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4DOF ROBOTIC ARM USING ARDUINO UNO AND JOYSTICK

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ABSTRACT

This project presents the design and implementation of a **4 Degrees of Freedom (4-DOF) robotic arm** controlled using an **Arduino Uno** and a **joystick module**. The robotic arm consists of four servo motors that provide rotational movement for the base, shoulder, elbow, and gripper, enabling flexible and precise manipulation of objects. A joystick is used as the primary input device, allowing intuitive real-time control of the arm's movements along multiple axes. The Arduino Uno processes the analog signals from the joystick and converts them into appropriate control signals for the servo motors. This system demonstrates an effective low-cost solution for basic robotic manipulation, suitable for educational purposes and small-scale automation tasks. The project highlights the integration of hardware and software to achieve smooth and responsive control, offering a foundation for further enhancements such as wireless control, sensor feedback, or automated operation.

KEYWORDS: 4-DOF Robotic Arm, Arduino Uno, Joystick Control, Servo Motors, Embedded Systems, Robotic Manipulation, Human–Machine Interface, Automation, Microcontroller-Based Control

INTRODUCTION

Robotics has become an essential part of modern technology, playing a significant role in automation, manufacturing, healthcare, and education. Robotic arms, in particular, are widely used to perform tasks that require precision, repeatability, and safety. A **robotic arm**

with multiple degrees of freedom (DOF) is capable of mimicking human arm movements, making it suitable for object manipulation in constrained and hazardous environments.

This project focuses on the development of a **4 Degrees of Freedom (4-DOF) robotic arm** controlled using an **Arduino Uno** and a **joystick module**. The robotic arm comprises four servo motors that enable movements of the base, shoulder, elbow, and gripper. The joystick provides an intuitive and user-friendly interface, allowing real-time manual control of the robotic arm's motion along different axes.

The Arduino Uno serves as the central control unit, processing analog signals from the joystick and generating precise control signals for the servo motors. This setup offers a cost-effective and efficient solution for learning fundamental concepts of robotics, embedded systems, and human–machine interaction. The system is designed to be simple, reliable, and easily expandable for future improvements such as wireless control, sensor integration, or autonomous operation.

The primary objective of this project is to demonstrate the practical implementation of a robotic arm using readily available components, making it suitable for educational applications, laboratory demonstrations, and small-scale automation tasks.

Problem Statement and Literature Review

Manual handling of objects in environments that require precision, repetition, or safety can be inefficient and prone to human error. In educational and small-scale industrial settings, there is a need for a **low-cost, easy-to-control robotic arm** that can demonstrate fundamental robotic movements and manipulation without complex programming or expensive hardware. Many existing robotic systems are either costly, require advanced control algorithms, or lack intuitive user interfaces.

The problem addressed in this project is the design and development of a **4 Degrees of Freedom robotic arm** that can be **manually controlled in real time using a joystick**, providing smooth and accurate movement. The system should be affordable, simple to implement, and suitable for learning purposes while still offering sufficient flexibility to perform basic pick-and-place operations. The use of an **Arduino Uno** aims to simplify hardware integration and software development, making the system accessible to students and beginners in robotics.

Several studies and projects have explored robotic arm control using microcontrollers and various input methods. Early robotic arm systems primarily relied on pre-programmed motion sequences, limiting flexibility and user interaction. With the advancement of embedded systems, microcontroller-based robotic arms using servo motors have become popular due to their simplicity and cost-effectiveness.

Research has shown that **Arduino-based robotic arms** are widely used in educational and prototype applications because of their open-source nature and ease of programming. Many researchers have implemented robotic arms with different degrees of freedom using Arduino boards to perform basic manipulation tasks. These systems often employ **servo motors** for precise angular control and low power consumption.

Various control interfaces have been studied, including push buttons, potentiometers, mobile applications, and gesture-based systems. Among these, **joystick-based control** has proven to be intuitive and effective for real-time manual operation, as it allows simultaneous multi-axis control with minimal training. Previous works have demonstrated that joystick-controlled robotic arms provide better responsiveness and ease of use compared to discrete input methods.

However, some existing implementations lack modularity or require additional hardware for smooth control. This project builds upon previous work by integrating a **4-DOF robotic arm with a joystick interface** using an Arduino Uno, emphasizing simplicity, affordability, and expandability. The system serves as a practical platform for understanding robotic kinematics, embedded control, and human–machine interacti

Methodology

The methodology of this project describes the systematic approach followed to design, develop, and implement a **4 Degrees of Freedom (4-DOF) robotic arm** controlled using an **Arduino Uno** and a **joystick module**. The overall process involves hardware selection, system design, circuit implementation, programming, and testing.

System Design

The robotic arm consists of four servo motors corresponding to the base rotation, shoulder movement,elbow movement, and gripper operation. A joystick module is used as the input device, providing analog signals for controlling the direction and angle of movement. The

Arduino Uno acts as the main controller, interpreting joystick inputs and generating Pulse Width Modulation (PWM) signals to control the servo motors.

