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Bionic Forearm Using Arduino

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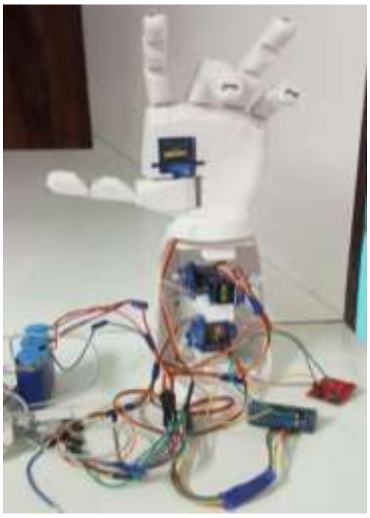
Abstract

The robotic arm, a sophisticated mechanical device akin to a bionic or prosthetic limb, emulates human arm functions across industries like industry, medicine, and space exploration. Its key components—controller, actuators, end effector—endow it with precise, efficient movement essential for diverse tasks. The controller's structure facilitates seamless motion, while actuators powered by electric or hydraulic systems enable varied actions. The end effector, at the arm's end, interacts with objects, broadening its operational capabilities. Overall, robotic arms epitomize precision and adaptability, proving invaluable in sectors requiring intricate manipulation and task execution.

Keywords: EMG Sensors, Arduino Nano, Electromyography, Hand Motions, Muscles Contraction

Introduction



In lower-income to middle-income countries like India, a significant number of individuals with disabilities face challenges accessing proper rehabilitation services and necessary assistive devices. According to a national sample survey on disabled persons conducted in July 2018, locomotor disability aid or application was not acquired by 7.1% of people due to affordability issues. Among people with locomotor disabilities, an artificial limb was used as an aid by 3.9%. This data indicates the lack of access to assistive devices further intensifies the difficulties faced by people with disabilities, hindering their ability to perform daily activities, participate in society, and achieve a good quality of life. This issue can be resolved with the accessibility and affordability of prosthetics which is crucial in providing equal opportunities and enhancing the well-being of individuals with locomotor disabilities.

To solve this problem, many researchers and engineers proposed the concept of prosthesis, well known as prosthetics, an artificial device that replaces a missing body part. Dr. Robert A. Mann developed one of

the first successful myoelectric prosthetic arms in the 1960s. This device used EMG signals to control the movement of the artificial limb. The core building blocks of a bionic arm encompass an interface system that connects the arm to the user's residual limb or nervous system, a bunch of sensors to determine muscle movements or signals, and selectors that respond to these inputs by executing corresponding conduct.
Nowadays prosthetics can be easily produced by 3D printing technology, which promotes flexibility, waste minimization and is cost effective.
A myoelectric prosthetic arm (bionic forearm) is essential for individuals with upper limb amputations, providing a high level of functionality and natural movement. By utilizing electromyographic signals generated by residual muscles, myoelectric prosthetics enable intuitive and precise control of hand and finger movements. This technology enhances the user's ability to perform intricate tasks, such as grasping and manipulating objects, contributing to increased independence and improved quality of life. The versatility of myoelectric prosthetic arms allows users to adapt to various daily activities, fostering greater social integration and psychological well-being.
The concept of accessibility and affordability of prosthetics focuses on filling the gap of unavailability of prosthetics with some basic functionalities of the hand which can change an amputee's life in every aspect of life. Its affordability can be easily achieved by integrating some simple electronic sensors and controllers along with 3D-printing technology.

Literature Survey

Ahirwar, D., Purohit, J., Semwal, V. B., Gawre, S., & Rajpurohit, discusses the fantasy of creating humanoid robot analysts with both human-like bodies and minds. Humanoid robotics, particularly in the realm of advanced mechanics, is considered a significant contemporary challenge. The goal is to develop robots that not only mimic human physical characteristics but also possess cognitive abilities, creating a holistic human-like artificial specialist. The field of humanoid robotics aims to comprehend and replicate complex interactions between robots, their environment, and humans [1].
Hassan, H.F.; Abou-Loukh, S.J., Ibraheem, try to develop a real-time control system for a 5-degree-of-freedom Aidee pen ROT3U robotic arm using surface electromyography (EMG) signals obtained from a wireless Myo gesture armband. The study focuses on distinguishing seven different hand movements using a pattern recognition system with three key components: segmentation, feature extraction, and classification. To segment the EMG signal, the overlap technique is employed, dividing the signal into portions. Six time-domain features, including Mean Absolute Value (MAV), Waveform Length (WL), Root Mean Square (RMS), Autoregressive Coefficients (AR), Zero Crossings (ZC), and Slope Sign Changes (SSC), are extracted from each segment. The classification of the seven hand movements is performed using three different classifiers: Support Vector Machines (SVM), Linear Discriminant Analysis (LDA), and K-Nearest Neighbor(K-NN). The research compares the performance of these classifiers to determine the optimal accuracy [3].

