from many people, and we are extremely fortunate that we have got this all from along the completion of our project work. Whatever we have done is only due to such guidance and assistance and we would like to thank them for their kind support.

D.D.S.M.Harshavardhan
Vuyyuru Shanmukha Reddy
Boppana Sai Abhiram

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CHAPTER-1

INTRODUCTION

1.1. INTRODUCTION

The evolution of robotics has been marked by a relentless pursuit of precision, adaptability, and efficiency, reflecting humanity's quest to augment and amplify its capabilities through technological innovation. In this trajectory, the advent of dual-arm robotic systems has emerged as a pivotal milestone, heralding a new era of robotic manipulation characterized by enhanced dexterity and versatility. Concurrently, the integration of magnetic pick and place functionality represents a paradigm shift in robotic manipulation techniques, offering novel solutions to challenges encountered in various industrial and research domains.

This thesis embarks on a comprehensive exploration of the design, development, and application of a dual-arm magnetic pick and place robot, underpinned by the utilization of Arduino microcontrollers, stepper motors, and A4988 stepper drivers. Positioned at the confluence of robotics, mechatronics, and automation, the project endeavours to bridge the gap between theoretical concepts and practical implementations, with a keen focus on addressing real-world challenges and requirements.

In conclusion, the proposed dual-arm magnetic pick and place robot represents a testament to the transformative potential of interdisciplinary collaboration and technological ingenuity, with ramifications extending far beyond the confines of academia and industry. By fostering a symbiotic relationship between theory and practice, innovation and application, this project seeks to usher in a new epoch of automation characterized by efficiency, adaptability, and human-centric design principles, ultimately empowering individuals and enterprises alike to thrive in an increasingly automated and interconnected world.

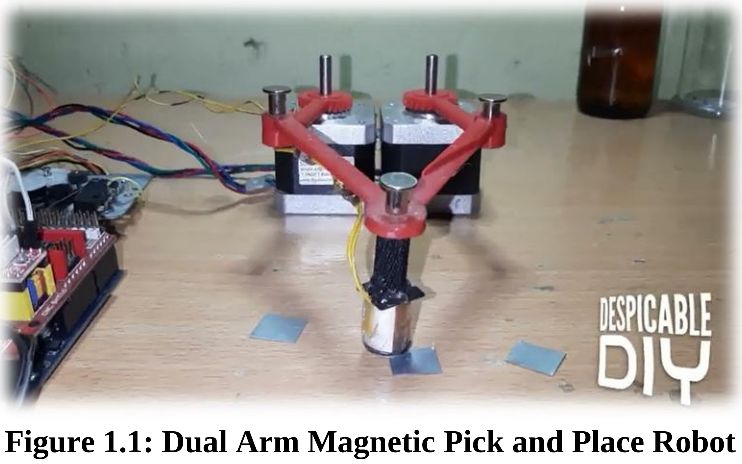

Figure 1.1: Dual Arm Magnetic Pick and Place Robot

1.2. NEED OF PROJECT

The imperatives driving the inception and execution of this project are manifold, stemming from the exigencies of contemporary industrial landscapes and the burgeoning demand for innovative automation solutions capable of addressing multifaceted challenges:

- **Optimization of Operational Workflows:** In an era characterized by escalating demands for efficiency and productivity, the integration of magnetic pick and place capabilities into a dual-arm robotic platform holds the promise of streamlining operational workflows and expediting task completion timelines across diverse industrial sectors, ranging from manufacturing and logistics to warehousing and beyond.
- **Mitigation of Labor-Intensive Processes**: By automating labour-intensive and repetitive handling tasks traditionally reliant on human intervention, the dual-arm magnetic pick and place robot not only liberates human capital for more value-added endeavours but also mitigates the risk of ergonomic injuries and fatigue associated with manual labour, fostering a safer and more conducive work environment.
- **Enhancement of Product Quality and Consistency:** Leveraging the precision and repeatability inherent to robotic manipulation, the project seeks to elevate standards of product quality and consistency, thereby fortifying the competitive positioning of enterprises operating within highly regulated industries such as electronics manufacturing, pharmaceuticals, and automotive assembly.
- **Promotion of Technological Accessibility and Affordability:** By leveraging open-source hardware and software platforms such as Arduino, the project endeavours to democratize access to advanced robotic technologies, lowering barriers to entry for aspiring roboticists, researchers, and entrepreneurs, and catalysing grassroots innovation and entrepreneurship within the global robotics community.

