

An Implementation of Robotic Hand Using Arduino Uno, Potentiometer, And Servo Motor

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Abstract-- This paper presents the design and implementation of a five-fingered robotic arm that mimics human hand movements using Arduino Uno, servo motors, and potentiometers. The system translates human finger gestures into corresponding robotic finger movements via analog input signals from potentiometers. This project demonstrates the potential of low-cost, microcontroller-based robotic systems for applications in prosthetics, teleoperation, and human-machine interaction.

Keywords -- Robotic Arm, Arduino Uno, Servo Motor, Potentiometer

I. Introduction

Robotics and the Internet of Things (IoT) are driving significant advancements in automation, prosthetics, and interactive systems. Among these, the development of robotic hands that mimic human motion stands out due to its wide range of applications, including assistive devices for amputees, remote manipulation in hazardous environments, and interactive educational tools.

This project focuses on building a five-finger robotic arm that replicates the movement of a human hand using affordable and accessible components such as the Arduino Uno, potentiometers, and servo motors. The system operates by reading analog input signals from potentiometers, which are manually controlled to represent finger joint movements. These signals are processed by the Arduino Uno, which sends corresponding pulse-width modulation (PWM) signals to five servo motors—one for each finger—resulting in synchronized and accurate finger motion. The design not only demonstrates fundamental principles of mechatronics and control systems but also serves as a foundation for future enhancements such as gesture recognition, wireless control, or integration with biosignals for prosthetic use.

II. Literature Survey

In recent years, robotic hand systems controlled by human gestures have become an area of active research, especially in fields like prosthetics, rehabilitation, and remote operation. A variety of sensors and microcontrollers have been explored to achieve intuitive and real-time control of such systems.

Patil et al. (2017) demonstrated a robotic arm model where potentiometers were used to sense angular positions of human fingers. The analog readings were processed through an Arduino Uno, which then controlled servo motors. Their results confirmed that potentiometers offer a reliable and accurate means of capturing motion input [1].

Ajazar Pathan and Rahul Mahide (2024), The study presents the development of a compact, self-driving robot car utilizing the Arduino Uno microcontroller, paired with essential components such as the L293N motor driver, ultrasonic sensor, and HC-05 Bluetooth module. The system operates in two primary modes: autonomous obstacle avoidance and manual control via a mobile app. In the autonomous mode, the ultrasonic sensor detects and navigates around obstacles, allowing the vehicle to operate independently. The manual mode enables users to steer the car using a smartphone through Bluetooth communication remotely. The project emphasizes a practical integration of embedded systems and basic robotics, combining both hardware setup and Arduino-based programming. It demonstrates the feasibility of low-cost autonomous systems and sets a foundation for more complex robotics applications involving real-time control, sensor integration, and user interaction [2].

Another implementation by Rizwan and Ilyas (2020) focused on building a cost-effective robotic hand driven by servos and controlled through potentiometers mounted on a glove. The system proved to be simple and functional, though careful mechanical alignment was needed for consistent readings [3].

In contrast, Shinde et al. (2016) introduced a gesture-controlled robotic arm that relied on flex sensors. These sensors changed resistance based on finger movements, translating user gestures into servo rotations via Arduino control. However, challenges such as signal instability and non-linear sensor response were noted, affecting overall precision [4].

A related project by Kumar and Gaur (2018) involved developing a prosthetic hand using flex sensors. They highlighted the compactness and comfort of using sensor-equipped gloves, though sensor calibration and signal noise posed significant limitations to consistent performance [5].

Building on these ideas, Al-Zoubi et al. (2022) implemented wireless communication for flex sensor signals, allowing for remote control of a robotic hand. While this improved user mobility, the design suffered from increased latency and occasional signal interference, which hindered precise real-time motion [7].

A comparative study by Patel and Rathi (2019) examined the performance of flex sensors against potentiometers. Their findings showed that potentiometers offered a more linear and stable response, making them more suitable for applications where accuracy and reliability are crucial. Flex sensors, although more flexible in form, were better suited for gesture approximation [8].

