Electromyography Based Prosthetic Hand

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Abstract. People who are adjusting to life without hands encounter a range of challenges. Losing hands can occur due to several causes, such as trauma, illness, congenital defects, or damage. This paper presents the development of an inno- vative electromyography (EMG) based prosthetic hand, designed to restore nat- ural movement and functionality for individuals with upper limb amputations. The prosthetic hand utilizes EMG signals from the user's skeletal muscles to con- trol the hand's movements, enabling intuitive and precise control. Advanced sig- nal processing and techniques decode the user's intentions and translate them into corresponding hand movements. The prosthetic hand features a range of motion that includes flexion, extension, and grasping, allowing users to perform various tasks easily. This paper aims to improve the quality of life for individuals with upper limb amputations, enhancing their mobility, independence, and overall well-being. The proposed system has the potential to revolutionize prosthetic technology, offering a more natural and effective solution for individuals with upper limb amputations.

Keywords: EMG Signal Processing, Prosthetic Hand, Upper Limb Amputations.

1 Introduction

Disability may be a nightmare for those who have to cope with obstacles throughout their lives that prevent them from contributing fully to society. Disabilities might make it difficult to be independent and included in society due to physical restrictions and cultural stigma. It's essential to remember that people with disabilities can overcome these challenges and have happy lives with the correct assistance and modifications. The majority of disabilities in today's world can be overcome with various assistive technologies and improvements in healthcare [1]. These advancements enable individ- uals with disabilities to lead fulfilling lives and actively participate in society. Moreo- ver, promoting inclusivity and raising awareness about the capabilities of people with disabilities can help break down societal barriers and eliminate the discrimination they face. Based on 2019 data, the number of people with upper limb amputations in the US and Japan is around 540,000 and 82,000, respectively [2]. Fifty to sixty percent of am- putees with upper limbs reportedly utilize prosthetic hands regularly. Electromyogram (EMG) signals, the interchange of ions in the muscle fibers produce minor electrical currents, which are formed by muscular activities (Relaxation or Contraction) repre- senting a person's inner physiological system, are used by MayoWare muscle sensor- based prosthetic hand, a type of externally driven prosthesis. Therefore, by identifying the movements acquired from electromyography data, EMG-based prosthetic hands en- able an amputee to move the prosthesis as naturally as a real hand. [3].

The development of a prosthetic hand is one of these improvements for those without hands, allowing them to regain the ability to perform everyday tasks and activities. It is a

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significant advancement in technology that has greatly improved the quality of life for individuals with hand disabilities. Recent advancements in 3D printing technology have completely changed the prosthetics field by lowering the cost and increasing the accessibility of custom-made prosthetic hands. For those with limb differences, it ena- bles the fabrication of complex designs and customized fits that lead to a more com- fortable and useful prosthetic hand. Furthermore, 3D printing lowers the overall mainte- nance expenses of prosthetic hands by making it simpler to repair or modify individual pieces [4].

A prosthetic hand is an electrical or mechanical device used to replace a hand that is missing or not working. A prosthetic hand is one type of assistive technology. An as- sistive device is any tool, apparatus, or technological advancement intended to facilitate the performance of tasks by people with impairments or restrictions that they may find challenging owing to their conditions [5]. For people who have lost a natural hand or have restricted hand use, prosthetic hands are designed to help. This paper involves an EMG-based prosthetic hand that uses muscle signals from EMG to control its motions. Individuals may acquire precise and natural hand movements and do complex activities with ease by correctly detecting and translating these signals. This ground-breaking technology promotes acceptance and equal opportunities for everyone by not only re- storing functioning but also enabling people with hand limitations to actively engage in a various aspects of life. A five-finger, three-dimensional hand is connected to a micro- controller and myoelectric sensors, which collect the body's electrical signals used to move muscles. The microcontroller then interprets these signals, translating them into the commands to move the hand in a particular way.

The proposed prosthetic hand reads small muscle signals to move the fingers and hand in a natural and precise way, almost like a real hand. It provides individual finger movement and control, whereas previous prosthetics had limited control and hand movements.

2 Methodology

The development of EMG-based prosthetic hand consists of two parts: The electronic part and the assembling of a prosthetic hand, which are demonstrated below in detail.

