EMG sensor based control strategy for hand function movements using 3D prosthetic hand

S.Surya[1], Dr.S.Ramamoorthy[2]
Research Scholar[1],Associate Professor[2]
[1,2]Department of Computer Science and Engineering, SRM Institute of Science and Technology ,Kattankulathur CampusChennai, India
E-mail : [1]suryacse05@gmail.com , [2]ramamoos@srmist.edu.in

Abstract:

This paper presents advancements in the design of a portable, compact, efficient and less cost development of 3D prosthetic hands. Electromyography sensor is a biomedical signal that records muscle contractions. It is capable of detecting muscle movements. This work implements the use of Electromyography (EMG) signals to build an assist system that enables patients with hand paralyzed to restore restricted hand functions.Monoplegia occurs when paralysis only impacts one arm or one leg. It is caused by injury to parts of the brain that control the movements of the limbs thus leading to problems in the signals flow through the muscles and brain. The proposed scheme seeks to collect data from muscles using EMG sensors, connected with Arduino UNO and the patient's hand movement control by using servo motors. Prosthetics are the most widely used support devices in the medical field. Prosthetics are synthetic extensions that are used to restore or replace missing or damaged body parts. The functions involve opening the hand , closing the hand , grasp, release or lift the object or items and they can be utilized by paralyzed patients to do fundamental hand movements on their own.This experimental results prove will rehabilitate monoplegia paralysis affected people should use this 3D printed prosthetic hand to continue with normal daily activities.

Keywords— Arduino, EMG sensor , Prosthetic Hand, Rehabilitation, Servo motor

INTRODUCTION

Electromyography is a biological signal that is produced by body muscle activity.It is a method for analyzing and collecting a sequence of electrical impulses sent by body muscles that is based on experimental.This signal can identify muscular contractions. EMG signal may be used to operate electronic prosthesis by detecting deliberate muscle contraction. Prosthetics are the most widely used support devices in the medical field.Furthermore, 3D printing has made it possible to design and create 3D models of a prosthetic limb that are customized to the patient's needs[8][9].

Patients may use a prosthetic hand to close the hand, open the hand, pick or lift up a pencil, carry water in glass, type letters on a keyboard, and more simple tasks. Electromyography can be used to analyze signals generated in muscles by brain activity, and 3D printing can be used to manufacture a prosthesis that is both inexpensive and completely functional[3]. This would allow patients to perform everyday tasks that may be much more difficult as an output of a limb-severing occurrence.

Electromyography is a diagnostic method used to understand the analyzing muscles electrical activity[5]. These potentials are generated from the muscles when they are stimulated electrically or neurologically.Prosthetic hand assist techniques are being rapidly used for upper and lower limb rehabilitation. These techniques provide high intensity training. It improves grasping and releasing capability of the paralysed patients[6].

Electromyographic signals (EMG) are one of the most viable options for this application, according to several studies, since they give extremely precise information on limb movements[12].The usage of electromyographic signals has grown throughout healthcare, with prosthetic devices for amputees[2] and people with limb paralyzed including it.[10]

In this research, the primary goal of this work is to facilitate the hand movement of a paralysed patient using a prosthetic hand. EMG signals captured from the limbs help in the movement of the hand through signals or gestures.This paper provides an overview of the design process as well as work standards for the prosthetic hand and point-by-point descriptions of numerous devices with implementations are described successfully in this work. An EMG signal, an Arduino, and a servo motor are utilized to operate a prosthetic hand[1][7]. To achieve the ultimate goal, using a servo motor to control the movement of the prosthetic hand.Furthermore, the actions are divided into four categories: extension, flexion, grab, and object lift.

The overview of this research paper consists of related research in section II, methodologies of the proposed work mentioned in section III. The experimental results are presented in Section IV, and the study conclusion is presented in Section VII.

I. RELATED RESEARCH

Nowadays a lot of people are affected by nervous problems that lead to stroke or paralysis . With a rising number of paralysis patients or amputees in need of treatment like rehabilitation , it's more important than ever to have a thorough assessment of each one[2]. Visual observation, patient surveys, and goniometry are presently used to make this assessment (The range of motion of a single joint is observed while the patient is at rest.). These procedures are vulnerable to subjectivity and human error, even when they are precisely conducted. In the existing system having two different types of treatment . The two types of treatment are the method of surgery and the oil treatment. In the case of oil therapy, it is necessary to enlist the assistance of others, and recovery takes a long time. The likelihood of recovery is extremely low and unpredictably low. It utilizes a copper-like setup to eliminate obstructions in the blood arteries in surgical procedures. The majority of blockages are cleared with this approach (not completely). Another disadvantage of this method is that it takes longer to heal.[8].