To balance the strengths and weaknesses of both sensors, Ansari et al. (2023) proposed a hybrid system that incorporated both potentiometers and flex sensors. This configuration improved gesture recognition accuracy but increased circuit complexity and overall cost, making it less ideal for budget-constrained applications [9].

Recent studies have explored various methods for replicating human arm movements in robotic systems. Low-cost sensors like potentiometers and flex sensors are widely used due to their simplicity and affordability. Potentiometers effectively capture joint angles such as shoulder, elbow, and wrist movements, while flex sensors are ideal for detecting bending motions in fingers and limbs. Although IMU and vision-based systems offer higher accuracy, they often introduce complexity, cost, or sensitivity to environmental conditions. To balance performance and simplicity, hybrid systems combining different sensors have been proposed. These studies demonstrate that even basic sensors, when integrated thoughtfully, can enable real-time and precise robotic arm control [10].

Overall, prior work illustrates that while flex sensors offer ergonomic advantages and ease of use, their inconsistent electrical characteristics can impact performance. Potentiometers, by contrast, deliver more precise, stable readings and are better suited for low-cost robotic hand control systems using Arduino and servo motors.

Several researchers have investigated different methods for controlling robotic hands, with a key focus on replicating the natural movement and grasping behavior of human fingers. Among these, electromyography (EMG) has gained attention for its ability to detect muscle activity and directly interface with the human nervous system. Despite its potential, EMG-based systems tend to be complex, requiring advanced signal processing algorithms, precise sensor placement, and are highly susceptible to noise—factors that hinder their usability in low-cost or educational applications.

Flex sensors have also been utilized to capture finger bending motions by detecting resistance changes. While they offer a relatively simple integration path, their durability over extended use, relatively high cost, and inconsistent accuracy in angle detection pose limitations for scalable or precise applications. Vision-based systems, though capable of capturing fine motion details, demand significant computational resources and operate poorly under variable lighting conditions, making them impractical for real-time or portable systems [11].

In contrast, potentiometer-driven systems offer a reliable and affordable method for capturing joint angles through direct analog input. Arduino-based implementations using potentiometers and servo motors have proven effective for simple robotic hands and finger control, especially in academic or proof-of-concept settings. However, most of these systems simplify the mechanics—either controlling only a few fingers or using basic on/off control schemes instead of proportional input. Very few works in the literature have addressed the challenge of enabling full five-finger articulation with fluid, real-time response that mimics human hand dynamics. The present project builds on this foundation by integrating five individual potentiometers and servo motors under Arduino control, enabling precise and proportional control of each finger in a compact, low-cost prototype.

System Design

Software requirement

Arduino IDE is used to develop this system, we used the Arduino IDE platform to type, compile, and upload the code.

Hardware requirement

The system is built around the Arduino Uno R3, a versatile microcontroller board used for processing inputs and controlling outputs. It serves as the brain of the project, managing signals between components. For actuation, five MG90S servo motors are utilized—each connected to a finger segment of the robotic arm to mimic natural hand movements. These servo motors are lightweight, metal-gear, and provide sufficient torque for small-scale robotics applications [6].

To capture motion from a human hand, five 10k ohm potentiometers are used. These variable resistors detect finger positions by converting angular displacement into corresponding analog voltage signals, which are then read by the Arduino to replicate the movement on the robotic hand.

Jumper wires are employed to establish reliable electrical connections between all components, ensuring efficient signal and power transmission across the circuit. The system is powered using either a standard USB cable connected to a computer or a dedicated 5V power supply, both suitable for delivering consistent voltage to the Arduino and servos.

The robotic hand structure itself is a do-it-yourself (DIY) assembly made creatively from ice cream sticks, forming a skeletal framework. This wooden structure acts as the physical base for the servo motors and allows finger-like articulation, making it a cost-effective and accessible model for robotics prototyping and educational projects [6][14].

