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Low-Cost Self-Calibrating Robotic Arm Using Potentiometer Feedback and Arduino Uno

Souvik Maiti[1], Srikant Khator[1], Souvik Jana[1], Sovan Dey Sutradhar[1], Souvik Das[1]
Anurima Majumdar[1], Palasri Dhar[1], Antara Ghosal[1]
Dept. of Electronics & Communication Engineering[1]
Guru Nanak Institute of Technology, Kolkata, India

Abstract: *The abstract describes a project that focuses on creating a low-cost robotic arm using an Arduino Uno, servo motors, and potentiometers. This robotic arm can automatically calibrate itself by using feedback from the potentiometers, which measure the position of its joints, eliminating the need for expensive sensors or manual adjustments. The design is aimed at educational settings and budget friendly projects, emphasizing affordability and ease of use while ensuring the arm operates reliably and accurately [1]*

Keywords: Robotic arm, Self- calibration, Potentiometer feedback, Arduino Uno, Low- cost robotics, Servo motor control, Closed-loop system

I. INTRODUCTION

Robotic arms are essential in various fields like manufacturing, healthcare, and education, but low-cost versions often face issues with accuracy due to factors like mechanical wear and power interruptions. This paper presents a solution by creating a self-calibrating robotic arm that uses simple components like servo motors, potentiometers, and an Arduino Uno to continuously monitor and adjust its joint angles, improving reliability without the need for expensive calibration systems. The design is cost-effective, using materials like cardboard for the arm's structure, making it accessible for educational and budget-conscious projects [2], [3].

II. LITERATURE REVIEW: SELF- CALIBRATION IN ROBOTIC ARMS

The literature review discusses various self- calibration techniques for robotic arms, which can be divided into sensor-based and model- based methods. Sensor-based systems use advanced tools like rotary encoders and cameras to accurately measure the position of the robot's joints, but these can be complex and expensive [4],[5].On the other hand, model- based approaches create mathematical models of the robot's movements and use algorithms to correct errors, which can be very accurate but require a lot of computing power and careful adjustments [6]; some researchers are also exploring hybrid methods that combine both approaches to achieve a good balance between cost and accuracy [7].

Using potentiometers to measure joint positions in robotic arms is a cost-effective solution that allows for real-time tracking without significant expenses. Research by Sharma et al. demonstrated this approach in a low-cost robotic arm [8], while other studies confirmed its reliability for simple systems [9], [10]. The proposed work builds on this idea by adding an automatic calibration routine at startup, which improves the accuracy and ease of use for budget-friendly projects.

III. METHODOLOGY: IMPLEMENTING SELF-CALIBRATION IN THE ROBOTIC ARM

A. Hardware Configuration

The methodology for implementing self-calibration in the robotic arm involves using four servo motors to control its joints, each paired with a potentiometer that measures the joint's position. An Arduino Uno microcontroller reads these measurements and adjusts the servos to ensure they start from a known position, or "home" angle, improving accuracy. This process automates calibration at startup, reducing the need for manual adjustments and making the system more user-friendly and cost- effective [11].

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B. Principle Of Operation

The principle of operation for the robotic arm's calibration involves a feedback loop between the potentiometers, which measure the joint positions, and the servo motors that control the arm's movements. When the arm powers up, the Arduino reads the voltage from the potentiometers and converts these readings into angles, which are then compared to preset 'home' angles. If the current position differs from the home position by more than a certain amount (like 5 degrees), the servo adjusts its position gradually until it aligns correctly, ensuring the arm starts from a known and accurate position for better performance in future movements [12].

C. Calibration Algorithm

The calibration algorithm for the robotic arm starts by reading the position of the joints using potentiometers, which convert analog signals into degrees. It continuously checks if the current joint angle matches a predefined "home" angle, and if there's a significant difference, it adjusts the servo motors in small steps until they align. This process ensures that the robotic arm is accurately calibrated each time it powers up, eliminating the need for manual adjustments and making the system simpler and more cost-effective.