1.3 OBJECTIVES

The overarching objectives guiding this endeavour are delineated as follows:

- **Holistic Mechanical Design:** Forge a robust and meticulously engineered mechanical framework to serve as the structural backbone of the dual-arm robot, balancing considerations of rigidity, weight, and scalability to facilitate seamless integration with magnetic pick and place mechanisms.
- **Synergistic Control System Architecture:** Architect a cohesive and synergistic control system, leveraging the computational prowess of Arduino microcontrollers to orchestrate the synchronized motion and precise manipulation of the dual-arm robot, fostering seamless coordination and synergy between its constituent subsystems.
- **Integration of Magnetic Pick and Place Modules:** Seamlessly integrate specialized magnetic grippers into the end-effectors of the robotic arms, harnessing the unique properties of magnetic attraction to enable the efficient and secure handling of ferromagnetic objects across a spectrum of shapes, sizes, and weights.
- **Algorithmic Refinement and Optimization:** Pioneering the development of bespoke algorithms tailored to the unique operational requirements of the dual-arm magnetic pick and place robot, spanning diverse domains such as path planning, object detection, trajectory optimization, and collision avoidance, thereby underpinning its autonomous operation and adaptive capabilities.
- **Rigorous Performance Evaluation and Validation:** Conduct exhaustive testing and validation procedures to rigorously evaluate the operational capabilities and performance metrics of the dual-arm magnetic pick and place robot across a gamut of simulated and real-world scenarios, iteratively refining and optimizing its functionality to align with user expectations and industry standards.

CHAPTER-2

DESIGN AND FABRICATION

2.1 CAD DESIGN

Cad design is obtained from the internet and 3d printed it

2.2 FABRICATION

2.2.1 STEPPER MOTOR CONNECTIONS

- **Motor X**: The A and A', B and B' wires are connected to the corresponding pins (22-25) on the first stepper motor driver.
- **Motor Y**: The A and A', B and B' wires are connected to the corresponding pins (8-11) on the second stepper motor driver.

2.2.2 STEPPER DRIVER CONNECTIONS

Power Supply:

- The external 12V power supply is connected to the motor driver power input pins (likely pins 26 and 27 for driver 1 and 12 and 13 for driver 2).
- The 5V power supply from the Arduino board is connected to the motor driver logic supply pins (likely pins 21 and 20 for driver 1 and 7 and 6 for driver 2).

Control Signals:

- The control signals from the Arduino board are connected to the motor driver step/direction pins (likely pins 20 and 21 for driver 1 and 6 and 7 for driver 2). These pins will be connected to Arduino pins 2, 3, 4, and 5 respectively.

Motor Windings:

- The windings of the first stepper motor (wires AA', BB') are terminated at pins 22-25 on motor driver 1.
- The windings of the second stepper motor (wires AA', BB') are terminated at pins 8-11 on motor driver 2.

2.2.3 LIMIT SWITCH CONNECTIONS

- The common (COM) terminals of both limit switches are connected to the ground pin of the Arduino board.
- The normally open (NO) contact of the first limit switch is connected to Arduino pin 6.
- The normally open (NO) contact of the second limit switch is connected to Arduino pin 7.

2.2.4 GRIPPER AND RELAY CONNECTIONS

- The input (IN) pin of the relay module is connected to Arduino pin 9.
- The ground (GND) and power supply (VCC) pins of the relay module are connected to the Arduino ground and 5V power supply respectively.
- The common (COM) terminal of the relay module is wired to the negative terminal of the 12V power supply.
- The normally closed (NC) contact of the relay module is connected to one terminal of the electromagnet.
- The remaining terminal of the electromagnet is connected to the positive terminal of the 12V power supply.

