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Assistive Device to Control Prosthetic Hand Movements Using Machine Learning Approach

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***Abstract*---**Smart Assistive devices developed to support the disabled people suffered with Monoplegia. The Monoplegia kind of a paralysis which have the impact on one arm or one leg. The person affected with this disease unable to move the hand or leg to perform their regular activities. The rehabilitation process of paralysis affected patient involves make them to perform their activities by own with the help of an assistive smart device. The device must be capable to identify the user intension of activity and assist them to perform the same task. The proposed work makes use of 3D prosthetic hand to replace the inactive hands of the patients. The prosthetic hands are synthetic extensions that are used to support or supplement the affected or disabled parts. The Electromyography sensors installed on this prosthetic hand produces the biomedical signal that records muscle contractions. These sensors are capable of detecting muscle movements and high variations in real time. The proposed work makes use of Electromyography (EMG) signals to build an assist system and identify the intended activity. These enables patients with hand paralyzed to perform the inactive hand functions. The various hand function movements involve opening the hand, closing the hand, grasp, release or lift the object or items and they can be recognized through the EMG Signal based patterns. The patterns allow the prosthetic hand to decide the type of activity the patient interested. The Deep Convolution Neural Networks are used to analyze the EMG signals and classify the patterns.

***Keywords*---**Prosthetic Hand, EMG sensor, Deep Learning, Convolution Neural Networks, Patterns etc.

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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 signals are used to analyze muscles variations generated by brain activity. The 3D printers are 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]. The paper identifies the target EMG signals generated from the muscles and stimulate the signals through electric and neuron-cells. Prosthetic hand based assistive techniques are being deployed on the upper and lower limb of the patients to control the activities. The proposed model performs the various data training operations to improve the Object grasping and releasing capabilities of disabled patients [6].

Electromyography 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 electromyography 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 to facilitate the hand movements of an affected patients using 3D prosthetic hand. The 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 the activities of the prosthetic hand. Furthermore, the actions are classified into four categories: extension, flexion, grab, and object lift.

Related survey

Overall survey on Paralysis attacks provides the statistics that many 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.

Methodology

The Proposed methodology make use of EMG sensors which is attached in the upper arm of the Hand to collect the movement signals. The EMG sensors attached surface electrodes collect the 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 the intended hand muscle (upper arm or forearm), the electrode installed on 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 electrode placed on the above elbow to analyze the variations in the most effective way. The electrodes utilized were silver or silver chloride electrodes with circular diameters of 10 mm. Before the electrodes were implanted, the skin must be 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 to recognize the hand gestures. The intensity of the EMG signal strength decides the type of activity initiated by the patients. The abnormal signal movement results into the high variations. These variations provide the better difference among the movements.

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 muscles for signal recording during hand movements, as illustrated in Fig. 1. shows the implantation of electrode on the wrist and above elbow of the patient’s hand, to collect the muscle variation data used of the analysis.

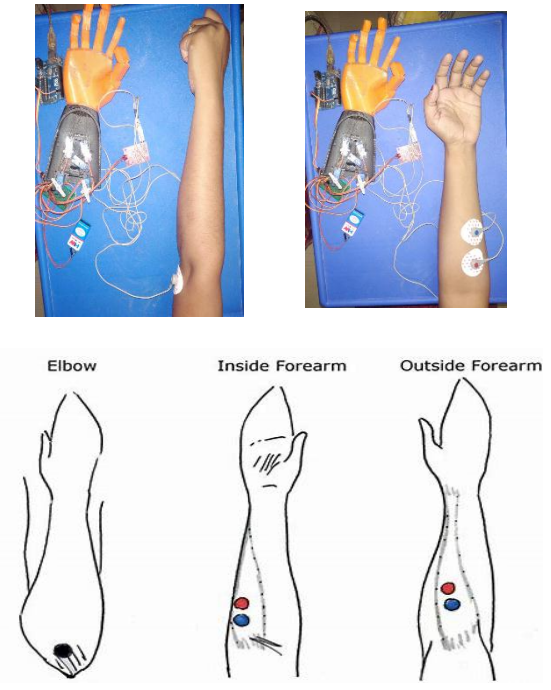

Figure 1. Electrodes placement for signal acquisition

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 close the hand, the signal received is considered as wrist flexion. This causes the motor to rotate the up and down motions, 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.

