Design and Fabrication of Pick and Place Robot

Abhijeet Nikam[1], Deep Parab[2], Yash Salunke[3], Jidnyasa Magar[4]
[1, 2, 3, 4]Dept of Mechanical Engineering
[1, 2, 3, 4]Savitribai Phule Pune University, Pune, India

Abstract- *Industrial automation has become an important part of modern manufacturing systems to improve productivity, precision, and efficiency. This paper presents the design and fabrication of a 5-Degree of Freedom (5-DOF) robotic arm for pick-and-place operations. The robotic arm is designed to automate repetitive material handling tasks commonly performed in industrial environments. The system consists of a mechanical arm structure, servo motors, gripper mechanism, Arduino Uno microcontroller, and control circuitry. CAD modelling of the robotic arm was carried out using CATIA software, and the components were fabricated using 3D printing technology with ABS plastic material. Kinematic analysis and torque calculations were performed to ensure proper movement and stability of the robotic arm. The developed robotic arm is capable of accurately picking and placing lightweight objects within a specified workspace. The system provides a cost-effective and flexible solution for small-scale industrial automation and educational applications.*

Keywords: Robotic Arm, Pick and Place Robot, Arduino Uno, Industrial Automation, 5-DOF

I. INTRODUCTION

Automation and robotics play an important role in modern industries by reducing manual effort and improving production efficiency. Robotic arms are widely used in manufacturing industries for operations such as material handling, assembly, packaging, welding, and pick-and-place applications. Pick-and-place robotic systems are mainly used for transferring objects from one location to another with high accuracy and repeatability.

The objective of this project is to design and fabricate a 5-DOF robotic arm capable of performing pick-and-place operations for lightweight industrial objects. The robotic arm is controlled using an Arduino Uno microcontroller and servo motors. The arm structure is designed using CATIA software and fabricated using 3D printing techniques.

The developed robotic arm consists of mechanical links, joints, servo motors, gripper mechanism, and a control system. The robotic arm provides a low-cost and flexible automation solution suitable for educational and small-scale industrial applications.

II. LITERATURE REVIEW

Several researchers have worked on robotic arms and industrial automation systems for pick-and-place applications.

1) Sharath Surati et al. discussed the importance of robotic arms in reducing human effort and improving productivity in industrial applications. Their work focused on robotic manipulators and automation techniques.
2) Adham Mohamed et al. presented the design and control of a robotic manipulator using Arduino Mega and servo motors for pick-and-place operations. The study included kinematic analysis and trajectory control of the robotic arm.
3) Kunal Chopade et al. developed a PLC-based pick-and-place robotic arm system using DC motors and gripper mechanisms for industrial automation.
4) Atharva Kulkarni et al. designed an Arduino Uno based robotic arm controlled using a mobile application through Bluetooth communication.

The review of existing systems helped in understanding robotic arm mechanisms, control systems, and actuator selection for developing the proposed robotic arm.

III. OBJECTIVES

The main objectives of the project are:

1. To design and develop a 5-DOF robotic arm.
2. To perform pick-and-place operations for lightweight objects.
3. To develop a gripper mechanism for object handling.
4. To integrate servo motors for joint movement.
5. To implement Arduino-based control of the robotic arm.
6. To perform kinematic and torque analysis.
7. To fabricate and test the robotic arm prototype.

IV. METHODOLOGY

The development of the robotic arm was carried out using the following steps:

1. Requirement analysis and study of pick-and-place operations.
2. Selection of 5-DOF configuration for proper movement and flexibility.
3. Design calculations for link dimensions and torque requirements.
4. CAD modelling of the robotic arm using CATIA software.
5. Selection of materials, servo motors, and electronic components.
6. Fabrication of components using 3D printing.
7. Assembly of mechanical and electronic systems.
8. Programming of Arduino Uno for robotic arm control.
9. Testing and validation of the robotic arm performance.