2.3 BLOCK DIAGRAM

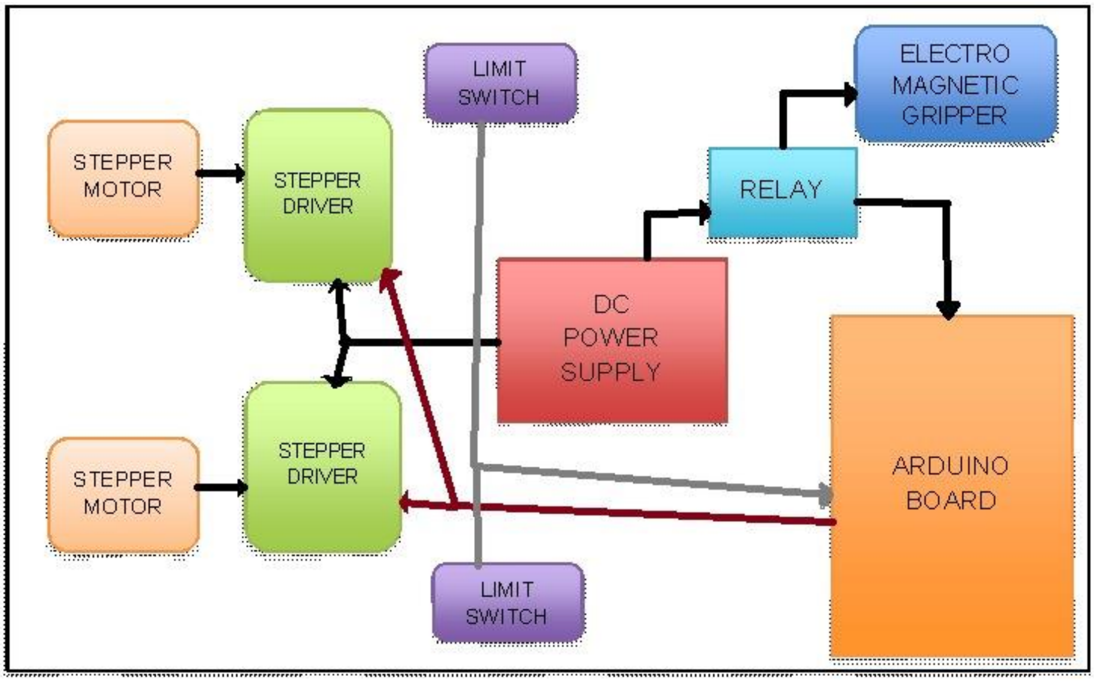

Figure 2.3: Block Diagram

CHAPTER 3
ACTUATORS, SENSORS, AND INTERFACINGS

3.1 STEPPER MOTOR

Stepper motors play a pivotal role in the functionality and performance of a dual-arm magnetic pick and place robot, offering precise control, high torque, and reliability in manipulating objects with magnetic grippers. Their suitability for such applications stems from their unique characteristics, making them indispensable components in the realm of robotics and automation.

- **Precision Positioning:** Stepper motors are renowned for their ability to move in precise increments, making them ideal for applications requiring accurate positioning, such as pick and place operations. In a dual-arm magnetic pick and place robot, stepper motors ensure that the arms move with precision, enabling the robot to manipulate objects with accuracy.
- **High Torque at Low Speeds:** Stepper motors can generate high torque even at low speeds, which is advantageous for applications requiring the manipulation of heavy or resistant objects, such as lifting and moving metallic components with magnetic grippers in a pick and place robot.
- **Step-by-Step Movement:** Stepper motors move in discrete steps, allowing for precise control over the motion of robotic arms. This characteristic is particularly useful for applications where the robot needs to follow predetermined paths or execute predefined sequences of movements, such as in assembly or sorting tasks.

Figure 3.1: Stepper Motor

3.2 STEPPER DRIVER-A4988

The A4988 stepper motor driver serves as a critical component in the dual-arm magnetic pick and place robot, facilitating precise control, synchronization, smooth motion, and reliability of the stepper motors. Its role is indispensable in ensuring the successful execution of pick and place tasks with accuracy and efficiency.