In this system, five potentiometers are used as input devices and are connected to the analog pins A0 through A4 on the Arduino UNO. These potentiometers generate variable voltage levels corresponding to their rotation,

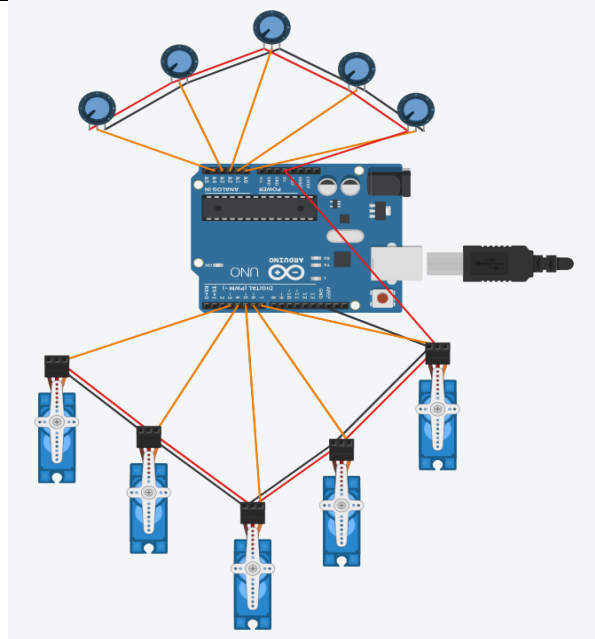


Fig. 1. Circuit diagram

which the Arduino reads as analog signals. The Arduino UNO functions as the central processing unit, interpreting the analog input values and converting them into appropriate angle positions, typically ranging from 0 to 180 degrees. These angle values are then transmitted as PWM (Pulse Width Modulation) signals to control the movement of five servo motors connected to digital pins D3 through D7. The entire setup is powered through a USB connection to the Arduino, while the servo motors are supplied with a regulated 5V power source to ensure stable operation.

Components Required

Arduino Uno

At the core of the system lies the Arduino Uno, a widely-used open-source microcontroller based on the ATmega328P. It provides 14 digital I/O pins (including 6 for PWM output), 6 analog inputs, and operates at 5V with a 16 MHz clock. The Arduino acts as the central controller, reading analog values from the sensors and sending corresponding control signals to the servo motors. Its ease of programming, USB interface, and compatibility with numerous components made it ideal for this project [2].

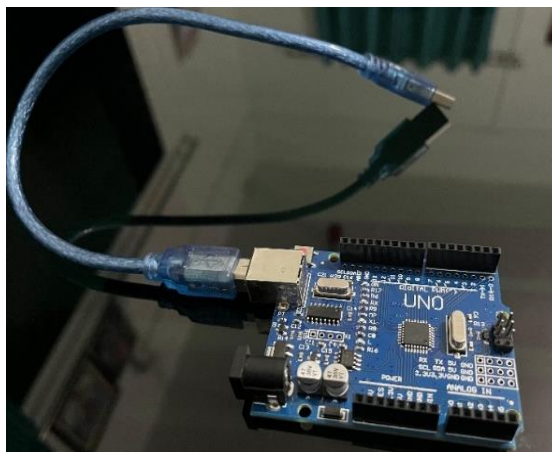


Fig. 2. Arduino Uno

Potentiometers

Potentiometers were used as the primary input devices to detect the angular position of the human fingers. These are three-terminal resistive components that provide variable voltage outputs based on the rotation of their shaft. When mounted on a glove or frame aligned with the user's fingers, the potentiometers rotated as the fingers bent, changing their output voltage. This voltage was then read by the Arduino through its analog input pins and translated into servo motor positions. Potentiometers provided consistent and linear responses, which greatly enhanced the accuracy of the robotic hand.

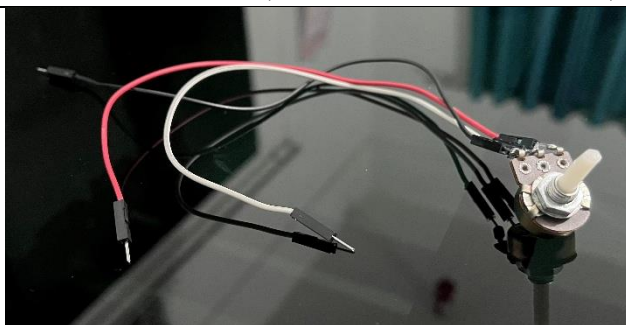


Fig. 3. Potentiometer

Servo Motors

The robotic fingers were actuated using standard 180° servo motors. These motors operate based on Pulse Width Modulation (PWM) signals received from the Arduino. Each motor was assigned to a single robotic finger and moved to a position based on the input value from the corresponding potentiometer. Servo motors were chosen due to their precision, ease of integration, and low power consumption. They provided smooth and immediate response to control signals, enabling real-time mirroring of finger motion [2].