AIM

The aim of making a bionic lower arm utilizing Arduino is to create a reasonable, customizable, and user-friendly prosthetic gadget. This incorporates empowering people with appendage contrasts or impedances to perform everyday errands successfully while prioritizing ease of utilization and integration of progressed highlights such as tangible input.

OBJECTIVES

The objectives of the bionic arm can be listed in many fields

1. Remediation Technology
2. Medical and surgical procedure
3. Laboratory & Research

- Implement a bionic arm that performs movements in multiple degrees of freedom including finger articulation, wrist rotation, and elbow flexion, to perform a wide range of tasks.
- Developing customizable gestures mapping bionic arm that allows users to perform specific movements through corresponding EMG signals and control the arm's behavior according to the needs and preferences of an individual.
- Embody sensory feedback mechanisms, such as pressure sensor and tactile sensor, into the arm to provide a user with tactile sensation and enhance controllability during interaction.
- Optimize the control system's energy efficiency to prolong the bionic arm's battery life, allowing users to use the prosthetic arm for a longer duration without frequent recharging.
- It can be used in neurological rehabilitation by providing targeted, customizable exercises to enhance motor control and coordination.

Features of the forearm

The features displayed in our model are basically of six types:

1. Flexion.
2. Extension.
3. Pronation.
4. Supination.
5. Grasping.
6. Release.

Flexion refers to the bowing movement that decreases the point between two body parts, ordinarily including the bowing of a joint. This activity happens in different parts of the body, such as the arms, legs, and spine, permitting a run of movement basic for everyday exercises and physical capacities like strolling, lifting, and coming.

Extension refers to the act of lengthening, extending, or drawing out something past its unique limits or length. In different settings, it can indicate the expansion of additional time, space, usefulness, or importance to an existing substance, such as a venture, understanding, due date, program, or physical structure. Expansions frequently give adaptability or oblige changes in circumstances.

Pronation is a normal movement of the foot that happens amid strolling or running. It includes the internal rolling of the foot from heel to toe as weight is exchanged amid each step. Pronation makes a difference retain stun and convey powers equitably, but over-the-top pronation can lead to foot and lower leg issues such as abuse wounds or flimsiness.

Supination. is a term utilized in life structures and physiology to portray a rotational development of the lower arm or foot that causes the palm or sole to confront upward or outward separately. It is the inverse development to pronation and includes the outward turn of the bones of the lower arm or foot, driving to a position where the palm or sole faces more anteriorly.

Grasping refers to the act of immovably holding onto a protest or concept utilizing the hand or judgment skills. In a physical sense, it includes clutching or seizing with the fingers or hand. Allegorically, it implies understanding or comprehending a thought, hypothesis, or circumstance. Getting a handle on includes both physical and cognitive perspectives of securing and holding onto something.

Figure 2: Grasping Motion

Release. typically refers to making an item or computer program accessible for open utilization after advancement and testing stages. It includes finalizing and disseminating an adaptation that meets quality guidelines and addresses distinguished issues. Discharges regularly incorporate unused highlights, enhancements, bug fixes, or security patches, stamping a turning point in the advancement cycle.

