MYOELECTRIC PROSTHETIC ARM

Project Reference No.: *48S_BE_3630*

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Keywords:
Electromyography, Prosthetic Arm, 3D printing, Amputee.

Introduction:

Upper limb amputation leads to significant functional impairment, affecting over 30% of global amputees. Traditional prosthetics, such as body-powered arms, lack precision and require substantial physical effort. Myoelectric prosthetics, however, harness electromyography (EMG) signals to control limb movement, offering intuitive and responsive operation.

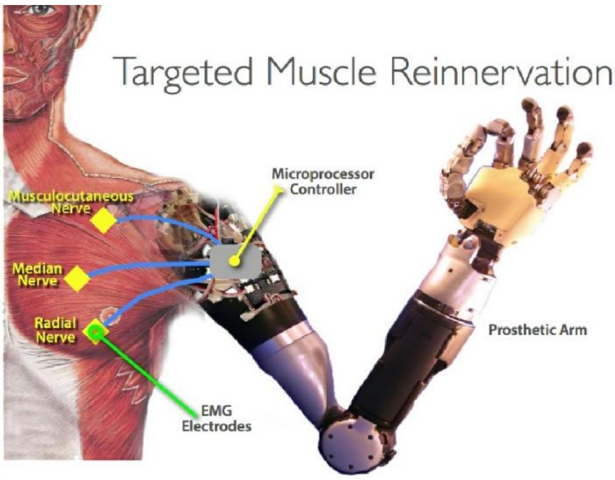

Figure 1: EMG Sensor based Prosthetic Arm

EMG sensors detect microvolt-level bioelectric signals from muscle contractions, which are amplified, filtered, and processed via a microcontroller. These signals drive actuators typically MG996R servo motors to replicate hand movements like grasping and releasing. 3D printing with PLA material enables cost-effective, lightweight, and customizable prosthetic designs, ensuring accessibility and comfort for the user. This project develops a myoelectric prosthetic arm using an EMG sensor interfaced with an Arduino, controlling servo-driven hand in response to muscle activity thresholds.

Objectives:

- To develop a functional prosthetic arm that replicates basic human hand movements.
- To utilize EMG signals from residual muscles to control the prosthetic hand.
- To fabricate the prosthetic arm using 3D printing for lightweight and cost-effective construction.
- To enhance the quality of life and autonomy of upper-limb amputees through electrically controlled prosthetics.

Methodology:

This project leverages a Myoelectric control system to develop a prosthetic arm that mimics the natural movement of a human limb using EMG signals. The methodology integrates sensor interfacing, microcontroller programming, signal processing, and 3D modelling.

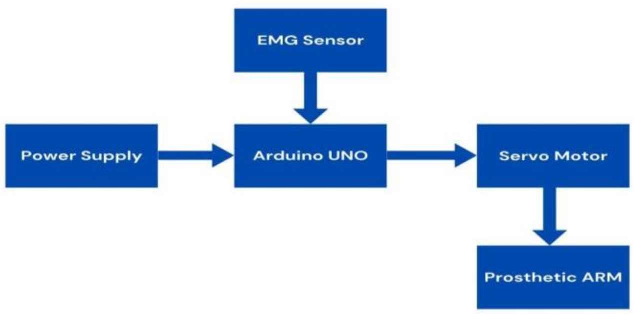

Figure 2: Flow diagram of the project

The components used are:
EMG Sensor
Arduino UNO
Servo Motor MG996R

An EMG sensor captures muscle signals from the biceps of the user. These bioelectric signals are in the range of 0–5 mV and are amplified, rectified, and filtered within the sensor module. The processed output is sent to the analog input of the *Arduino UNO* for further signal processing.

Figure 3: Hand in Relaxed Stage

To calibrate the system, muscle activity data was collected from 100 individuals under two conditions: relaxed and while holding a 350g object.

Figure 4: Holding an object of 350 grams

These values were averaged to set upper and lower thresholds for motor control. Based on the signal intensity, the Arduino drives an MG996R servo motor, which actuates the fingers of a 3D-printed PLA-based prosthetic hand. The servo is controlled using PWM signals generated by the Arduino and is programmed to rotate to specified angles based on signal strength.

The prosthetic hand was designed using thinker cad, then exported as an STL file and sliced using Cura software. The design was printed with PLA filament. Power is supplied by a power bank for Arduino and two 9V batteries in series for the EMG sensor to support ±9V operation. The EMG sensor uses three electrodes two for differential muscle signals and one reference electrode placed over a bony region. The final system enables the amputee to control the prosthetic arm with muscle contractions alone, allowing actions like grasping and releasing objects intuitively. The system was tested with an actual amputee subject to validate the accuracy and functionality.

Result:

The developed prosthetic arm successfully responded to EMG signals captured from the user's biceps. The threshold voltage for muscle activation was established at 118 mV (holding) and 0 mV (relaxed) based on data collected from 100 individuals. The servo motors actuated the 3D-printed fingers accurately when muscle contraction was detected above the threshold, mimicking natural grasping and releasing actions.