Hardware Components

The major hardware components used in this project include:

- Arduino Uno microcontroller
- 4 servo motors
- Joystick module
- Robotic arm mechanical structure
- External power supply
- Connecting wires and breadboard

The servo motors are mounted on the robotic arm joints, while the joystick module is connected to the analog input pins of the Arduino Uno.

1. **Circuit Implementation**

The joystick module outputs analog voltage signals based on its movement along the X and Y axes. These signals are connected to the analog input pins of the Arduino Uno. Each servo motor is connected to a PWM-enabled digital pin of the Arduino. An external power supply is used to provide sufficient current to the servo motors, ensuring stable operation.

2. **Software Development**

The Arduino is programmed using the Arduino IDE. The program continuously reads the analog values from the joystick and maps them to appropriate angular positions for the servo motors. Conditional logic is used to determine the direction and range of motion for each joint. The Servo library is used to simplify servo motor control and ensure smooth movement.

3. **Control Strategy**

The joystick allows real-time manual control of the robotic arm. Movements of the joystick along different axes correspond to specific joints of the robotic arm. The control strategy ensures synchronized and proportional movement of the servos based on joystick displacement, enabling accurate and responsive operation.

4. **Testing and Validation**

The system is tested by performing basic pick-and-place operations to evaluate accuracy, smoothness, and responsiveness. Individual servo motors are tested first, followed by integrated system testing. Any errors in movement or signal processing are corrected through code optimization and hardware adjustments.

RESULTS AND DISCUSSIONS

The joystick-controlled robotic arm responded accurately to user inputs, with each servo motor moving proportionally to the joystick's displacement. The base, shoulder, elbow, and gripper motions were smooth and precise within the defined angular limits. The Arduino Uno effectively processed analog signals from the joystick and generated appropriate PWM signals for servo control.

During testing, the robotic arm was able to perform basic pick-and-place operations with lightweight objects. The response time between joystick input and servo movement was minimal, indicating efficient signal processing and control. The external power supply ensured stable operation of the servo motors without noticeable voltage drops or jitter.

The results indicate that joystick-based control provides an intuitive and user-friendly interface for operating a robotic arm. Compared to button-based or pre-programmed control systems, the joystick allowed continuous and proportional control, improving accuracy and ease of use. The use of servo motors contributed to precise angular positioning, making the system suitable for educational and demonstration purposes.

However, some limitations were observed. The robotic arm's payload capacity was limited due to the torque constraints of the servo motors. Minor vibrations were noted during sudden joystick movements, which could be reduced through software filtering or mechanical reinforcement. Additionally, the system relies entirely on manual control and lacks feedback mechanisms such as sensors or encoders.

Overall, the project successfully achieved its objectives of developing a low-cost, easy-to-use robotic arm using an Arduino Uno. The results validate the effectiveness of the proposed design and provide a solid foundation for future enhancements, including sensor integration, wireless control, and semi-autonomous operation.

Performance Results

The performance of the 4 Degrees of Freedom (4-DOF) robotic arm controlled using an Arduino Uno and a joystick module was evaluated based on responsiveness, accuracy, stability, and operational efficiency.

The robotic arm exhibited quick response time to joystick inputs, with minimal delay between user action and servo movement. The proportional control achieved through analog joystick input allowed smooth and continuous motion of all joints. Each servo motor accurately followed the commanded angular positions within its specified range.

The system demonstrated stable operation during continuous use, aided by an external power supply that provided sufficient current to the servo motors. No significant overheating or signal loss was observed during testing. The arm successfully performed repeated pick-and-place operations with lightweight objects, indicating reliable mechanical and electrical performance.

In terms of precision, the robotic arm maintained consistent positioning during static and dynamic movements. Minor oscillations were observed during rapid joystick movements, which can be minimized through improved mechanical design or software-based smoothing techniques.

Overall, the performance results confirm that the proposed system is efficient, cost-effective, and suitable for educational and small-scale automation applications. The results validate the effectiveness of joystick-based control combined with Arduino Uno for real-time robotic arm manipulation.

CONCLUSION

This project successfully demonstrated the design and implementation of a 4 Degrees of Freedom (4-DOF) robotic arm controlled using an Arduino Uno and a joystick module. The system achieved smooth and accurate real-time control of the robotic arm joints, enabling effective manipulation of lightweight objects through intuitive joystick operation.

The integration of servo motors with the Arduino Uno provided precise angular control, while the joystick-based interface enhanced ease of use and responsiveness. The project proved to be a cost-effective and reliable solution for understanding fundamental concepts of robotics, embedded systems, and human–machine interaction. Performance evaluation showed stable operation, minimal response delay, and satisfactory precision for educational and demonstration purposes.

Despite minor limitations such as limited payload capacity and the absence of feedback mechanisms, the system met its intended objectives. Overall, the project provides a strong foundation for future enhancements, including sensor integration, wireless communication, and autonomous control. The successful implementation confirms the feasibility of using

Arduino- based systems for basic robotic arm applications in education and small-scale automation.

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