Table 3.2.1: Stepper Driver specifications

Minimum operating voltage	8 V
Maximum operating voltage	35 V
Continuous current per phase	1 A
Maximum current current phase	2 A
Minimum logic voltage	3 V
Maximum logic voltage	5.5 V
Microstep resolution	FULL, ½, ¼, 1/8 AND 1/6
Reverse voltage protection	No
Dimensions	15.5 X 20.5 mm (0.6” X 0.8”)

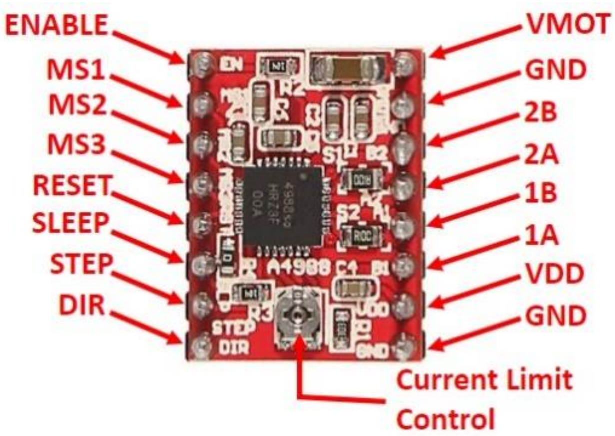

Figure 3.2.2: Stepper Driver-A4988

A4988	Connection
VMOT	8-35 V
GND	Motor Ground
SLP	Reset
RST	SLP
VDD	5V
GND	Logic Ground
STP	Pin 3
DIR	Pin 2
1A, 1B, 2A, 2B	Stepper Motor

Table 3.2.2: Stepper Driver-A4988 connection

3.3 ELECTROMAGNET

The electromagnet is a vital component in the dual-arm magnetic pick and place robot, enabling efficient, versatile, and precise manipulation of ferromagnetic objects. Its non-contact gripping capabilities, combined with adaptability and speed.

- **Versatility**: Electromagnets offer versatility in handling objects of various shapes, sizes, and weights. Unlike mechanical grippers, which may require customization for different objects, electromagnets can adapt to a wide range of materials as long as they are ferromagnetic, such as steel or iron.
- **Non-Contact Gripping**: Electromagnetic gripping provides a non-contact method of manipulation, minimizing the risk of damage to delicate or sensitive objects. This is particularly beneficial in applications where precise and gentle handling is essential, such as in assembly or electronics manufacturing.
- **Object Pickup:** The electromagnet is responsible for picking up ferromagnetic objects from a source location, such as a conveyor belt or storage bin. When activated, the electromagnet creates a magnetic field strong enough to attract and hold the object securely.
- **Object Transportation:** Once the object is picked up, the electromagnet facilitates its transportation to a desired destination. By controlling the activation and deactivation of the electromagnet, the robot can move the object along predefined paths or trajectories with precision.
- **Object Release**: Upon reaching the destination, the electromagnet releases the object by deactivating the magnetic field. This allows the object to be deposited at the desired location, such as an assembly station or packaging area, ready for further processing or handling.

Figure 3.3: Electromagnet

3.4 12V RELAY MODULE-1 CHANNEL

The 12V relay module with 1 channel plays a crucial role in the operation of the dual-arm magnetic pick and place robot, especially in controlling the activation and deactivation of the electromagnets. The 12V relay module with 1 channel plays a pivotal role in the dual-arm magnetic pick and place robot, facilitating the control of electromagnets for object gripping and releasing. Its compatibility, versatility, and reliability make it an indispensable component in the robotic system, contributing to efficient and precise manipulation of ferromagnetic objects.

Figure 3.4: 12V Relay Module – 1 Channel

Table 3.4.1: Single channel Relay module pin description

Pin Number	Pin Name	Description
1	Relay Trigger	Input to active the relay
2	Ground	0V reference
3	VCC	Supply input for powering the relay coil
4	Normally open	Normally open terminal of the relay
5	Common	Common terminal
6	Normally closed	Normally closed terminal

3.5 ARDUINO UNO

Arduino Uno plays a pivotal role in the dual-arm magnetic pick and place robot, providing centralized control, flexibility, real-time responsiveness, and sensor integration capabilities essential for efficient and intelligent operation. Its versatility and programmability empower developers to create sophisticated robotic systems tailored to specific applications and requirements.