Figure 3: Release Motion

TARGETED MUSCLES

The forearm muscles can be simply divided into five sections-

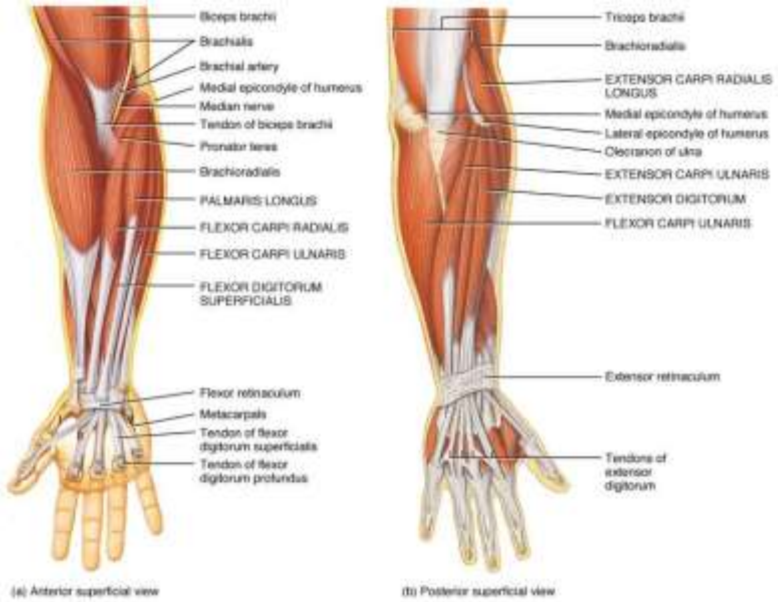


Figure4: Targeted Muscles

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1. Flexors (Bend It In):
- Flexor Carpi Radialis: A muscle that helps bend and abduct (move away) the wrist.
- Palmaris Longus: A slender muscle aiding in wrist flexion and tensioning the palmar fascia.
- Flexor Carpi Ulnaris: Assists in bending and adducting (moving toward) the wrist.
- Pronator Teres: Makes the forearm rotate inward (pronate).

2. Flexors of Fingers and Thumb:
- Flexor Digitorum Superficialis: Flexes fingers and wrist simultaneously.
- Flexor Digitorum Profundus: Flexes the fingers, especially the last joints.
- Flexor Pollicis Longus: Flexes the thumb.

3. Pronators (Rotate It In):
- Pronator Quadratus: Rotates the forearm inward, helping with tasks like turning a doorknob.

4. Extensors (Straighten It Out):
- Extensor Carpi Radialis Longus and Brevis: Straightens and abducts the wrist.
- Extensor Digitorum: Straightens the fingers and the wrist.

5. Brachioradialis (Your Helper):
- Brachioradialis: A helper in flexing the forearm at the elbow and aiding in pronation and supination. These muscles work together like a team, allowing you to perform various hand and wrist actions, from typing and holding objects to turning your palm up or down. It's this teamwork that gives your hands and wrists an incredible range of movements.

METHODOLOGY

A typical block diagram of the approach of implementation and designing of a bionic arm using Arduino is given below-

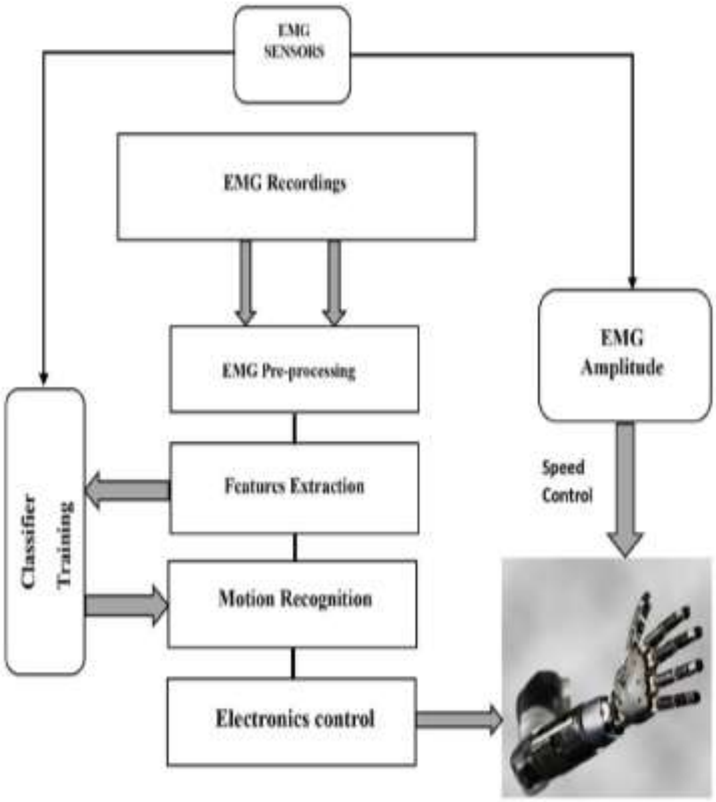

Figure5: Implementation and designing of a bionic arm

CLASSIFIER TRAINING The classifier learns to associate specific patterns in the EMG signals with different intended movements (e.g., opening, ending, rotating the wrist). This involves using a labeled dataset of EMG signals and corresponding movement markers to produce a model that can prognosticate the movement associated with new, unseen EMG signals.