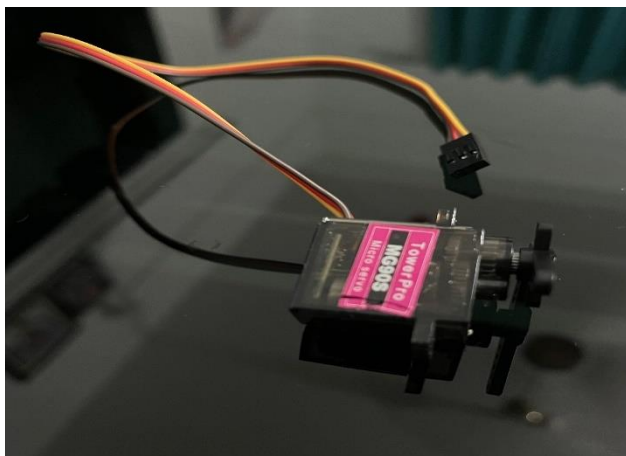


Fig. 4. Servo Motor

Flex Sensors

Flex sensors were initially explored as an alternative to potentiometers. These sensors change their resistance in response to bending. The idea was to mount flex sensors on a glove such that they would detect the degree of finger bending and send corresponding analog signals to the Arduino. However, several challenges emerged during implementation. The resistance change of flex sensors was nonlinear and difficult to calibrate. Additionally, the output was affected by noise and external conditions such as temperature. The sensors also degraded over time with repeated use. Due to these limitations, the flex sensors did not produce the desired level of accuracy or repeatability, and were ultimately not used in the final model.

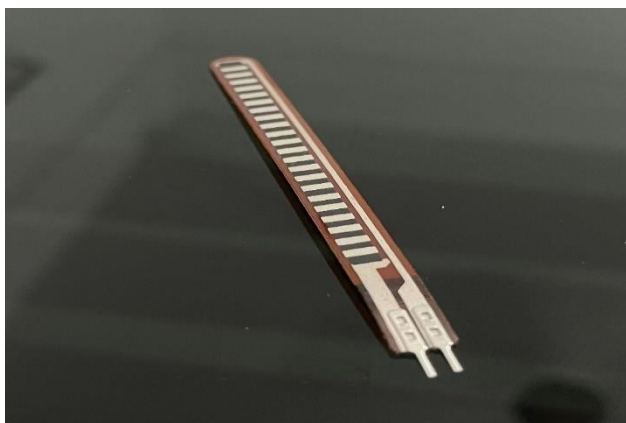


Fig. 5. Flex Sensor

Implementation

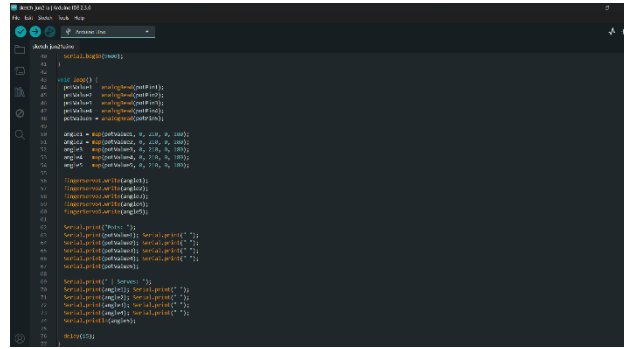


Fig. 6. ArduinoIDE Code

As depicted in Fig. 6, Potentiometers are connected to the Arduino Uno's analog input pins (A0–A4), with each one corresponding to a specific finger. As a user bends their fingers, the resistance of the potentiometers changes, producing analog voltage signals. These signals are read by the Arduino using “analogRead()”, returning values ranging from 0 to a calibrated maximum of 210 (instead of the default 1023) to match the effective range of the potentiometers. The Arduino then maps these values to servo angles between 0° and 180°, which control the corresponding servos to replicate the finger positions on the robotic hand.

