Review on the Developments in Prosthetic Amputation Technology

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***Abstract*- Prosthesis or prosthetic amputation is the method of replacing a body part with an artificial part. A Prosthetic hand is an artificial device which replaces the missing hand of an amputee. The artificial device could be either non-moving aesthetic arm or an automated motor controlled movable arm. The automated movement is controlled by various methods which are discussed in this paper. Control methods of EMG and EEG are discussed here. Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. It is recorded using a device called Electromyogram which detects the electric potential generated by muscle cells when they are electrically or neurologically activated. Electroencephalography (EEG) is a method to record electrical activity of the brain, using electrodes placed along the scalp. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. This paper compares these methods of prosthesis and proposes reviews on them.**

***Index terms*- Amputation, Electroencephalography, Electromyography, Prosthetic hand, Rehabilitation, Signal Processing.**

I.INTRODUCTION

India is a country where deaths and accidents are increasing rapidly. Co-relating these two, deaths due to accidents are becoming more and more common. Among them, losing body parts in the accidents is also a major incidence. On an average 410 people lose their lives due to road accidents every day and 23,000 people lose their arms every year in India. The main reason for amputees is either industrial accidents or car accidents involving vehicles. Not only accidents are the case, people are disabled due to several other factors too. In India, there are about 5 million disabled people (in movement/motor functions). The people become disabled when affected with neuromuscular disorders such as multiple sclerosis (MS) or amyotrophic lateral sclerosis (ALS), brain or spinal cord injury, Myasthenia gravis, brainstem stroke, cerebral palsy, etc. In order for them to lead a normal life, they are in need of prosthetics. Hand prosthesis is an artificial device which replaces the missing hand and it is expected to fulfill the functional and aesthetic requirements of the amputated biological counterpart. Hand prosthesis can be achieved by various methods. of them, Electromyography (EMG) and Electroencephalography (EEG) are more successful and widely used. The aim of this paper is to review these methods and point out their efficiency and drawbacks

II. PROPOSED METHODOLOGIES

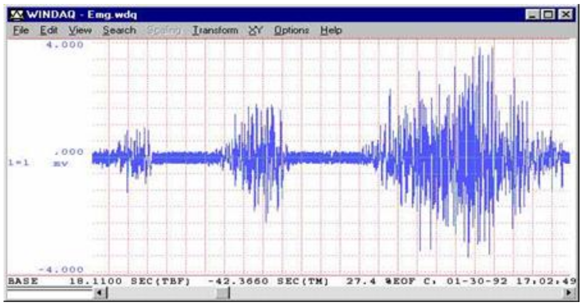
A. Electromyography

Electromyography is a technique for evaluating and recording the electrical activity produced by skeletal muscles. It is recorded using a device called electromyogram which detects the electric potential generated by muscle cells when they are electrically or neurologically activated.

There are two kinds of EMG: surface EMG and intramuscular EMG. Surface EMG assesses muscle function by recording muscle activity from the surface above the muscle on the skin. Surface electrodes are able to provide only a limited assessment of the muscle activity. More than one electrode is needed because EMG recordings display the potential difference (voltage difference) between two separate electrodes.

Intramuscular EMG can be performed using a variety of different types of recording electrodes. The simplest approach is a monopolar needle electrode. This can be a fine wire inserted into a muscle with a surface electrode as a reference; or two fine wires inserted into muscle referenced to each other. Diagnostic monopolar EMG electrodes are typically insulated and stiff enough to penetrate skin, with only the tip exposed using a surface electrode for reference. Fig 1 [7] shows a raw EMG signal.

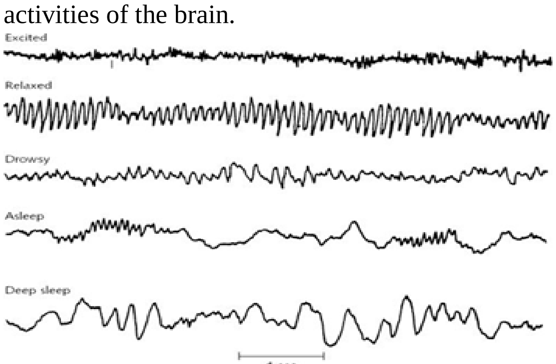
Fig 1 [7]



B. Electroencephalography

Electroencephalography (EEG) is a method to record electrical activity of the brain, using electrodes placed along the scalp. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain.