- **Motion Control:** Arduino Uno controls the stepper motors responsible for the movement of the dual-arm robot. It generates the necessary step and direction signals to drive the stepper motors, enabling precise positioning and coordinated motion of the robotic arms during pick and place tasks.
- **Electromagnet Control:** Arduino Uno triggers the 12V relay module to activate or deactivate the electromagnets used for gripping and releasing objects. It sends control signals to the relay module based on programmed logic and sensor inputs, enabling dynamic manipulation of ferromagnetic objects.
- **Sensor Processing:** Arduino Uno processes sensor data to gather information about the robot's surroundings and the objects being manipulated. It analyzes sensor readings to detect objects, determine their positions and orientations, and make decisions regarding pick and place actions based on programmed criteria and constraints.
- **Task Execution:** Arduino Uno executes programmed algorithms and logic to perform pick and place tasks efficiently and autonomously. It coordinates the sequence of actions, monitors the status of components, handles exceptions and errors, and adapts the robot's behaviour in real-time to optimize performance and achieve desired objectives.

Figure 3.5: Arduino uno

3.6 INTERFACING (FLOWCHART)

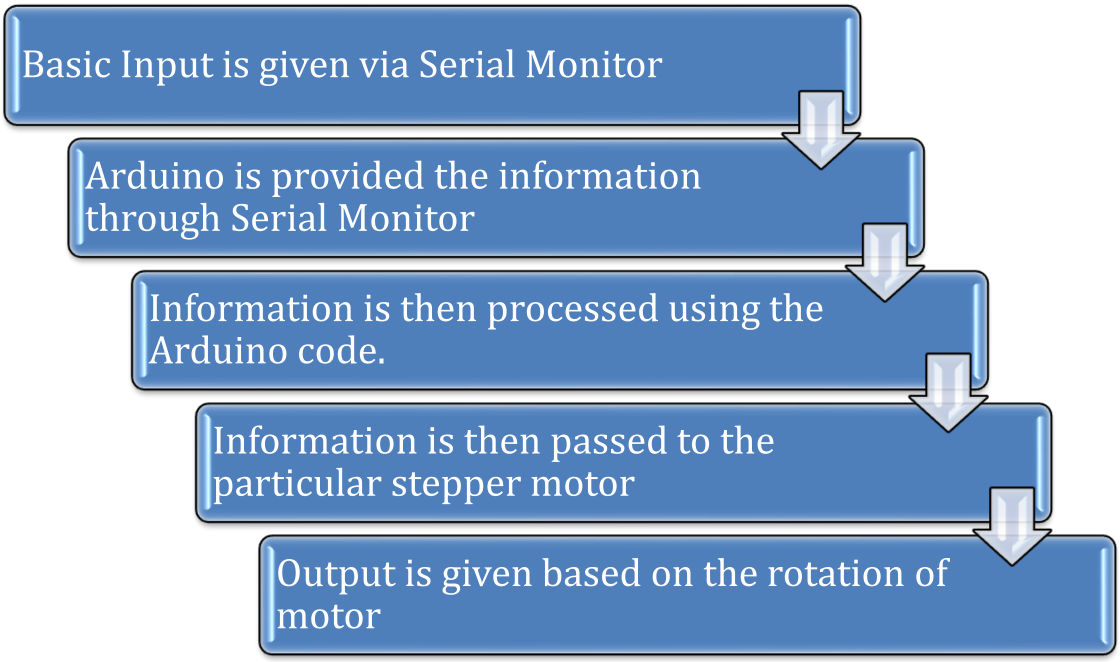

Figure 3.6: Interfacing (Flowchart)

The entire workflow is shown in Fig 3.6 where each and every function has been explained. As the first function, basic input has received through Serial Monitor. The information is then passed and processed through Arduino Uno, which gives the output as the rotation of Stepper Motor, which in turn rotates the robotic arm.

