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Prosthetic Arm Control Using EMG

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Abstract

For people who have lost their natural hand, a prosthetic hand is a particular tool. Losing a hand has an impact on a person's outlook on life in addition to being a physical issue. When others bring up their disability, many people start to feel weak, sad, or even despairing. This might sometimes lead to terrible situations, such as depression or worse. This is a low-cost prosthetic hand that will help people feel powerful and lead a regular life. While prosthetic hands are now available on the market, most of them are highly expensive. Our objective is to create one that is high-quality but significantly less expensive. Despite its basic looks, it will be dependable and practical. Everyone should be able to buy the equipment because disability is indifferent to wealth. Although prosthetic hands are less expensive in several western nations, we still find it difficult to compete with them due to their stronger economies. Our project can therefore truly have an impact. We had two main goals in this project. The most important one was to create a prosthetic hand that helps amputees (people without a hand) do simple daily tasks. Our system uses EMG signals (tiny electrical signals from muscles) to control hand movements. This is the project for controlling a prosthetic arm with EMG signals involves using surface electromyography (EMG) sensors to detect muscle contractions These signals are amplified and filtered to remove noise, then processed by a microcontroller like an Arduino to recognize intended hand movements. The microcontroller then sends commands to servo motors or other actuators to control the prosthetic arm's fingers and wrist, allowing for functional tasks like gripping and releasing objects.

Keywords: Prosthetic Arm, EMG Sensor, Aurdino, Amplified Signals, Amputees.

INTRODUCTION

Now a days **it** is difficult to control hand, wrist, and elbow movements, people who lose their upper limbs frequently find it difficult to operate sophisticated mechanical arms. Previous research attempted to simplify this by employing intelligent control systems that anticipate the user's actions; however, the majority of these only function for a portion of the arm, not the entire arm. The present computer simulations are not rightly merged with the modern robotics systems, and prosthetic hardware is very expensive. In order to address this issue, we developed PROACT (Prosthetic Arm Control Testbed), a platform that tests new methods to prosthetic arm control using augmented reality. In order to test PROACT, we asked individuals with normal arms to do basic tasks both with and without smart control features. The findings indicate that this method can direct future research and facilitate the usage of prosthetic arms. This platform is the first to apply AR for prosthetic research, incorporate step-by-step task modelling, and test semi-autonomous full-arm control.[1] . For people who have lost their legs, lower limb prosthetic limbs are crucial due to their help them to walk and move again. Many improvements in these devices have been crafted in recent years, especially with the use of advanced technology in semi-active and active prosthetics.53 different prosthetic designs, including knee-ankle, knee-only, and ankle-only prostheses, were looked at in this review. It studied their sensors, controls, mechanical parts, and actual user operations. In order to further improve these prosthetics in the future, the study also identifies a few issues that still need to be resolved [2].

For us to hold and control objects properly, our natural hands depend on touch. But the majority of prosthetic hands have touch sensors, which makes it hard for users to feel objects or react fast in case that something starts to slip. Using touch (tactile) sensors attached to a prosthetic hand, this research creates a special algorithm that detects slippage. So as to create a simple output that shows when sliding happens, the system filters and processes the inputs from the sensors. For testing, a prosthetic hand attached to a robotic arm has a fingertip equipped with these sensors. To verify accuracy, various surfaces, forces, and speeds were used in the studies. The algorithm's ability quickly detect slippage and assist the prosthetic hand in reacting in real time, as shown by the results, made object handling more secure and reliable[3] .

The capacity of users to feel what they are getting is a major drawback of robotic hands, which often contributes to their termination. Using sensory feedback may reduce phantom limb pain in while improve hand control. So as to address this, we developed the B: Ionic glove, an original glove with integrated sensors and actuators that is worn over a robotic hand. When pressure is detected by soft fingertip sensors, the glove uses small shape memory alloy (SMA) actuators in an armband to gently compress the user's arm. We discovered that the most effective sensor design for touch detection was a circular one. According to a user survey, respondents could quickly identify the location of the glove's feedback, but they had a tougher time determining how strong it was. Because of this, the glove is a helpful step toward more realistic-feeling artificial hands [4].