EMG SENSORS EMG sensors, which are surface electrodes placed on the user's residual limb, capture the electrical activity generated by muscle contractions. These sensors convert the electrical signals into analog or digital signals that are then processed. It provides a more detailed view of how the electrical activity from the user's muscles is captured using EMG sensors before being processed and used for training the classifier and controlling the bionic arm.

EMG RECORDING This block represents the interface that connects the EMG sensors to the system for EMG signal recording. The interface may include analog-to-digital converters (ADCs) that convert the analog EMG signals from the sensors into digital signals for further processing and analysis.

EMG PRE-PROCESSING This block encompasses various preprocessing techniques applied to the recorded EMG signals. Preprocessing steps may include filtering to remove noise, normalization to account for variations in signal amplitudes, feature extraction to extract relevant signal characteristics, and segmentation to divide the signals into meaningful segments for analysis.

FEATURES EXTRACTION This block involves extracting relevant features from the pre-processed EMG signals. These features could include time-domain statistics, frequency-domain characteristics, or other specialized parameters that capture the distinctive aspects of muscle activity for different movements.

MOTION RECOGNITION The extracted features are fed into a motion recognition process. In this block, machine learning algorithms, such as neural networks or support vector machines, are trained on labelled datasets to recognize patterns in the features associated with specific movements (e.g., gripping, rotating). Once trained, these algorithms can accurately classify and predict the intended motion based on the extracted features.

EMG AMPLITUDE EMG Amplitude Analysis This block involves analyzing the width of EMG signals to determine the intensity or strength of muscle contractions. This analysis could be used to modulate the force exerted by the bionic arm, allowing users to control the grip strength or other movements based on their muscle activity position.

ELECTRONICS CONTROL This block represents the electronic control components of the bionic arm system, including motor drivers, actuators, and feedback mechanisms. It receives control commands from the Arduino and translates them into physical movements of the bionic arm.

V. CIRCUIT DIAGRAM

This is a circuit diagram of the bionic forearm using Arduino: -

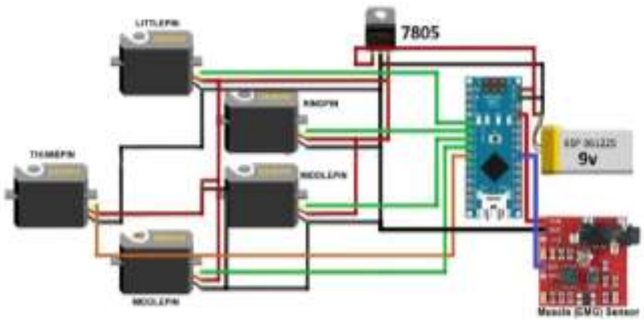

Figure 6: Circuit Diagram

Bionic Arm Model

A robotic arm or bionic arm, commonly known as prosthetics may be a mechanical gadget outlined to imitate the capacities of a human arm, performing assignments with exactness, and proficiency. Ordinarily utilized in mechanical settings, therapeutic methods, space investigation, and other areas, automated arms are flexible devices competent of a wide extend of applications. At its center, a mechanical arm comprises of a few basic components. The controller serves as the most body of the arm, composed of joints and joins that empower development. Actuators, which are frequently electric engines or water powered barrels, give the control fundamental to move the arm's joints, permitting it to perform different movements. The conclusion effector, found at the arm's limit, is the device or connection that interatomic with objects or performs particular errands.