2.1 Electronic part

The EMG signals were recorded using the MayoWare sensor, an advanced version of the muscle sensor. It provides a rectified signal because it contains a built-in instrumen- tal amplifier, a low-pass filter, a high-pass filter, and rectifiers. The sensor is placed on the muscles of the forearm (the flexor digitorum profunds, flexor digitorum superfi- cials). The individual signals detected from the thumb, middle finger, ring finger, index finger, and little finger were recorded separately for each of the respective muscles.

As impulse single is detected from skeletal muscles by the MayoWare muscle sen- sor, which then assesses each signal by the microcontroller's programming, as the mus- cle activates or reaches the threshold value the motors start to move according to muscle movement detected by the EMG sensor. The motors are further connected to fingers with nylon fibers which helps in performing finger movement then the amputee can perform all of the regular hand functions, like gripping and holding objects.

2.2 Assembling of a prosthetic hand

The 3D design of the prosthetic hand is taken from the Inmoov hand website printed with Polylactic Acid (PLA) material and assembled as shown in (Fig. 1). PLA is an easy-to-use 3D printing material. It can be printed at low temperature, does not require environmentally controlled build chambers, and can be purchased in filament form at a low cost. However, it exhibits low heat resistance relative to other 3D printing materials and may not meet the mechanical requirements of the application due to its mediocre strength properties [6].

The main goal in designing the prosthetic hand was to successfully guide the nylon fibers, which control the fingers, through the entire hand. This involved carefully rout- ing the fibers from the servo motor's pulley wheel, through the cable rob and string tensioner, and then through the rotwrist1 component via the cable holder in the wrist. Finally, the fibers emerge from the forearm, passing through the big gear and into the palm. After guiding the fibers through the designated holes in the palm for each finger, there is a need to thread them through the individual fingers. To do this, pass each side of the thread through opposite ends of the finger pulleys. Then, route the thread back in the opposite direction, aiming to pass it through the pulley again, making sure to keep the string taut. This process ensures a smooth and secure connection for finger movement [7].

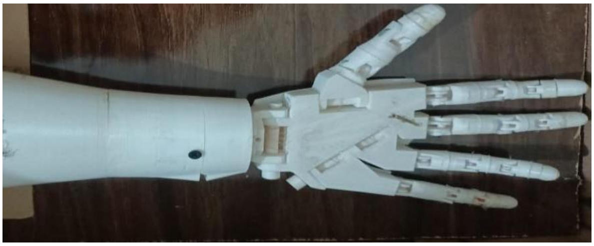
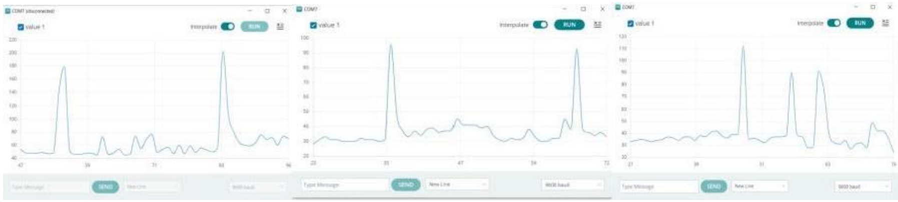


Fig. 1. 3D design of the prosthetic hand

3 Results & Discussion

The prosthetic hand is controlled by EMG signals, which are generated by the residual muscles of the user. The mechanism of muscle contraction and relaxation is processed, as signals detected from muscles and interpreted by a microcontroller and demonstrate how to design and control actions based on incoming signals. There are various types of muscle, skeletal muscles, smooth muscles, and cardiac muscles. The skeletal muscles are responsible for human body movement. Our focus is on skeletal muscles, which facilitate human movements. Muscle Contraction EMG is a method that measures the physiological movements in the skeletal muscles to research and analyze muscle activ- ity. The electrical signals that are produced by the body's neurons and result in these physiological fluctuations can be measured by the EMG technique. These signals in- clude flexing and contracting of the muscles. The task of sending the neuron signal to the muscle fibers is carried out by a tiny functional unit known as the motor unit. An ionic shift occurs when the electrical signal from the neuron reaches the muscle. A small potential difference will occur between the inside and outside of a muscle cell, generating a potential between muscle fibers.