V. CAD MODELING AND DESIGN

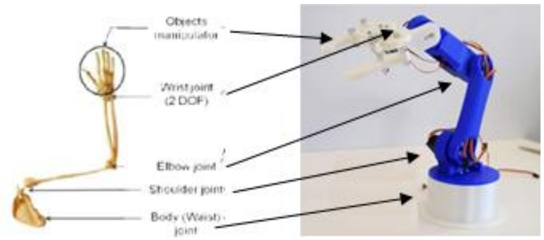
The CAD model of the robotic arm was developed using CATIA V5 software. The robotic arm consists of a base platform, multiple links, joints, servo housings, and a gripper mechanism. ABS plastic material was selected due to its lightweight properties and ease of manufacturing using 3D printing.

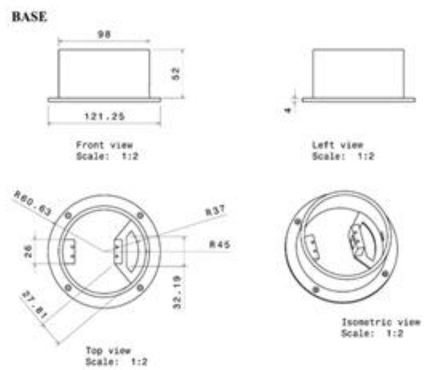
The robotic arm consists of five rotational joints that provide flexibility and movement within the workspace. Servo motors are mounted at each joint to provide controlled rotational motion. The gripper mechanism is designed to securely hold and release lightweight objects during operation.

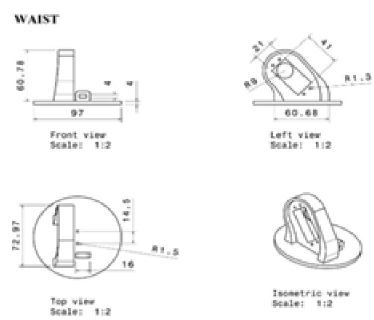
The robotic arm structure was designed considering:

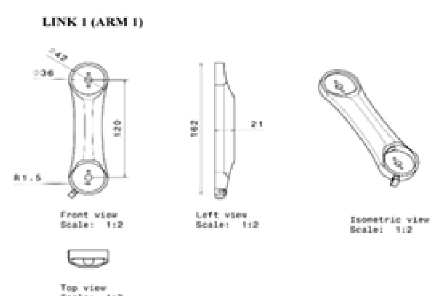
- Lightweight construction
- Structural stability
- Easy assembly
- Smooth joint movement
- Low power consumption

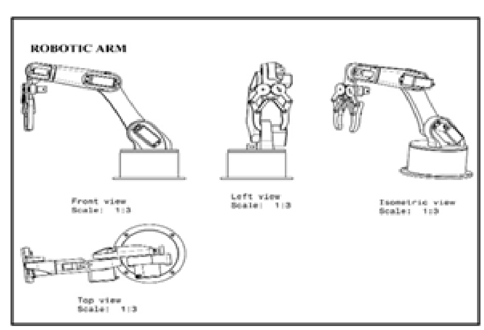
CAD simulations were performed to validate the movement and interference between components.











VI. COMPONENTS USED

Sr. No.	Component	Description
1	Arduino Uno	Main controller
2	Servo Motors	Joint actuation
3	Gripper Mechanism	Object handling
4	HC-05 Bluetooth communication	Wireless Module
5	ABS Plastic	Structural components Parts
6	Power Supply	Electrical power source
7	Jumper Wires and PCB	Electrical connections

VII. ANALYSIS AND CALCULATIONS

A. Kinematic Analysis

Kinematic analysis is used to determine the position, movement, and workspace of the robotic arm without considering the forces acting on the system. The developed robotic arm consists of five degrees of freedom (5-DOF), which provide sufficient flexibility for pick-and-place operations.

The robotic arm includes:

- Base rotation
- Shoulder movement
- Elbow movement
- Wrist rotation
- Gripper actuation

The forward kinematics of the robotic arm is used to determine the position of the end effector based on joint angles and link lengths.