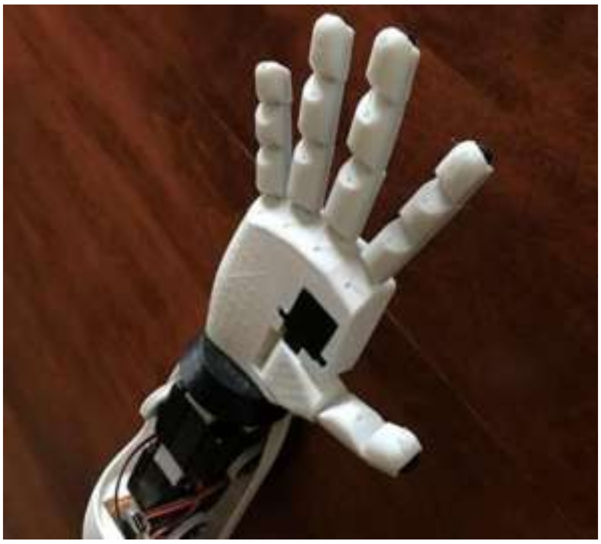

Figure 7: Bionic arm

EMG Muscle Sensor Module V3.0

The EMG Muscle Sensor Module V3.0 is a compact and versatile device used for monitoring and measuring electromyography (EMG) signals generated by muscles. It features surface electrodes that can be attached to the skin over muscle groups to detect electrical activity during muscle contractions. This module typically connects to microcontrollers like Arduino or Raspberry Pi, enabling real-time EMG data acquisition and analysis for applications in prosthetics, biofeedback, muscle rehabilitation, and human-machine interfaces. With its user-friendly design and analog output, the EMG Muscle Sensor Module V3.0 is widely used by researchers, developers, and enthusiasts to explore muscle-related physiological data and create innovative projects.

Figure 8: EMG Sensor

Arduino Nano V3

The Arduino Uno R3 is based on the ATmega328P microcontroller, which is a member of the AVR family of microcontrollers. It runs at 16 MHz and has 32KB of flash memory for storing your program. The Arduino Uno R3 is often recommended for beginners due to its ease of use and extensive community support. It's a great choice for learning electronics and programming, and it can be used for a wide range of projects, from simple LED blinking experiments to more complex robotics and automation applications.

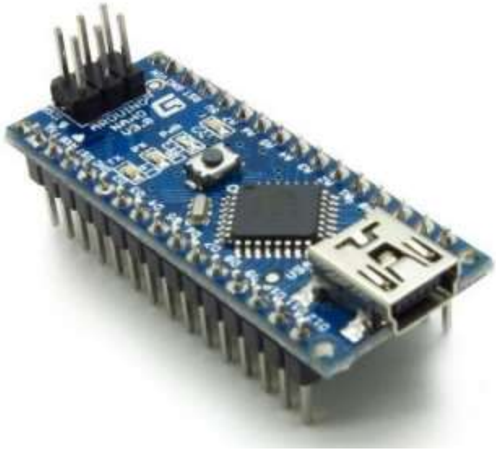

FIGURE 9: ARDUINO NANO

LOOKUP TABLE

A lookup table plays a crucial role in mapping input values to desired output actions. Essentially, it serves as a reference or guide that the system uses to determine the appropriate response based on the input received. the reference is given below and how the output has been obtained through the sEMG sensor on the software Arduino IDE.

HAND ACTION	EMG SIGNAL RANGE	BINARY VALUE
OPEN HAND	0-200	0001
CLOSE HAND	201-400	0010
FLEXION	401-600	0100
PRONATION	601-800	1000
SUPINATION	801-900	0011
EXTENSION	901-1023	1100

Figure 10: Interfacing Result

Acknowledgment

The advancement of a bionic lower arm utilizing Arduino would not have been conceivable without the devotion and skill of various people and organizations. We expand our most profound appreciation to the Arduino community for their open-source stage, which served as the establishment for this extend. Extraordinary much appreciated to the analysts, engineers, and designers who contributed their time, information, and imagination to plan and actualize the bionic lower arm. Also, we recognize the back of our supports and collaborators, whose commitments were priceless in bringing this inventive innovation to fulfillment. This extend speaks to a collaborative exertion pointed at upgrading availability and usefulness within the field of prosthetics.

Achievements of our project

- Our project is funded by a Government Organization, the Council of Science and Technology, Uttar Pradesh (CSTUP).
- In the project evaluation ceremony of the Council of Science and Technology Uttar Pradesh (CST-UP) held on 27 April 2024, we were awarded with 3rd consolation prize under the Engineering Student Project Grant Scheme, project ID -1111.
- We won 3rd prize under the Best Start-up category in Start-up Showcase Meet 2024, held on 29 April 2024 at Rajkiya Engineering College, Sonbhadra.

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