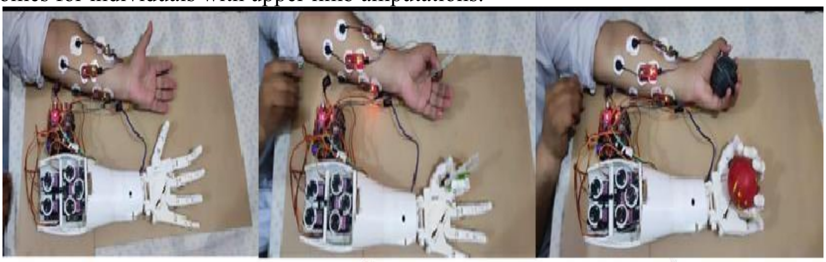
A 3D printed hand prosthesis designed for underdeveloped countries with limited resources has been created to find the best possible collaboration between cost and technological performance. For this goal, myoelectric stimulation has been selected as the activation signal since it improves prosthesis-person integration and makes prosthe- sis operation easier. The electromyography signal is captured by the MayoWare muscle sensor placed on the amputee or on skeletal muscles, which then sends electrical im- pulses to the hand prosthesis, allowing for more natural and intuitive movements. The MayoWare muscle sensors were placed on various muscles of the forearm or residual hand, where they captured different signals as the muscles contracted or relaxed. The EMG signals graph displays the EMG sensor signals as muscles perform activities fin- gers move and the signal graph reaches to threshold value/ peak value the y-axis shows the amplitude in microvolts and the x-axis shows time in seconds as shown in the fol- lowing (Fig. 2 a) shows thenar muscle movement which is responsible for thumb finger flexion, (Fig. 2 b) shows Flexor digitorium muscle movement which is responsible for index and middle finger and (Fig. 2 c) shows a ring and little finger movements.



a b c

Fig. 2. (a) Thumb, (b) Index and middle, (c) Ring and little finger signal

The EMG signals from the Flexor Digitorum Superficialis (FDS) muscle group, rec- orded using the EMG system, showed a significant increase in amplitude during the gripping phase, peaking at 200 microvolts at 7 seconds, indicating effective control of the prosthetic hand. The signals were filtered and processed using a developed algo- rithm to extract the relevant features and reduce noise. The prosthetic hand was con- trolled using a real-time control system, which translated the EMG signals into motor commands to actuate the hand's movements. The subject was able to perform a variety of tasks, including releasing, holding objects, and grasping with a high degree of accu- racy and precision, as shown in (Fig. 3 a, b, c) respectively. The results demonstrate a significant improvement in prosthetic hand control compared to traditional control methods and suggest the potential for improved functional outcomes for individuals with upper limb amputations.



a b c

Fig.3. (a) Full hand relaxes, (b) Holding a card, (c) Grasping a ball

The illustrations above demonstrate that fingers have a wide range of motion, allowing them to cover a similar range as human hand movements. The flexible structure of the fingers enables all finger joints to move simultaneously, or individual joints can move in coordination to achieve various shapes when grasping objects. This flexibility in the finger structure facilitates the ability to grasp several objects.

EMG-based prosthetic hands have a profound impact on both social and psycholog- ical aspects of an individual's life, improving their overall quality of life. By providing natural and precise movements, these prosthetics enable users to regain independence and confidence in their daily lives and promote social acceptance. Psychologically, it helps to restore motor control and muscle function, muscle withering, and improve overall physical health, while also reducing fatigue and discomfort.

4 Conclusion and Future Work

This paper shows that the EMG signals from the skeletal muscle group are used to control a prosthetic hand. The results showed a significant improvement in prosthetic hand control, with accuracy and precision in performing various tasks. The EMG sig- nals provides a more intuitive and natural control method, allowing individuals with upper limb amputations to regain functional capabilities.

Future developments in EMG-based prosthetic hand movement and sensitivity will be enhanced, machine-learning algorithms will be implemented for better control and near-to-natural hand movements. The signal processing will be improved, further wrist movement will be performed and allow users to perform complex tasks with ease. Ad- ditionally, more extensive data will be collected, feedback from actual users will be included and case studies will be included for understanding the real-world usability of the prosthetic hand's effectiveness and performance.

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