CHAPTER-4

RESULTS, DISCUSSIONS AND APPLICATIONS

4.1 RESULT

The culmination of this research is a dual-arm magnetic pick and place robot, integrating cutting-edge electromechanical components with advanced robotics principles. Utilizing Arduino Uno microcontroller, stepper motors with A4988 drivers, a 12V relay module, and electromagnets, this system epitomizes interdisciplinary synergy. Through iterative refinement, it offers versatile and precise object manipulation. Coordinated by Arduino Uno, it demonstrates synchronized motion and real-time adaptability. The 12V relay module ensures prompt electromagnet control. This robot signifies a transformative tool in industrial automation, streamlining workflows and enhancing productivity and safety. It represents a milestone in robotics, showcasing the fusion of technology and engineering to tackle real-world challenges

4.2 SCHEMATIC DIAGRAM

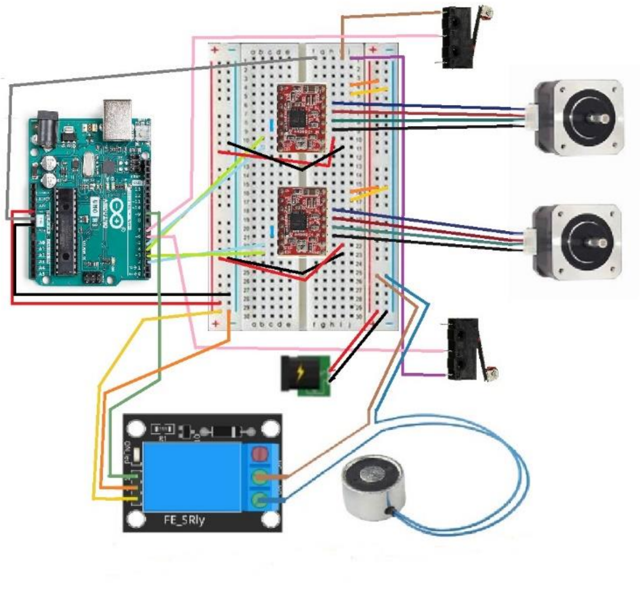

FIGURE 4.2: SCHEMATIC DIAGRAM

4.3 CONNECTIONS

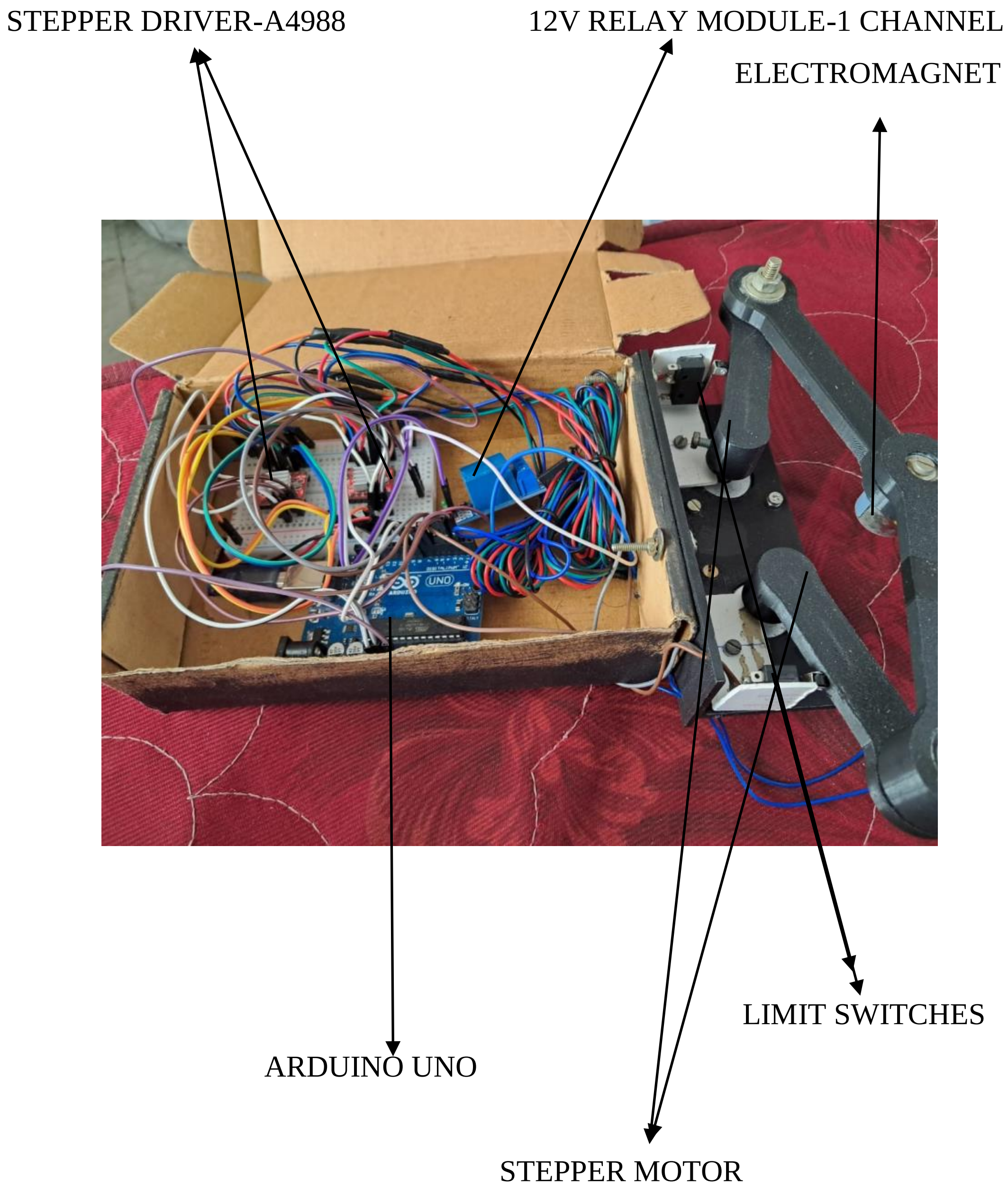

FIGURE 4.3: CONNECTIONS

4.4 CODE EXPLANATION

1. Header Includes and Pin Definitions:
   - The code includes the AccelStepper library (#include <AccelStepper.h>) for controlling stepper motors.
   - It defines several pin numbers (X_STEP_PIN, X_DIR_PIN, X_LIMIT_PIN, Y_STEP_PIN, Y_DIR_PIN, Y_LIMIT_PIN, GRIPPER_PIN) for connecting the stepper motors, limit switches, and a gripper.

2. Motor Configuration:
   - The code creates two AccelStepper objects, xMotor and yMotor, for controlling the stepper motors.
   - It sets the motor driver type to AccelStepper::DRIVER.
   - It defines the number of steps per revolution (STEPS_PER_REV) and microsteps (MICROSTEPS) for the motors.

3. Motor Parameters:
   - The code sets the maximum speed (MAX_SPEED) and acceleration (ACCELERATION) for both motors.

4. Setup Function:
   - In the setup() function:
     - It sets the pin modes for the limit switches and the gripper pin.
     - It calls the homeMotors() function to home the motors.
     - It initializes the Serial communication at a baud rate of 9600.

5. Loop Function:
   - In the loop() function:
     - It checks if data is available from the Serial port.
     - If data is available, it reads two floating-point numbers (xAngle and yAngle) from the Serial port.
     - It inverts the yAngle to account for the flipped Y-axis orientation.
     - It prints the angles to the Serial port for debugging.
     - It calculates the target positions (xPos and yPos) based on the angles.
     - It commands the motors to move to those positions using xMotor.moveTo(xPos) and yMotor.moveTo(yPos).
     - It waits until both motors have completed their movements by checking xMotor.run() and yMotor.run().