With the use of virtual limitations inspired by humans, we suggest a secure adaptive control method for robotic knee prosthesis. For more natural walking, the amputee's thigh motion guides the knee movement, unlike fixed routines. While a composite reaching law minimizes vibration and enables quick reaction, a reference admittance model increases flexibility against ground impacts. Lyapunov-based back-stepping control is used in the system's design to provide stability and security. According to simulation studies, this approach gives robotic knees good motion tracking and efficient operation [5] .

This study demands fuzzy/PD control in conjunction with EMG signals to enable voluntary control of prosthetic hands. To power the motors, EMG pulses are filtered and converted into voltage signals. The system regulates the impact force and grip position using the voltage level and pulse timing, respectively. With this method, users can move and control their prosthetic hand naturally using natural signals [6].

This paper presents a system for force estimation using surface EMG signals from the eight channels of the MYO armband. Nineteen regression models were tested to continuously estimate force in natural movements for two-degree-of-freedom rehabilitation robots. The Gaussian Process Regression model performed best, achieving **a** root mean square error of 1.18–1.77 N. Additionally, an exponential algorithm reduced force estimation errors further, providing accurate and reliable force predictions for robotic control [7].

This study utilizes improved mathematical modelling to develop a voice control system for prosthetic robot arms. A four-jointed RRRR robot arm was used to assess the system's tools. The created technology improves current methods in voice recognition by around 11%, according to the results. According to the study, voice instructions can be utilized to control prosthetic limbs in an efficient manner, giving users a convenient and hands-free method of using the device [8].

The objective of the project is to build a prosthetic arm that is operated easily and cost of the prosthetic arm will be less. The proposed method uses EMG SENSORS to operate prosthetic arm .EMG SENSOR collects the muscle contractions in the user's remaining limb, such as the forearm or upper arm. Then processed by a microcontroller like an Arduino to recognize intended hand movements. The microcontroller then sends commands to servo motors or other actuators to control the prosthetic arm's fingers and wrist, allowing for functional tasks like gripping and releasing objects.

LITERATURE SURVEY

The Author Shivani Guptasarma and Monroe D. Kennedy published this work in 2024–2025 under the domain of Assistive Robotics, Prosthetics, and Augmented Reality for Human Enhancement. The method involves developing the Prosthetic Arm Control Testbed (PROACT)**,** an AR-based immersive simulation platform for testing intelligent control strategies in whole-arm prostheses. The problem addressed is that current prosthetic arms have limited control due to low-DOF EMG inputs, high rejection rates (30–80%), and lack of effective solutions for whole-arm control. Existing hardware is expensive, and current simulators are not well-integrated with robotics frameworks. PROACT offers a low-cost, open-source testbed to study semi-autonomous, intent-informed control for prosthetic arms **[1].**

The researchers Ilaria Fagioli, Alessandro Mazzarini, Chiara Livolsi, Emanuele Gruppioni, Nicola Vitiello, Simona Crea, and Emilio Trigili published this work in 2024 in the domain of Robotic Rehabilitation, Prosthetics, and Mechatronics. The method used is a systematic review of 53 semi-active and active lower limb prosthetic prototypes, analyzing their mechatronic design, sensing and control strategies, and end-user performance evaluation. The problem addressed is that most commercial prostheses are still passive, offering limited energy return and poor adaptability, leading to inefficient gait, mobility restrictions, and secondary health issues. This review identifies advancements while also highlighting open challenges in achieving natural, efficient, and widely adoptable robotic lower limb prostheses **[2].**

This Authors Rocco A. Romeo, Clemente Lauretti, Cosimo Gentile, Eugenio Guglielmelli, and Loredana Zollo (2021) worked in the domain of tactile sensing for prosthetic hands**.** They proposed a signal-processing algorithm using tactile sensors embedded in a bioinspired fingertip, based on filtering, rectification, and envelope detection to identify slippage. The system was tested on a prosthetic hand mounted to a robotic arm across multiple surfaces and velocities, proving low-latency and reliable slip detection. The problem addressed is that most prosthetic hands lack tactile sensing and effective algorithms, limiting dexterity and safe manipulation **[3]**.