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 electromyography. Electromyography measures the electrical potential produced by muscle cells through the electrodes as seen 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 signal from the electrodes is further analyzed to operate a prosthetic arm or hand.

B. 3D Prosthetic Hand:

The 3D Prosthetic Hand designed with fusion 360 degree using the Cura software, then printed with a 3D printer. The actuator controls the servo motors and every servo motors are used to connect every finger. The Arduino UNO microcontroller used to control the servo motors. The Prosthetic hand provide the real time sample structure of Hand and various fingers to identify and control its operations. To 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.

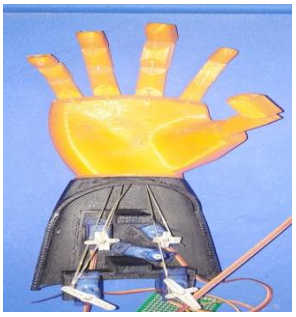

Figure 2. Design of 3D Prosthetic Hand

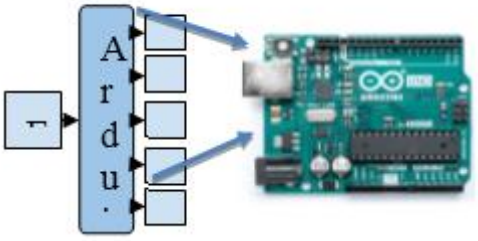

Figure 3. Finger Control movements using Arduino UNO

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.

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.

Classification of rotation directions

The various Finger movement Rotation directions are identified through the servo motors. The servo motors used to provide the angle in which user turn the finger to perform the particular action. These actions are incorporated in the process of Gesture recognition to identify the user intention to move the objects.

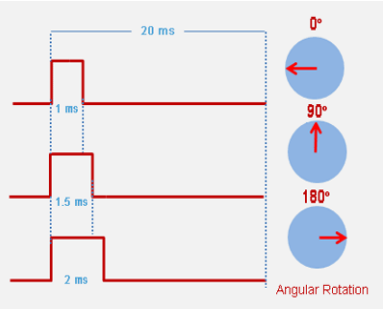

Figure 4. Classification of Rotation Direction

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. The Board make use of 9V Watt battery in a cost-effective manner, dependable, and focused low-power solution for powering the device. Its best found in circuits with long battery life so it can run for extended periods of time.

Deep Convolution Neural Networks

Deep Learning is a kind of machine Learning Model which used to build the Artificial Intelligence system. The Deep Convolution Neural Networks (DCNN) mostly used to identify the Patterns in the Image or Videos. The Proposed EMG Signal based prosthetic hand identify the Hand gesture pattern through Deep CNN. The model classify the type of activity the user intended to perform through the pattern derived from the model.

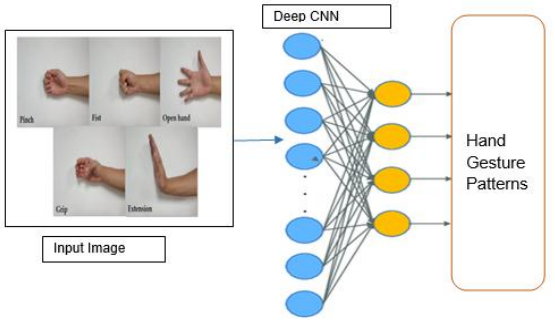

Figure.5. Deep CNN Model

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 Prosthetic hand designed and controlled by servo motors in this application.