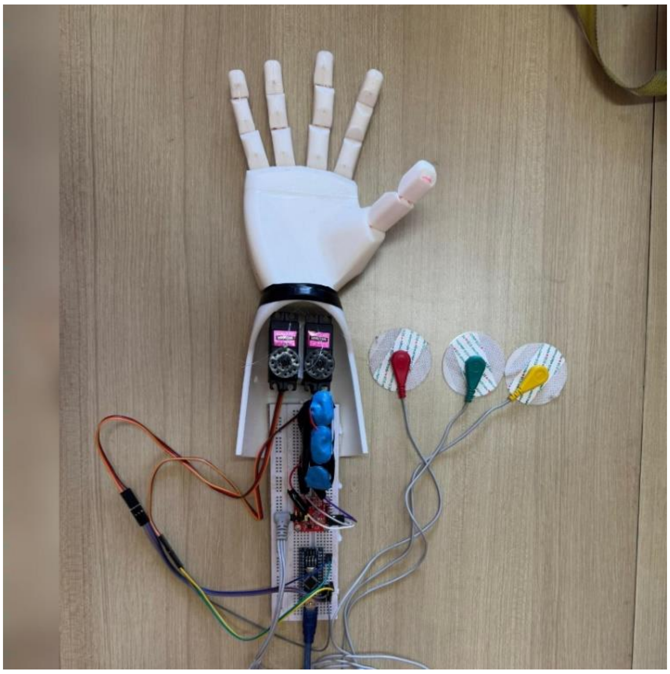

Figure 5: Model of the project

The prosthetic arm was tested on a real amputee subject. The EMG signal plots showed similar patterns to those from non-amputee users, confirming the device's adaptability. Real-time plots visualized through the Arduino IDE's serial plotter confirmed system responsiveness and reliability.

Conclusion:

This project successfully developed a functional myoelectric prosthetic arm using EMG signals and servo motors controlled by an Arduino microcontroller. By analyzing muscle activity from the biceps, the system could replicate natural hand movements like grasping and releasing. Testing on both normal individuals and an amputee confirmed the system's reliability and usability. The 3D-printed arm was lightweight, cost-effective, and customizable, showcasing the potential of affordable prosthetic solutions. This work paves the way for future enhancements such as gesture classification, sensory feedback, and multi-finger control to further improve user experience.

Project Outcome & Industry Relevance:

The primary outcome of this project is the successful development of a cost-effective, functional myoelectric prosthetic arm controlled using EMG signals. It demonstrates that muscle signals from an amputee's residual limb can effectively be translated into mechanical movements through real-time microcontroller processing. The arm performs basic yet essential tasks such as grasping and releasing objects, thus restoring partial functionality.

Industry Relevance:

This project contributes to the biomedical engineering and assistive technology industries by offering a low-cost, customizable prosthetic alternative. It holds potential for application in rehabilitation centre's, prosthetics manufacturing units, and rural healthcare settings where affordability and accessibility are critical. It also serves as a strong foundation for future commercial development of intelligent, user-friendly prosthetic limbs.

Working Model:

All components, including the EMG sensor, Arduino microcontroller, MG996R servo motors, and the 3D-printed prosthetic hand, were physically assembled and tested.

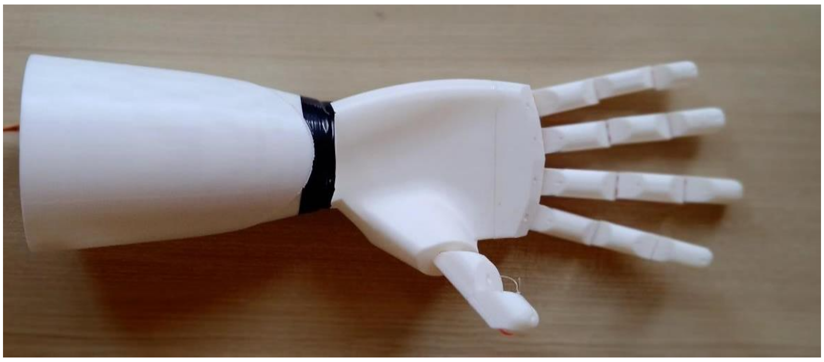

Figure 6: 3D Printed Hand

Real-time signal acquisition and actuation were achieved using biological signals, ensuring that the prosthetic system functions as intended in practical, real-world scenarios. No simulation or theoretical-only study was conducted.

Figure 7: Working Hand Model

Project Outcomes and Learnings:

This project led to the successful development of a fully functional prosthetic arm that responds in real time to electromyography (EMG) signals. The system was accurately calibrated using muscle activity data collected from 100 individuals, and its functionality was validated through testing on an amputee subject, proving its practical applicability. Table shows the values of EMG collected:

Sample No	Relaxed Hand	Hand Holding Object
1	2 mv	123 mv
2	0 mv	126 mv
3	1 mv	110 mv
4	1 mv	122 mv

A durable and ergonomic prosthetic arm was designed and 3D-printed using PLA material, showcasing the feasibility of using affordable and accessible technologies. Throughout the project, the team gained extensive hands-on experience in bio signal acquisition and processing, particularly with EMG data. They also learned to interface biomedical sensors with microcontrollers to control servo motors effectively, allowing for natural limb movements. In addition, the project highlighted the complexities of human-machine interaction in assistive devices. Valuable technical skills were developed in areas such as 3D modelling, embedded systems, and hardware-software integration, laying a strong foundation for future work in bio-robotics and wearable healthcare technologies.

Future Scope:

The future scope of this project includes:

1. Integration of Gesture Recognition Algorithms:
   Using machine learning techniques to classify multiple muscle signals for fine motor control, enabling complex hand gestures like pinching, pointing, or rotating.
2. Wireless EMG Interface:
   Replacing wired connections with wireless modules (e.g., Bluetooth or Wi-Fi) to improve portability, comfort, and user convenience.
3. Sensory Feedback Mechanism:
   Implementing haptic feedback to provide the user with a sense of touch, pressure, or position, enhancing control and usability.