Authors Melanie F. Simons et al. (2021) worked in the domain of soft robotics and sensory feedback for prostheses. They introduced the B: Ionic glove, a wearable device with electro-fluidic fingertip sensors and SMA actuators that provide tactile feedback by gently squeezing the user’s arm. User studies showed participants could distinguish stimulation locations, demonstrating effective sensory feedback. The problem addressed is that most upper-limb prostheses lack natural feedback, leading to high rejection rates and phantom limb pain **[4].**

Authors Yongshan Huang, An Honglei, Qing Wei, and Ma Hongxu published this work in 2021 in the domain of robotic knee prostheses and adaptive control systems. They proposed a robust adaptive admittance control scheme using human-inspired virtual constraints**,** where the prosthetic knee trajectory is driven by thigh motion rather than pre-programmed gait cycles. The method employs a reference admittance model, composite reaching law, and Lyapunov-based back stepping design to ensure compliance, stability, and finite-time convergence. The problem addressed is that existing finite state impedance control (FSIC) strategies require extensive parameter tuning, rely heavily on precise gait phase switching, and lack adaptability across users and locomotion modes **[5].**

Authors Saeed Bahrami Moqadam, Seyed Mohammad Elahi, An Mo, and WenZeng Zhang published this work in 2018 in the domain of prosthetic hand control using bio signals and intelligent hybrid systems. They proposed **a** hybrid control method that combines fuzzy logic/PD control with EMG signals as direct voluntary commands. The EMG signals were filtered into stepping pulses (0–6 V) and used as inputs to both the fuzzy logic unit (affecting grasping force) and PD controller (affecting grip position). The problem addressed is that conventional prosthetic hands—whether body-powered or electric—have limitations such as poor usability, high cost, or lack of natural control, which this hybrid bio signal-based approach aims to overcome.[6].

Authors Thantip Sittiruk, Kiattisak Sengchuai, Apidet Booranawong, Paramin Neranon, and Pornchai Phukpattaranont published this work in human–robot interaction and biomedical signal processing. They developed a force estimation system using surface electromyography (EMG) signals from an eight-channel MYO armband, testing nineteen regression models across varied arm postures and rehabilitation scenarios. The Gaussian process regression model achieved the best performance with low RMSE (1.18–1.77 N), while an exponential algorithm further reduced estimation errors. The problem addressed is that accurate, posture-independent muscle force estimation remains challenging but is crucial for prosthetic control, rehabilitation robots, and natural human–machine interaction [7]**.**

PROPOSED METHODOLOGY

The aim of the advised prosthetic robotic arm is to help those who have lost a hand as a result of illnesses, accidents, or impairments. Flex sensors are used to detect finger bending, and EMG sensors are used to detect electrical signals from muscles. A tiny controller, such as an Arduino, receives these impulses and uses them to control the robotic arm's motors. The prosthetic arm provides a natural and intuitive reaction by simulating the user's muscular contractions and finger bends. The system is lightweight, easy to use, and reliable because it operates on basic rules rather than complex AI. Users may carry out daily tasks more easily with this design while still being independent and productive.

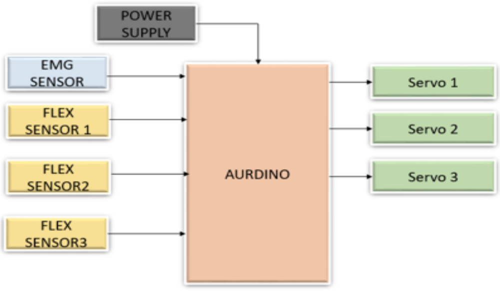

FIG.1. BLOCK DIAGRAM OF THE PROPOSED METHODOLOGY

HARDWARE WORK FLOW:

- **EMG Sensors**

FIG 2: EMG SENSOR

A prosthetic arm is a device that assists those who have lost a hand in performing everyday tasks including picking, pointing, and holding. The prosthetic arm has to understand what the user wants to do order to move like a human hand. EMG sensors are useful in this situation. Electromyography, or EMG for short, is a technique for measuring the minuscule electrical signals produced by our moving muscles. These signals are automatically sent by our muscles whenever we attempt to move our fingers or hands. These impulses can be picked up by EMG sensors from our arm's skin. The prosthetic arm can determine exactly what the user wishes to do by reading these signals. The forearm muscles, which typically move the fingers and wrist, have EMG sensors attached to them. The muscle contracts when someone tries to close their hand or bend a finger. The electrical signal from that contraction is detected by the EMG sensor. Because these signals are so tiny, a tiny circuit is used to amplify them so the microcontroller can understand them. The prosthetic arm's microprocessor functions similarly to its brain. It processes the impulses and instructs the wrist and finger motors on how to move. Some simple and natural method of controlling the prosthetic arm is by using EMG sensors. There is nothing new for the person to learn. Simply moving their hand causes the prosthetic arm to move as well. Compared to using costly devices like buttons or brain sensors, this is far simpler. Because EMG sensors are thin and light, they do not add weight or discomfort to the arm. Since they are non-invasive, there is no need for surgery or internal body insertions. Fast and real-time control is another benefit of EMG sensors. The signal from the muscle causes the prosthetic arm to move nearly instantly. The motions appear fluid and natural as a result. Simple operations like opening the hand, grabbing a bottle, or pointing a finger can be controlled by EMG sensors without the need for complex programming or artificial intelligence. They are also reasonably priced, so more individuals can afford the prosthetic arm. All things considered, EMG sensors are ideal for a prosthetic arm since they can read the natural signals from the muscles, react fast, are comfortable, easy to use, and reasonably priced. They facilitate daily tasks and increase the user's sense of control by allowing the mechanical hand to be moved organically. EMG sensors, motors, and a basic controller enable a prosthetic arm to carry out duties similar to those of a genuine hand without requiring advanced programming. Because of this, EMG sensors are the best option for controlling prosthetic arms.

FIG 3: WORKING OF EMG SENSOR

FLEX SENSORS

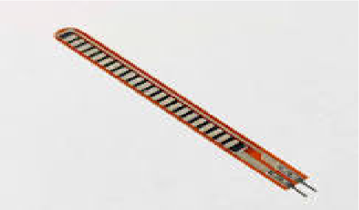

FIG 4 FLEX SENSOR

Flex sensors are specialized instruments that detect finger bending or movement. Typically, they are tiny strips that, when twisted, alter their electrical resistance. The resistance varies with increasing sensor bending. Flex sensors are fitted to the user's glove or the fingers of the prosthetic hand in a prosthetic arm. The flex sensor measures the amount that each finger bends as the user bends their fingers. Similar to EMG signals, this data is transmitted to the microcontroller. Since EMG only indicates when the user wishes to move, not precisely how much each finger should move, flex sensors are included in addition to EMG sensors. EMG, for instance, can identify when a user wishes to close their hand, but it is unable to determine whether they want to hold lightly or firmly. With the use of flex sensors, you can precisely regulate the angles of your fingers. This facilitates the prosthetic hand's natural motions, such as picking up small things, pressing a button, and gently holding a cup. Combining flex and EMG sensors improves the prosthetic arm's accuracy and responsiveness. Flex sensors provide precise finger locations, while EMG provides the intention to move. This combination makes jobs easier and more natural by enabling the user to manage each finger individually. Additionally, it enhances the arm's general functionality, enabling more fluid and human-like movements. Because flex sensors are small and simple to install, they do not add weight or discomfort to the arm. They are dependable and long-lasting, which is crucial for daily use. The arm can exactly understand human commands thanks to the combination of flex sensors and EMG, even in the absence of advanced AI algorithms. Like a real hand, the prosthetic can bend, open, and close fingers. Flex sensors also aid in adjustment and calibration. To ensure comfort and accuracy, each user can modify the sensors to fit the size and strength of their hands. EMG and flex sensors work together to make the prosthetic arm natural, intuitive, and easy to use. In everyday tasks including eating, writing, and grasping items, users can restore their independence without difficulty. All things considered, flex sensors improve the prosthetic arm's precision, control, and natural feel, making it a perfect partner for anyone in need.