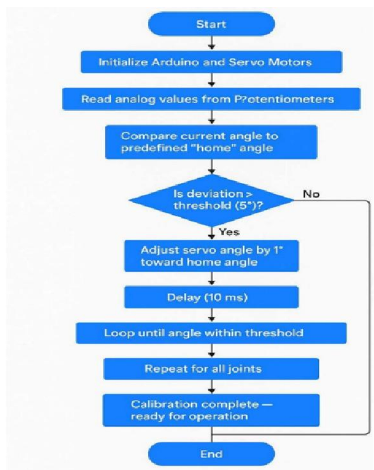

Figure 1: Flowchart of Algorithm

Arduino Pseudo-Code Snippet:

```
Int     potValue        = analogRead(potPin);
int currentAngle = map(potValue, 0, 1023, 0,
180);
while
(abs(currentAng
le      - homeAngle) >
5) {
currentAngle    =
adjustServo(currentAngle, homeAngle);
delay(10);
}
```

D. Advantages

The technique discussed offers several benefits for robotic systems. By using potentiometer- servo pairs, it removes the need for extra sensors, which simplifies the design and lowers costs. Additionally, it automatically corrects the position of the robotic arm each time it starts up, ensuring consistent performance without needing manual adjustments, and its

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modular design allows for easy expansion by adding more components, making it ideal for educational purposes and initial project testing [13], [14].

IV. HARDWARE

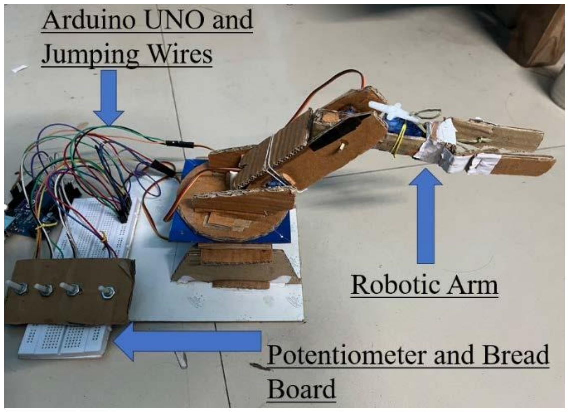

Figure 2: Hardware Of Proposed Robotic Arm

The robotic arm is constructed using cardboard as the primary structural material, making it lightweight, low-cost, and easy to assemble or modify. The design includes four joints, each actuated by a servo motor securely mounted onto the cardboard frame using hot glue or screws. Each joint also integrates a 10kΩ potentiometer fixed in place to measure angular position

The arm typically consists of a base, shoulder, elbow, and wrist segment, connected using cardboard brackets and pivots that allow rotational movement. Reinforcements are added to key load-bearing points to improve stability and durability. Despite its simplicity, this cardboard-based structure provides sufficient rigidity for light tasks and serves as a practical platform for demonstrating robotic motion and control systems angles.

A. Circuit Diagram

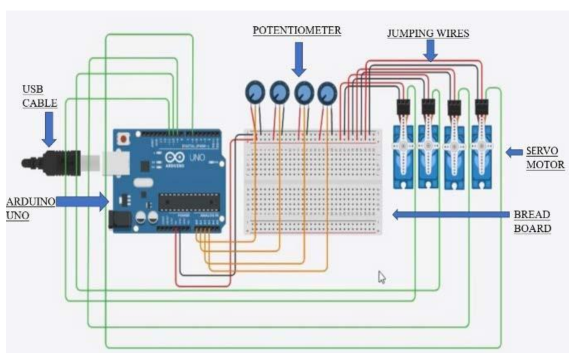

Figure 3: Circuit Diagram

The virtual circuit diagram of Robotic Arm is created using tinkerCAD virtual environment.

V. CONCLUSION

The conclusion of the study highlights a new and affordable method for self – calibrating a 4 – degree- of-freedom (4-DOF) robotic arm using potentiometers for feedback and an Arduino Uno for control. This system ensures precise positioning of the arm's joints through a straightforward feedback loop that adjusts the servo angles during setup. Designed with simple materials like a cardboard frame, this robotic arm is well-suited for educational purposes, hobby projects, and quick prototyping, while also allowing for future improvements such as gesture control and advanced algorithms for better functionality.

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