The position of the end effector is calculated using:

$$X = L_1 \cos \theta_1 + L_2 \cos (\theta_1 + \theta_2)$$
$$Y = L_1 \sin \theta_1 + L_2 \sin (\theta_1 + \theta_2)$$

Where:

- L_1= Length of first link
- L_2= Length of second link
- θ_1= Joint angle of first link
- θ_2= Joint angle of second link

The calculated workspace confirmed that the robotic arm can successfully reach the required pick-and-place locations within the designed operating area.

B. Dynamic Analysis

Dynamic analysis is used to determine the torque and force requirements for proper movement of the robotic arm joints.

The torque required at each joint is calculated using:

$$T = F \times r$$

Where:

- T= Torque (N-m)
- F= Force acting on the joint (N)
- r= Distance from joint axis (m)

The force acting on the arm is calculated by:

$$F = m \times g$$

Where:

- m= Mass of object (kg)
- g= Acceleration due to gravity (9.81 m/s²)

Sample Calculation:

Assuming:

- Mass of payload = 0.5 kg
- Distance from joint = 0.15 m

Force acting on arm:

$$F = 0.5 \times 9.81$$
$$F = 4.905 \text{ N}$$

Torque required:

$$T = 4.905 \times 0.15$$
$$T = 0.73575 \text{ N-m}$$

Based on the calculated torque values, suitable servo motors were selected for smooth and reliable operation of the robotic arm.

The analysis confirmed that the robotic arm structure and selected actuators are capable of handling lightweight objects during pick-and-place operations.

VIII. FABRICATION AND ASSEMBLY

The robotic arm components were fabricated using 3D printing technology. Individual parts such as links, base platform, gripper components, and servo housings were printed separately and assembled using fasteners.

Servo motors were integrated at each joint and connected to the Arduino Uno controller. The electrical connections were completed using jumper wires, power supply modules, and PCB boards.

The robotic arm was programmed using Arduino IDE software. Servo motor signals were used to control the movement of each joint and perform pick-and-place operations.

IX. RESULTS AND DISCUSSION

The developed robotic arm successfully performed pick-and-place operations for lightweight objects within the designed workspace. The robotic arm demonstrated smooth movement, proper gripping action, and good positioning accuracy.

The system showed the following results:

- Successful object pickup and placement
- Stable operation of servo motors
- Smooth joint movement
- Good repeatability and positioning accuracy
- Reliable operation within the specified workspace

The robotic arm provides a cost-effective solution for small-scale industrial automation and educational applications.

X. CONCLUSION

This project presented the design and fabrication of a 5-DOF robotic arm for pick-and-place applications. The robotic arm was successfully designed using CATIA software and fabricated using 3D printing technology. Arduino Uno and servo motors were used to control the movement of the robotic arm.

The developed robotic arm demonstrated the ability to perform accurate and repeatable pick-and-place operations for lightweight objects. The system is economical, flexible, and suitable for educational as well as industrial automation applications.

Future improvements may include machine vision, artificial intelligence, higher payload capacity, and advanced automation features.

XI. ACKNOWLEDGMENT

The authors express sincere gratitude to Prof. Dr. N.D Rao, Department of Mechanical Engineering, PK Technical Campus, for valuable guidance and support throughout the project work.

REFERENCES

[1] Sharath Surati, Shaunak Hedaoo, Tushar Rotti, Vaibhav Ahuja, Nishigandha Patel, “Pick and Place Robotic Arm”, IRJET.
[2] Adham Mohamed, Ahmed Abd-Elmonen, Ahmed Asem, Ahmed Atef, Ahmed Kamal, “Design and Control of a Robotic Manipulator for Pick and Place Applications”.
[3] Kunal Chopade, Abhiraj Bholane, Prasad Naifade, Jitendra Gaikwad, “Pick and Place Robotic ARM using PLC”, IJERT.
[4] Atharva Kulkarni, Shrinidhee Kulkarni, Ajay Kulsange, Shubham Mane, Deepak Munde, “Robotic Arm using Arduino Uno”, IJRASET.
[5] Arduino Uno Technical Documentation.