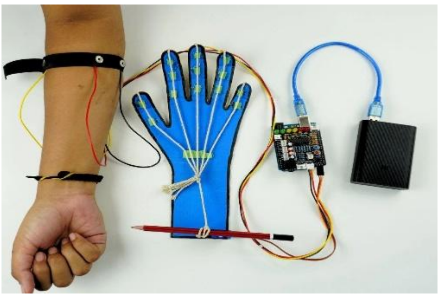

FIG 5: WORKING OF FLEX SENSOR

- **Microcontroller (Arduino)**

FIG 6: AURDINO

The prosthetic arm's microprocessor functions similarly to its brain. Information from the sensors on the user's arm and fingers is sent to a tiny computer, like an Arduino. When the user tries to move their hand, the EMG sensors pick up electrical impulses from the muscles. The amount that each finger bends is measured by flex sensors. Every one of these signals is transmitted to the microcontroller. It is the microcontroller's responsibility to interpret these signals and determine the user's desired action for the hand. It uses thresholds or basic rules to function. For instance, the microcontroller recognizes that the user want to close the hand if the EMG signal from a muscle is strong. The EMG detects the user's desire to open their hand if the signal is faint. To make hand movements more accurate and organic, the microcontroller can also use the flex sensor data to find out how much each finger should bend. The servo motors get commands from the microcontroller once it has processed the signals. The prosthetic hand's fingers and wrist are fitted with these motors. After that, the motors move in accordance with the user's commands. This enables the prosthetic hand to carry out actions such as pointing a finger, taking up a pen, and gripping a cup. Because the entire procedure is so rapid—almost instantaneous—the hand moves in unison with the user's muscles. Simple logic is used to program the microcontroller. The arm can function without sophisticated artificial intelligence. It just obeys the rules: make a specific movement when a particular signal is detected. As a result, the system is dependable, lightweight, and simple to operate. Future additions like Bluetooth control, data logging, and smartphone connectivity also become easy by using a microcontroller. Because it can manage several motors at a time, the hand can move its fingers in unison. Additionally, it aids in calibration, allowing the sensors and motors to be adapted to the user's comfort level and strength. In conclusion, the microcontroller makes the decisions. It determines what movement is required by listening to the data from flex sensors and EMG, then instructs the motors on how to move. The prosthetic hand would not move naturally without the microcontroller because the sensors and motors could not cooperate. It is the most crucial component that makes the prosthetic hand easy and comfortable to use by bridging the gap between the user's intention and its actual movement.

- **Servo Motors**

FIG 7: SERVO MOTOR

The components of the prosthetic hand that move the fingers and wrist are called servo motors. They function similarly to the prosthetic hand's muscles. The servo motors are in charge of converting the microcontroller's decisions into actual movements, while the EMG and flex sensors identify the user's intents. Typically, each finger has its own servo motor, and an extra motor may be present on the wrist to enable rotation. The EMG sensors pick up muscle activity when the user tries to bend a finger or close their hand. Flex sensors measure the degree of finger bending. The microcontroller receives these signals, decodes them, and then instructs the servo motors. To move the fingers or wrist precisely as the user wants, the motors then turn their shafts. As servo motors are so accurate, they may move at a precise angle instead of just spinning. This enables smooth and organic motions by allowing each finger to flex slightly or completely. A servo can, for example, bend a finger further to hold a water bottle firmly or softly close it to hold a paper cup. In order to properly lift, turn, or arrange objects, the wrist motor can also rotate the hand. Servo motors operate at high speeds and react to microcontroller inputs nearly instantaneously. This indicates that the user's muscular action causes the prosthetic hand to move in real time. Additionally, they are lightweight and compact, making the prosthetic arm easy to wear and pleasant. Despite having motors in each finger, the arm is nevertheless lightweight enough for everyday use. The prosthetic hand can perform a wide range of motions, such as opening, shutting, pointing, and gripping items of varying sizes, thanks to the use of servo motors. Because the motors obey basic instructions about how much to rotate, they are straightforward to control using an Arduino or microcontroller. Because of this, the system is dependable and predictable, which is crucial for users. In the end, the prosthetic arms mechanical muscles are called servo motors. They convert electrical data into actual movement by following instructions from the microcontroller. Without servo motors, the prosthetic hand would not be able to move, no matter how powerful the sensors or microprocessor are. Servo motors enable the prosthetic hand to move naturally, smoothly, and easily together with EMG and flex sensors, a microcontroller, and a 3D-printed structure, assisting users in taking their independence in daily tasks.