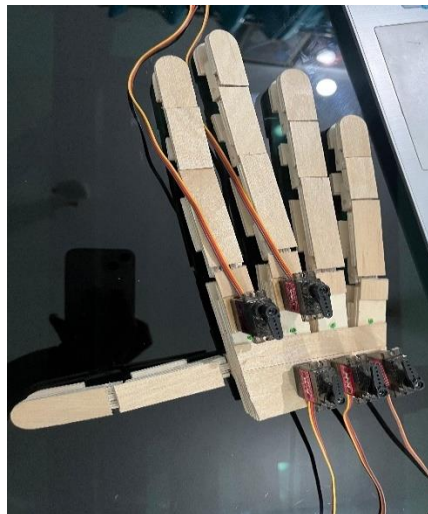


Fig. 7. Robotic Hand

Fig.7 show robotic hand is built using Ice Cream Stick, each joint actuated by servo motors. The servos receive analog input from the Arduino, based on potentiometer readings from the glove, to replicate the user's finger movements in real time.

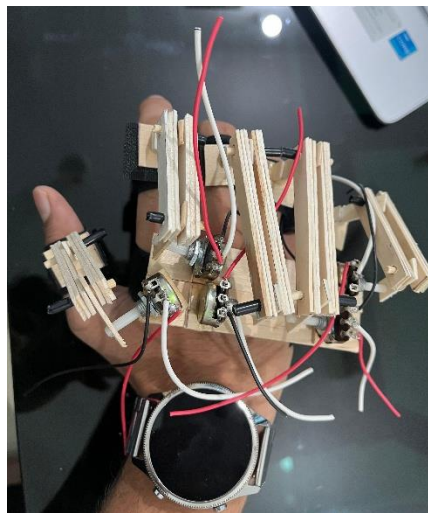


Fig. 8. Wearable Glove with Mounted Potentiometers for Finger Movement Detection

The glove is designed with five individual potentiometers, each strategically positioned to align with one of the user's fingers—thumb, index, middle, ring, and little finger. These potentiometers are mechanically linked in such a way that when the user bends or straightens a finger, the corresponding potentiometer rotates in tandem with the finger's movement. This rotation alters the resistance within the potentiometer, producing a variable analog voltage signal.

These analog signals are continuously transmitted to the Arduino Uno R3, which interprets the voltage levels to determine the exact degree of each finger's bend. Based on this real-time data, the Arduino then generates precise control signals for the corresponding servo motors on the robotic hand. As a result, the robotic fingers replicate the user's hand gestures with a high degree of accuracy, allowing for intuitive and natural remote control of the robotic hand through simple finger movements.

III. Results and Discussion

Responsiveness: The system demonstrates a high level of responsiveness, with the robotic fingers accurately replicating human finger movements with an average delay of approximately 15 milliseconds. This near real-time response ensures a natural interaction between the user and the robotic hand, making the control intuitive and efficient.

Precision: The servo motors provide smooth and accurate motion that is directly proportional to the input received from the potentiometers. This results in fine-grained control, where even small changes in finger position on the human hand lead to corresponding adjustments in the robotic fingers, enabling precise mimicry of gestures.

Jitter: A slight amount of jitter is observed in the finger movements. This is primarily caused by small fluctuations in the analog signals coming from the potentiometers. Although the movements remain functional and visually accurate, implementing signal smoothing techniques such as moving average filters or low-pass filters could further enhance consistency and reduce this minor vibration [14].

Stability: The overall system performs reliably over multiple trials. Even with repeated usage, the servo motors and sensors maintain their synchronization and output consistency, indicating stable operation. There is no significant degradation in performance, showcasing the durability and robustness of the setup for prolonged demonstrations or educational use.

IV. Conclusion

This project successfully demonstrates a cost-effective and accessible design of a five-fingered robotic hand controlled by potentiometers and Arduino. The system mirrors human hand movements in real time with decent accuracy and responsiveness. Its simplicity makes it ideal for learning, research, and further development into more complex assistive or industrial systems. This method can be used for making a full version of human arm including wrist, elbow and shoulder joint.

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