The results of this research assist persons who have lost or are paralyzed in one of their hands. It is very helpful for those people. The Prosthetic Hand is made at a low cost. The entire system may be finished for less than 14,000 rupees, making the prosthetic hand incredibly economical in comparison to the current robotic hand concept. Prosthetic hand is Very easily portable. Because of the lightweight 3D printed prosthetic hand, the paralyzed person/loss of hand may easily take it with them or use a glove type.

II. METHODOLOGY

The initial stage is to use surface electrodes to collect EMG data from the patient arm. In EMG sensors, three electrodes are utilized: two electrodes are used for recording the signal, while the third electrode acts as a reference electrode. After selecting on the target muscle (biceps or forearm), one

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

electrode is put in the center of the muscle body, while the other is put at the muscle's end and in the direction of the muscle length.The reference electrode is put on the above elbow since it is shown to be the most effective.The electrodes utilized were silver/silver chloride (Ag/AgCl) electrodes with circular diameters of 10 mm. The distance between the centers of the conductive portions of the bi-polar electrodes was fixed between 1 and 1.5 cm. The electrodes were pre-gelled to reduce electrode-to-skin impedance. Before the electrodes were implanted, the skin was sanitized with a sanitizer. The processed EMG data are also utilized to distinguish forearm movement and distinguish forearm hand states such as flexion and extension. The paralyzed patient's forearm hand can be moved with the aid of a prosthetic hand.

A. Acquisition of Signal using EMG Sensor:

Three electrodes were used to capture the EMG signal for muscle movement : two EMG surface electrodes (bipolar) and one reference electrode.Surface electrodes for bipolar EMG are implanted on the Flexor Carpi Radialis and Biceps Brachii muscles for signal recording during hand movements, as illustrated in Fig. 1.The common reference electrode was put on the wrist or above elbow of the patient’s hand, since this was shown to be the best position for obtaining data.

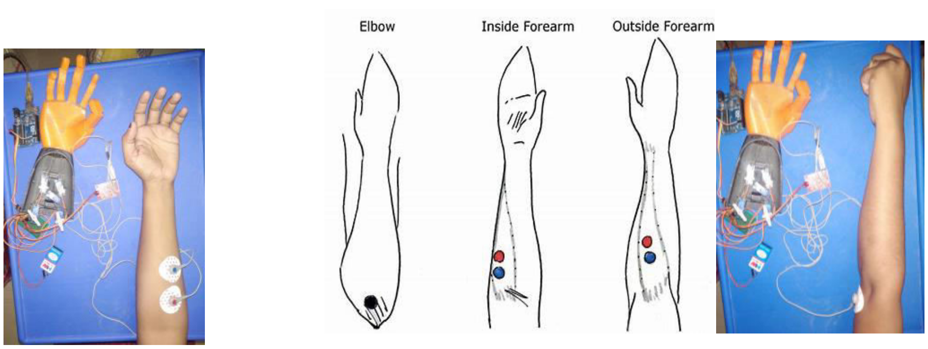


Fig. 1. Electrodes placement for signal acquisition

B.Control of Prosthetic Hand :

Using signals obtained from wrist and elbow motions, the prosthetic hand was intended to help the hand's elbow motions. After processing, the EMG signals were sent into an Arduino UNO as a control signal.If the person closes his hand, the signal received is considered as wrist flexion.This causes the motor to rotate in an upward and downward motion, allowing paralyzed patients' arms to open and shut their hands, grab objects, and raise and release them.The motor is supplied by an external power supply, and its control input is attached to the PWM ports in Arduino UNO. As a result, EMG signals captured from the healthy arm were used to effectively operate the prosthetic arm.