The brain's electrical charge is maintained by billions of neurons. Neurons are electrically charged by membrane transport proteins that pump ions across their membranes. Neurons are constantly exchanging ions with the extracellular milieu, for example to maintain resting potential and to propagate active potentials. Ions of similar charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their vicinal ions, and this process goes on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal in the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push or pull voltages between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG. Fig 2 [8] shows the EEG signals during various activities of the brain.



III. EMG CONTROLLED PROSTHESIS

The first widely used method of prosthesis is the application of EMG or Electromyography. It is a technique for evaluating and recording the electrical activity produced by skeletal muscles. It is recorded using a device called electromyogram which detects the electric potential generated by muscle cells when they are electrically or neurologically activated. These signals have been extensively used as a control signal in robotics, rehabilitation and health care. In this paper, an EMG controlled prosthesis proposed by a team from Amrita University, Coimbatore, Tamil Nadu [5] is reviewed. EMG signal is acquired from the amputee arm and processed to generate respective control signals, which can be used to drive the prosthetic devices. Whenever a person intends to move the hand, a small amount of electric current is generated from the muscle fiber by exchanging the ions across the membrane. This is referred as signaling process. This signal which causes the muscle fiber to contract is called Electromyogram (EMG). EMG can be measured either by placing electrodes into the muscle (invasive method) or by placing the electrodes over the skin (noninvasive method).

Measuring EMG signal with high accuracy depends on the properties of the electrode, contact of the electrode to the skin and amplifier design. Since the amplitude of the EMG signal is very less, noise will affect the strength of the EMG signal. There are many factors which affect the strength of the EMG signal such as Interference due to power hum, noise due neighboring muscles, DC or Baseline offset, dead cells in the skin, quality of electrodes etc.

A. EMG Signal Processing

Since the raw EMG signal is difficult to process, features are extracted from the signal. Features like mean absolute value, mean absolute value slope, waveform length, zero crossing, Root mean square value (RMS), phase coherence value and frequency energy value can be extracted from the signal [2][3]. For EMG feature extraction, RMS and frequency energy are selected.RMS is chosen as a feature for extraction because it gives the amplitude (envelope of the EMG signal) of muscle movements, and reduces the presence of noise due to interference. RMS is obtained by the following equation.

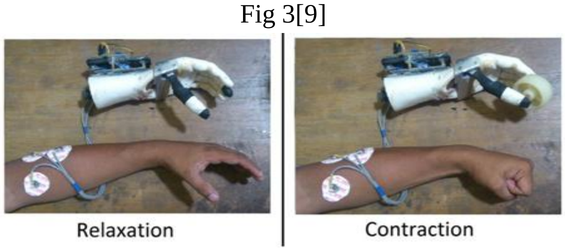
$$RMS = \sqrt{\frac{1}{n}\sum_{x=1}^{n} EMG(x)^2}$$

Frequency energy is the measure of energy in the signal and it indicates the firing rate of muscles. Energy of the signal in frequency domain is obtained by taking Fast Fourier Transform.

B. Methodological conclusion

- To find the efficiency of the developed system, experiments.
- Signal were taken from various hands and found to be at desired voltage.
- RMS and Energy features were extracted and plotted for different intensities of contraction and found that person's with good muscle strength were able to produce EMG with good amplitude and energy.
- Due to good signal strength, the RMS and Energy features were enough to classify the signal; this reduces the number of computations performed. Fig 3 [9] shows an EMG controlled Prosthetic arm functioning.

Fig 3[9]



C. Inference and Review

The EMG controlled prosthetic arm is effective and conventional way of prosthesis. It functions by the signals obtained during the movement of muscles. It works due to an electrode embedded into the muscle cells or an electrode kept on the surface of skin. This method of prosthesis works well when the nerve is preserved and functions well. But when it is damaged, this method is useless. For a perfect individual this method works with an accuracy of 96%, if this is the case, for an individual with damaged nerves, this method is ineffective. Hence the limiting parameters are accurate signal acquisition and undamaged nerves.

