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Design and Control of a 3-DOF Robotic Arm Using Potentiometer Feedback

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Abstract- This research paper presents the design, development, and implementation of a 3-Degree of Freedom (3-DOF) robotic arm using potentiometer-based feedback and an Arduino controller. The system focuses on achieving accurate position control through closed-loop feedback. The proposed model integrates mechanical design, kinematic modeling, electronic interfacing, and embedded programming. Potentiometers are used to monitor joint angles and improve precision and repeatability. The system is cost-effective and suitable for educational and light industrial applications.

Keywords— Robotic Arm, 3-DOF, Arduino, Potentiometer Feedback, Servo Motors, Automation

I. INTRODUCTION

Robotic arms play a crucial role in automation and manufacturing industries. With advancements in embedded systems and sensors, robotic systems have become more accessible and affordable. A 3-DOF robotic arm provides sufficient flexibility for basic manipulation tasks such as pick-and-place, drawing, and sorting.

Traditional robotic arms often rely on open-loop control, which lacks accuracy. This research introduces potentiometer-based feedback to enhance precision and reliability. The integration of feedback allows real-time monitoring of joint positions, making the system more robust.

II. LITERATURE REVIEW

Various studies have explored robotic arm designs using Arduino and servo motors. Previous work highlights the importance of kinematics, control algorithms, and hardware optimization. Some research focuses on drawing robots, while others emphasize industrial applications.

Recent advancements include feedback-based systems where sensors improve accuracy. Potentiometers are widely used due to their

simplicity, low cost, and ease of integration. This paper combines insights from multiple research works to develop a comprehensive system.

III. SYSTEM OVERVIEW

The system consists of mechanical, electrical, and control subsystems. The robotic arm includes three joints controlled by servo motors. Each joint is equipped with a potentiometer to measure angular displacement.

Main components

- Mechanical structure (3 links and joints)
- Servo motors (actuators)
- Potentiometers (feedback sensors)
- Arduino Uno (controller)
- Power supply unit

Mechanical Design

The robotic arm is designed with three rotational joints:

- Base rotation (Joint 1)
- Shoulder joint (Joint 2)
- Elbow joint (Joint 3)

Materials such as aluminum and acrylic are used to ensure strength and lightweight construction. Proper alignment and joint stability are essential for smooth operation.

Kinematic Analysis

Kinematics is essential for determining the position and motion of the robotic arm. Forward kinematics calculates the end-effector position based on joint angles.

$X = L1*\cos(\theta1) + L2*\cos(\theta1+\theta2) + L3*\cos(\theta1+\theta2+\theta3)$ $Y = L1*\sin(\theta1) + L2*\sin(\theta1+\theta2) + L3*\sin(\theta1+\theta2+\theta3)$

Inverse kinematics is used to determine joint angles for a desired position. This improves accuracy and control.

Hardware Implementation The hardware system includes:

- Arduino Uno microcontroller
- Three servo motors
- Three potentiometers
- External power supply

Each potentiometer is connected to the analog input pins of the Arduino. Servo motors are connected to PWM pins. The feedback signal from potentiometers is used to adjust motor position.

Circuit Design

The circuit integrates servo motors and potentiometers with Arduino. Proper grounding and power supply are critical. External power ensures stable motor operation.

Control System

The control system uses feedback from potentiometers to adjust servo positions. This creates a closed-loop control system.

Steps:

- Read potentiometer value
- Compare with desired position
- Adjust servo angle
- Repeat continuously

This improves precision and reduces error.

Arduino Programming

The Arduino code reads analog values and controls servos accordingly. The program ensures smooth movement and accurate positioning.

IV. RESULTS AND DISCUSSION

The system demonstrates improved accuracy compared to open-loop systems. The potentiometer feedback allows real-time correction. The robotic arm performs tasks such as object handling and drawing efficiently.

Applications

- Industrial automation
- Educational projects
- Medical assistance devices
- Pick-and-place operations

Advantages

- Low cost
- High accuracy due to feedback
- Easy implementation
- Scalable design

Limitations

- Limited payload capacity
- Accuracy depends on sensor quality
- Requires calibration

Future Scope

Future work can include:

- Adding more DOF
- Using advanced sensors
- Implementing AI-based control

V. CONCLUSION

This paper presents a cost-effective and efficient 3-DOF robotic arm with potentiometer feedback. The system demonstrates improved accuracy and reliability. It is suitable for various applications and provides a strong foundation for further research.

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