III. EXPERIMENTAL SETUP

A. EMG Sensor:

Electromyography is a modern clinical neuroscience research strategy for observing and monitoring muscle strength electrical activity. It is carried out with the aid of an electromyograph. Electromyography measures the electrical potential produced by muscle cells through the electrodes as seen

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

in Fig 2. Three non-invasive skin surface electrodes are placed near the field during the procedure. As a result, the voltage of the EMG signal might be positive or negative at any given instant.These electrodes are often used to obtain individual muscle fiber action potentials. The total of the action potentials of all the muscle fibers in a single motor unit which may be detected by electrodes, is called the motor unit action potential (MUAP). The signal from the electrodes is further analyzed to operate a prosthetic arm or hand.

Fig 2. EMG Sensor for signal acquisition

B.3D Prosthetic Hand:

Prosthetics in 3D Hand-drawn with fusion 360 degree and cura software, then printed with a 3D printer. The actuator was controlled by servo motors and individual servo motors were used to connect every finger. An Arduino UNO microcontroller was used to control the servo motors.

Focus on producing a safer prosthetic arm that is 3D printed with a compact structure that can carry a suitable weight and can grip numerous common things in a flexible manner in this research.

Fig 3. Design of 3D Prosthetic Hand

C. Arduino UNO :

Fig 4. Work flow of Control the fingers movement using Arduino UNO

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

The motions of prosthetic hands are controlled by an Arduino UNO with servo motor and receive signal from hand using EMG sensors attached in hand. To process and control servo motors, signals from EMG sensors are sent to the Arduino Uno package. The prototype's operation is powered by an Arduino and a servo SG90. To control the movement of the fingers, each finger is attached to a servo motor.

D. Servo Motor:

A servomotor is a linear or rotary actuator that enables perfect measurements of sequential or angular position and velocity. It is made of an appropriate motor and a position feedback sensor. It also needs a powerful controller, which is frequently a special unit created specifically for use with servo motors. Servo motors are used in a variety of sectors, including medical and industrial applications, as shown in Figu**re 5**. The motor power supply is turned off once the shaft of the motor has been tracked to the required position. If this is not the case, turn on motor in the proper direction.

Fig 5. Servo Motor

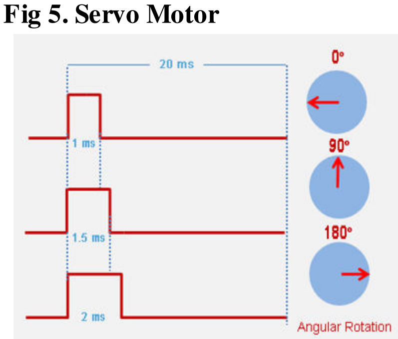


Fig 6. Rotation Direction

Servo motors can rotate from 0 to 180 degrees, but they may also rotate up to 210 degrees, based on the model. Applying an Electrical Pulse of the right width to the Control pin will control the degree of rotation. Per 20 milliseconds, Servo tests the pulse.The servo can be rotated to 0 degrees with a 1 ms (1 millisecond) pulse, 90 degrees (neutral position) with a 1.5 ms pulse, and 180 degrees with a 2 ms pulse. All servomotors connect straight to +5V supply rails, however the amount of current they use must be considered. If you want to use more than two servo motors, a suitable servo shield should be designed.

The servo motors are in control of the fingers' movement and can complete the activity. The user performs like opening and shutting the hand's five fingers , the Arduino will send the required signals to the servo motors to perform activity, which entails a five-second break between each open and close the hand.

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

E. Battery:

Fig 7.Battery used in this model.

The Hi Watt 9V battery is a cost-effective, dependable, and focused low-power solution for powering your device. It's best found in circuits with long battery life so it can run for extended periods of time.This battery is used in this work model.

F. EXPERIMENTAL SETUP:

The Prosthetic hand's functioning mechanism and flow are represented in this block diagram. EMG sensors attached to the residual muscle in the patient's arm and prosthetic hand are controlled through a servo motor. Sensors detect EMG impulses, which are then analyzed in Arduino and transformed to prosthetic hand motions. The individual finger movements of the 3D designed and printed hand are controlled by servo motors in this application.