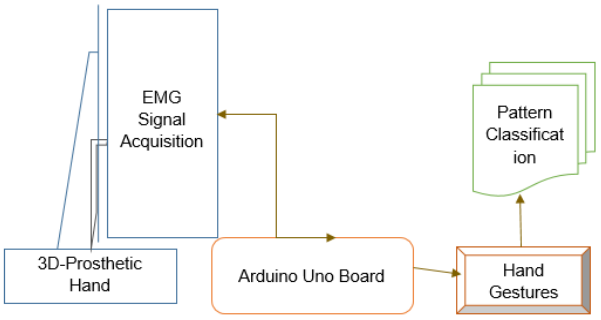

Figure 6. Working Mechanism of the Prosthetic Hand

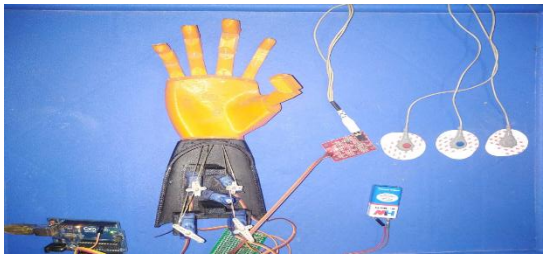

Figure 7. Sample Working Mechanism of the Prosthetic Hand

A. 3D Prosthetic Hand Modelling

The 3D Prosthetic Hand modeled using various hand gesture Patterns. The specification of various fingers provides the type of hand movement.

Table 1
Specification of Prosthetic Hand

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		

Results and Discussion

The Implementation of prosthetic hand works with supported sensors to analyze the pattern. 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 and EMG signal, the prosthetic hand starts functioning. The assessment of prosthetic hands conducted using the day today activities in 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.

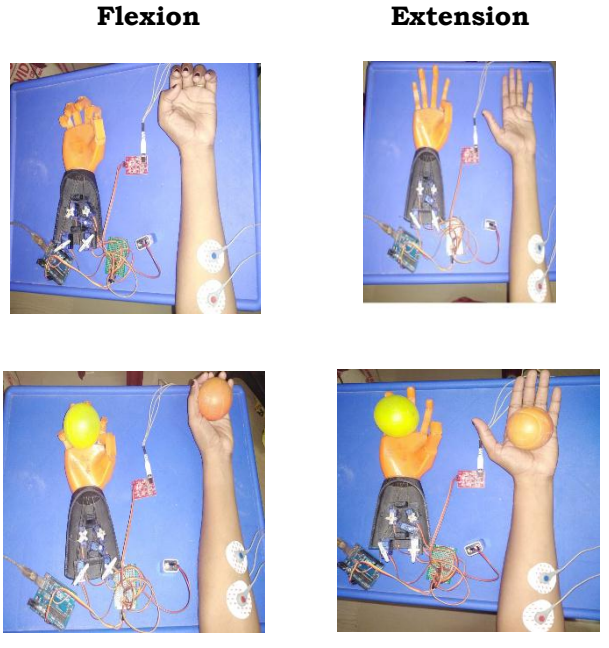

Figure 8. Testing the prosthetic hand in four different forms

Table 2
Trials of Prosthetic Hand

Sample 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

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 improved further in the next stage.

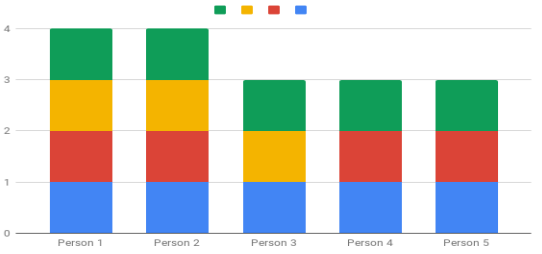

Figure 9. Prosthetic hand performance evaluation

Conclusion

The disabled Patients having numerous forms of hand impairments and due to paralysis attack patients have difficulties in their daily activities. The proposed research paper introduces the smart Prosthetic hand based assistive device to support the disable people. The model designs the lightweight 3D-printed prosthetic hand which controlled by the Arduino. In this paper, a prosthetic arm designed to assist individuals with functional hand open, hand close, grasp and lift the object. Using 3D prosthetic hand and biological signals, the model suggests the pattern which efficiently rehabilitate the paralyzed hand in real time. 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. The proposed model accurately identifies the type of intended action of the patients through Deep Convolution Neural Networks. The smart hand gesture movement patterns are also making the greater impact on this assistive device.

Future Scope

The proposed model can be extended with more EMG sensor fixed at various directions of arm motions in the future. The model provides further scope for development of hand gesture recognition/biological signals using the EMG sensor or some other muscle sensor. A system with more advanced ML algorithms may use to detect signals /gestures made by the people for automation.

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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.