IV. EEG CONTROLLED PROSTHESIS

The disadvantage of myoelectric prosthesis is that it requires the nerves to be undamaged. This is overcome by the introduction of electroencephalography controlled prosthesis. This method is prescribed in a paper developed team from R.S.C.O.E, Pune [4]. In this paper, the idea proposed by them is reviewed. EEG-based brain controlled prosthetic arm is a non-invasive technique that can serve as a powerful aid for severely disabled people in their daily life, especially to help them move their arm voluntarily. Brain Computer Interface (BCI) systems [1] has been developed to address this need. Recent advancements in BCI have presented new opportunities for development of new prosthetic arm interface for such people based on thought or brain signals. BCIs systems elude the conventional channels of communication which is muscles and speech instead they provide direct communication and control between human brain and physical devices by translating the brain activity into commands in real time.

BCI uses noninvasive EEG signals to acquire signal from the brain, being a relatively low cost solution and also avoids dangerous surgery for invasive method where electrodes are placed inside of brain called implants. The EEG technique assumes brainwaves recording by electrodes attached to the subject's scalp [1]. This system comprises of extracting the raw brainwaves, processing the signal, classifying them into different command signals and interfacing them to the prosthetic arm.

A. Detection of Signals

This stage primarily targets at the careful detection of the EEG signal from the user scalp. Human brain consists of millions of neurons, each nerve cells connected to one another by dendrites and axons. Every time we think, feel, sense, move, or remember something, our neurons are at work. That task is carried out by small electric signals that zip from neuron to neuron. The signals are generated by differences in electric potential which are carried by ions on the membrane of individual neuron. Detecting these signals can help interpret what they mean and use them to control a device of some kind. EEG measures voltage fluctuations emerging from ionic current within the neurons of the brain. In the brain, there are millions of neurons, each of which creates small electric voltage fields.

This team uses a device called Neurosky Mindwave mobile headset [6] to detect the brain signals. It consists of dry electrodes and a specifically designed electronic circuit. It is noise resistant and is battery powered. It has an electronic chip inside it called as ThinkGear, which converts the raw signals into digital signals.

B. Acquisition of Signals

The signals detected and converted by the headset are acquired during this stage. The headset does the work of detecting, processing the raw signals to digital form. These signals are acquired using MATLAB which extracts the raw brain signals and transmits it.

C. Transmission and Mapping of Signals

Transmission of signals means the transfer of the converted process from the MATLAB to the prosthetic arm. These transmitted signals are mapped to the prosthetic arm by the help of microprocessors. This microcontroller embeds the command for every brain signal into the prosthetic arm.

D. Working and Experimentation

This method of prosthesis that uses EEG controlled functioning works with the brainwaves and thinking. The raw waves are detected and acquired and then converted into digital signals which are transmitted and mapped to the prosthetic arm. This arm, in general, works on our attention level and it is the limiting factor here. It requires the mind to be trained and focused or else the desired action of the arm is not performed. One has to have a single mind and thought if he needs to move the arm. Hence training the mind before achieving full performance of the arm is necessary. Fig 4[10] shows an amputee controlling his bionic hand using EEG brain interface.Fig 4[10]

E. Inference and Review

EEG controlled prosthetic arm is innovative and shows promise. It tackles the limitations met by the EMG powered bionic arm, that is, it does not require nerve interface and doesn't bother about its functioning. It is a lifesaving technology for the disabled persons who have nerve problems. It could make their dream of having a functioning hand come true, literally, since this technology works on ones thought and ability to focus. This is the plus of this technology, but this also is the drawback. It requires highly trained mind for its full efficient functioning and it doesn't function well for regular minds. Hence the amputees have to train their mind for several months before unlocking the full potential of this technology. Also based on the experiments done by the team that proposed this, even for a trained mind, it could only produce precision of 80%. The experiments were done with limited EEG sensors, but the precision could be increased if the number of sensors is increased, then more waves could be detected and functioning is also increased dramatically. Therefore the limiting parameters in this EEG controlled prosthetic arm are the number of EEG sensors and having a trained mind to focus.

V. CONCLUSION

Rehabilitation is a blooming field that provides a new life to the trauma-affected subjects. In it the stream of prosthesis is vast and promising area for development. Among the different types of prosthetic amputation technologies, the two methods of implementation of prosthetic amputation, namely, EMG powered and EEG powered, are the most effective way to rehabilitate a subject, where he is brought a step closer to the life he lost due to the trauma. This review paper is based on the context and base work from two papers by different authors on various methods of prosthesis. Here the methods and analysis done based on the two methods are discussed. The referent authors and their paper are also mentioned in the references.

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