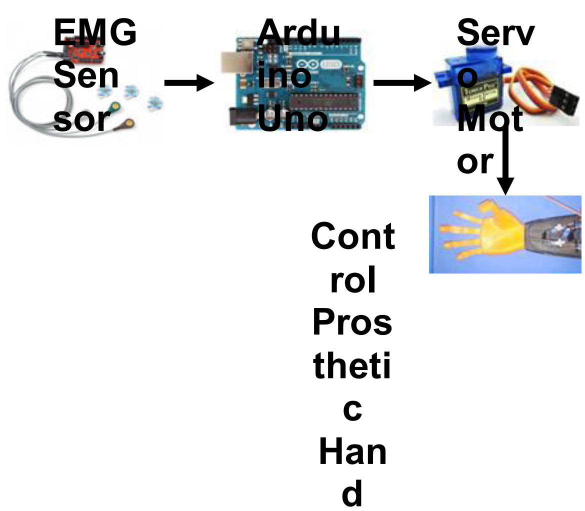


Fig. 8: Working Mechanism of the Prosthetic Hand

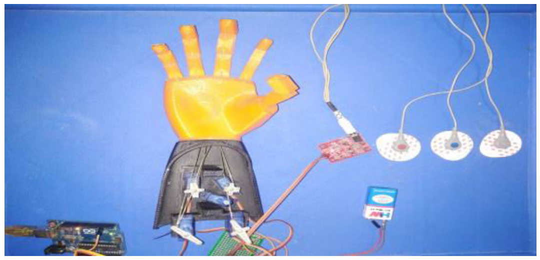


Fig. 9: Sample Working Mechanism of the Prosthetic Hand

IV. 3D Prosthetic Hand Modelling

S. No	Part Name	No.of joints	Design of 3D Prosthetic Hand
1.	Baby Finger	3	
2.	Ring Finger	3	
3.	Middle Finger	4	
4.	Index Finger	3	
5.	Thumb Finger	2	
6.	Palm		
7.	Wrist		

Table 1. Specification and Design of Prosthetic Hand.

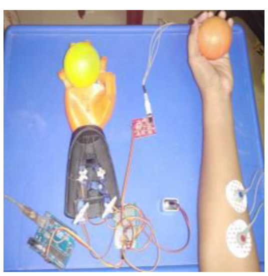
V. RESULTS AND DISCUSSION

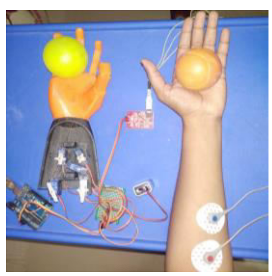
This whole system of prosthetic hand works with a battery. This basic frame is formed with 3D printed parts which makes the connection with servo motors, which are controlled by the Arduino board through input signal given by the EMG Sensor.Using EMG signal, the prosthetic hand starts functioning. The evaluation of prosthetic hands is conducted using the basic activity of daily life.

A task for testing prosthetic hand in four different ways: The process involves: 1. Opening the hand or extension 2. Closing the hand or flexion 3.Grasping the object 4.Release or lift the object.

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

Extension **Flexion**





Grasping the object **Release the object**

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

Fig 10. Testing the prosthetic hand in four different ways

Trials	Movement of the Hand Function			
	Extension	Flexion	Grasping the object	Release the object
Person 1	Yes	Yes	Yes	Yes
Person 2	Yes	Yes	Yes	Yes
Person 3	Yes	No	Yes	Yes
Person 4	Yes	Yes	No	Yes
Person 5	Yes	Yes	No	Yes

Table 2: Trials of Prosthetic Hand

The results of five people's testing of the Prosthetic Hand are shown in Table 2. Four types of trials are included: Extension, Flexion, Grasping the object and Release the object.The experiment's outcome is represented in Fig.11.The accuracy of the system should further improve for the next stage.