- **Prosthetic Hand Structure**

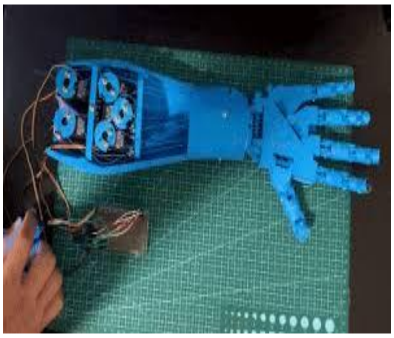

FIG 8 STURCTURE OF THE PROSTHETIC ARM

Consider an artificial hand that functions similarly to your own. We refer to this as a prosthetic hand. It is composed of components that move using tiny motors rather than muscles. Because the hand is 3D printed from PLA, a lightweight plastic, it is both sturdy and comfortable to wear. Like a genuine hand, it has fingers and a wrist. A tiny motor known as a servo motor powers each finger. The finger straightens or bends when the motor operates. This enables the hand to point at objects, grasp them, or hold them gently. To enable the hand to perform more actions, the wrist can tilt or twist. Certain prosthetic hands can even detect minute impulses from the user's muscles, allowing for genuine hand control. It is simple to pick up pencils, cups, or balls since the fingers have joints that allow them to flex in various directions. The motors are powered by batteries, and each finger is instructed on how to move by a tiny control system. Certain hands are able to recall simple motions, such as pointing a finger or holding a cup. Because user safety is a top priority, the motors are carefully controlled to prevent injury. The hand is securely held on the arm by straps or sockets. Some hands even incorporate sensors that detect the force of the object being held. The hand is made by engineers to be sturdy, lightweight, and comfortable to wear all day. People can use it to write, type, eat, and perform everyday tasks with experience. People can live normally and independently with the help of modern prosthetic hands, whose look lifelike. It feels almost like a real hand since technology controls every movement of the fingers and wrist. 3D printing makes it possible to replace damaged parts fast. These hands are incredible tools because of their lightweight construction, motors, and intelligent controls. They enable people to perform daily duties, restore confidence, and completely enjoy life.

RESULT AND DISCUSSIONS

In terms of functionality, weight, and use, the 3D-printed prosthetic hand's development using servo motors and lightweight PLA material produced promising outcomes. This model is significantly lighter than conventional prosthetic hands made of metal or heavier plastics, which makes it more comfortable to use for extended periods of time. Because each hand can be manufactured based on the user's arm size, 3D printing significantly decreased costs and simplified modification. During testing, the fingers and wrist were effectively driven by the servo motors, allowing for grabbing, holding, and pointing. Pens, glasses, and tiny bottles may all be held in the steady grip. Compared to conventional prosthetics that just employ hooks or basic open-close mechanisms, this design enabled multi-joint finger movement, increasing flexibility for everyday tasks. However, because of the motors' limited torque, the servo-based design was somewhat limited in its ability to lift heavy things. This 3D-printed servo motor hand is less expensive and easier to operate than sophisticated myoelectric hands, which require pricey sensors and advanced motors. Although expensive hands can replicate extremely natural human motions, most people cannot buy them. However, our design offers a reasonably priced substitute with respectable capability for daily duties. Simple programmed movements were more dependable for users without strong muscle signals, although in other situations, the use of EMG (muscle signal) sensors allowed for more natural control. The lightweight PLA construction was also found to lessen fatigue after extended use. Although the 3D-printed joints functioned flawlessly, frequent, intensive use might cause wear and tear. This implies that after a while, maintenance or part replacement might be required. Thankfully, compared to traditional prosthetics, 3D printing makes part replacements quick and affordable. In short up, this prosthetic hand strikes a balance between cost, usefulness, and comfort. It is lighter and provides better mobility than regular hard prosthesis. It is more affordable and easier to use than costly, advanced robotic hands. Therefore, even though this design cannot completely match the strength or complexity of sophisticated commercial prosthetics, it is best suited for users who seek a low-cost, lightweight, and effective prosthetic hand for routine everyday activities.

CONCLUSION

In this paper, we concluded that for everyday tasks, the 3D-printed servo motor prosthetic hand offers a portable, affordable, and useful alternative. It is more basic than pricey myoelectric hands, but it provides more comfort and mobility than conventional prosthesis. For practical usage, it offers a compromise between price, usefulness, and accessibility. For future scope we can add AI algorithms. With that algorithms the device can find user’s daily patterns, provide smoother and more natural hand movements.

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