4.5 APPLICATIONS

Dual arm pick and place robots are commonly used in various industrial applications were precise and efficient handling of objects is required. Some common applications include:

1. **Assembly line operations:** Dual arm pick and place robots can be used to assemble products by picking up components from one location and placing them in the correct position for assembly.
2. **Material handling:** These robots can be used for picking up and moving heavy or delicate materials in manufacturing facilities, warehouses, and distribution centres.
3. **Packaging and palletizing:** Dual arm pick and place robots can be used for picking and placing items into packaging containers or onto pallets for shipping.
4. **Electronics manufacturing:** These robots can be used for handling delicate electronic components during the assembly process to ensure accuracy and precision.
5. **Food and beverage industry:** Dual arm pick and place robots can be used for sorting, packing, and palletizing food and beverage products in processing plants and distribution centres.
6. **Pharmaceutical industry:** These robots can be used for handling and packaging medications, medical devices, and other pharmaceutical products with high precision and cleanliness standards. Overall, dual arm pick and place robots are versatile tools that can improve efficiency, accuracy, and safety in a wide range of industrial applications.

4.6 LIST OF COMPONENTS USED

S.NO	COMPONENT NAME	QUANTITY
1	STEPPER MOTOR	2
2	RELAY MODULE	1
3	DC POWER SUPPLY	1
4	POWER CORD	1
5	JUMPER WIRES	-
6	A4988-STEPPER DRIVER	2
7	GRIPPER	1
8	ARDUINO UNO	1
9	LIMIT SWITCH	2
10	ARDUINO CABLE	1
11	BREADBOARD	1

TABLE 4.6: LIST OF COMPONENTS

CHAPTER-5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In this study, we focused on the pick-and-place work of a dual-arm robot and proposed a motion planning method that minimizes the time taken to finish the work. Compared to the conventional method, which determines which arm moves an object only using the object positions, the proposed method in the simulation results plans a path that considers the dual-arm robot’s operation range and minimizes the maximum path length of the arms. It was confirmed that the proposed method minimized the time taken to finish the pick-and-place work. It was also confirmed that the path planning using the RRT enabled the dual-arm robot to execute the pick-and-place work without collisions between the arms.

5.2 FUTURE SCOPE

In the future, we need to examine in more detail the following two topics. The first is hand-over work. The dual-arm robot needs to be able to hand over an object from the left to right arm if the existing object can only be reached by the left arm and the goal position point can only be reached by the right arm (and vice versa). Second, we plan to extend the CA to three-dimensional space, that is, xyzzy coordinates on the plane

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APPENDIX

Code:

```
#include <AccelStepper.h>

#define X_STEP_PIN 2

#define X_DIR_PIN 3

#define X_LIMIT_PIN 6

#define Y_STEP_PIN 4

#define Y_DIR_PIN 5

#define Y_LIMIT_PIN 7

#define GRIPPER_PIN 9

#define STEPS_PER_REV 200

#define MICROSTEPS 16

#define MAX_SPEED 1000.0

#define ACCELERATION 1000.0

AccelStepper xMotor(AccelStepper::DRIVER, X_STEP_PIN, X_DIR_PIN);

AccelStepper yMotor(AccelStepper::DRIVER, Y_STEP_PIN, Y_DIR_PIN);

void setup() {

  xMotor.setMaxSpeed(MAX_SPEED);

  xMotor.setAcceleration(ACCELERATION);

  yMotor.setMaxSpeed(MAX_SPEED);

  yMotor.setAcceleration(ACCELERATION);

  pinMode(X_LIMIT_PIN, INPUT_PULLUP);

  pinMode(Y_LIMIT_PIN, INPUT_PULLUP);

  pinMode(GRIPPER_PIN, OUTPUT)
```

```
  homeMotors();
  Serial.begin(9600);
}
void loop() {
  if (Serial.available()) {
    float xAngle = Serial.parseFloat();
    float yAngle = Serial.parseFloat();
    yAngle= -1*yAngle;
    Serial.print("angle x:");
    Serial.print(xAngle,'\n');
    Serial.print(" angle y:");
    Serial.println(yAngle,'\n');
    if( xAngle>0 &&yAngle<0 )
    {int xPos = angleToPosition(xAngle);
    int yPos = angleToPosition(yAngle);
    xMotor.moveTo(xPos);
    yMotor.moveTo(yPos);}
    while (xMotor.run() || yMotor.run()) {}
```