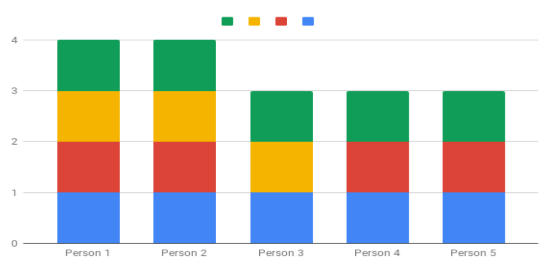


Fig 11. Prosthetic Hand Performance Evaluation Chart

VI. CONCLUSION

Patients having numerous forms of hand impairments have difficulties in their daily activities, which is why this research proposes a light-weight, low-cost prosthetic hand as an alternative to the current devices.In this we have prepared the lightweight 3D-printed prosthetic hand which consist of Arduino, servo motor and sensor. Using Arduino board programming the whole system is controlled through a servo motor to perform the daily life activities. In this paper, a prosthetic arm designed to assist individuals with functional hand open, hand close, grasp and lift the object.Using a prosthetic hand and biological signals, this research suggested an efficient approach to rehabilitate the paralyzed hand in real time.The work allows the paralyzed patient to improve the muscle condition of the arm/hand. The EMG sensor's feasibility is utilized to detect the patients' muscular activity. Using electrical signals are converted into actions, helping the paralysis patients to utilize the damaged or affected hand.By the control strategy proposed in this research, the paralyzed patients will greatly regain their self-confidence and also take care of themselves.

Future Scope

The researchers want to analyze more at EMG samples from various directions of arm motions in the future. Researchers are going on to develop hand gesture recognition/biological signals using the EMG sensor or some other muscle sensor. A system with more advanced algorithms than proposed and existing one has to be developed, and use the same to detect signals /gestures made by the people for automation.

Acknowledgement

I would like to give special thanks to My Guide for his continued support and valuable advice. I thank him for his diligent efforts in guiding me in every part of my analysis of research work.

References

[1] Tabassum, Ms Humera, and Veena Saraf. "A Low Cost Prosthetic Hand using Arduino and Servo Motors." International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 9 Issue 07, July-2020.

[2] Sakib, Nazmus, and Md Kafiul Islam. "Design and Implementation of an EMG Controlled 3D Printed Prosthetic Arm." In *2019 IEEE International Conference on Biomedical Engineering, Computer and Information Technology for Health (BECITHCON)*, pp. 85-88. IEEE, 2019.

[3] Farooq, U., U. Ghani, S. A. Usama, and Y. S. Neelum. "EMG control of a 3D printed myo electric prosthetic hand." In *IOP Conference Series: Materials Science and Engineering*, vol. 635, no. 1, p. 012022. IOP Publishing, 2019.

[4] Imran, Alishba, William Escobar, and Freidoon Barez. "Design of an Affordable Prosthetic Arm Equipped with Deep Learning Vision-Based Manipulation." *arXiv preprint arXiv:2103.02099* (2021).

[5] Utane, Akshay S., Mahesh Thorat, Shivam Kale, Dakshayani Sangekar, and Shivani Kondhekar. "Assisting system for paralyzed and mute people with heart rate monitoring." (2019).

[6] Divakaran, Sindu, T. Sudhakar, D. Haritha, and Khudsiya Afshan. "Hand Function Improvement for Hemiplegic Patients Integrated with IOT." *Journal of Pharmaceutical Sciences and Research* 11, no. 9 (2019): 3137-3139.

[7] VanHuy, Tran, Dao Tuan Minh, Nguyen Phan Kien, and Tran Anh Vu. "Simple robotic hand in motion using arduino controlled servos." *International Journal of Science and Research (IJSR)* 6, no. 3 (2017): 972-975.

[8] Krishnavarthini, M., N. Sivakami, P. Suganya, M. Sheerinbegum, and G. Saranya. "Raspberry Pi Based Paralyze Attack Rehabilitation System." (2017).

[9] Mounika, M. P., B. S. S. Phanisankar, and M. Manoj. "Design & analysis of prosthetic hand with EMG technology in 3-D printing machine." *Int. J. Curr. Eng. Technol* 7, no. 1 (2017): 115.

[10] J. Ma, N. V. Thakor, and F. Matsuno, "Hand and wrist movement control of myoelectric prosthesis based on synergy," *IEEE Transactions on Human-Machine Systems,* vol. 45, pp. 74- 83, 2015.

[11] Khan, Rafiqul Zaman, Noor Adnan Ibraheem, and Natarajan Meghanathan. "Comparative study of hand gesture recognition system." In *Proc. of International Conference of Advanced Computer Science & Information Technology in Computer Science & Information Technology (CS & IT)*, vol. 2, no. 3, pp. 203-213. 2012.

[12] M. A. Oskoei and H. Hu, "Myoelectric control systems—A survey," *Biomedical Signal Processing and Control,* vol. 2, pp. 275-294, 2007.