Prosthetic Arm Control Using Electromyography (EMG) Signal

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Abstract— **Due to accidental trauma, war, and congenital anomalies, human beings are suffering since a long ago. Also, amputation and deformity have been carried out. Human hand has complex hierarchical control with large number of degrees of freedom. Thus, the efforts need to perform different movements are relatively small. Beside this, prosthetic arms are only an imitation of the natural hand, with considerably decreased movement freedom & clutching competencies. This paper presents the artificial myoelectric arms that an amputee needed to replace his/her amputated arms with prostheses. In this paper, acquisition of the most useful bio-signals for the prosthetic arm control is demonstrated. In addition, the process of extracting control information from the raw myoelectric signals is described. This paper describes a method to control artificial arm by dint of EMG signals.**

***Keywords* – Electromyography (EMG) signal, prosthetic arm, EMG based control**

I. INTRODUCTION

A prosthesis arm is an artificial device that substitutes the missing part of a hand which may be lost through trauma, disease or congenital condition. It functions as a natural hand. The human nervous system comprises brain, spinal cord and peripheral nerves. The nervous system carries control signals for every peripheral as well as hand [1]. All the controlling signals for a hand generate in brain and propagate through nerves to the hand. These control signals stimulate the muscles that control the movement of hand [2]. The prosthetic arm is controlled using those brain signals and those signals can be captured by several ways. One of the better techniques is to capture signals from the muscle surface. Electromyography (EMG) is an electro-diagnostic medicine system for assessing and recording of electrical activities formed by skeletal muscle. The EMG signals can be analyzed to detect medical deformities, stimulation level and enrolment order. It also analyzes the biomechanics of human or animal movement. In addition to these, EMG signals are recommended by researchers as a control signal for prosthetic devices [3].

Several researches are carried out to control a prosthetic arm theoretically [4][5]. However, in this research work it is implemented and applied it to an amputee person. In this paper, the prosthetic arm controlling technique for a trans-humeral amputation patient is studied with the help of single channel EMG signal capturing. To develop a prosthetic arm control mechanism and apply it to an amputee patient is the key purpose of this research.

II. METHODOLOGY

The prosthetic arm functions on the basis of EMG signals collected from the human skin surface. Collected EMG signals are processed and then employ to control prosthetic arm. EMG signal signifies the summation of the action potentials of muscle which leads to the shrinkage of muscle fibers. To eliminate motion artifacts, environment and device noise, the recorded EMG signals are amplified and filtered. This elimination of external impacts on natural muscle activation increases accurateness & usability of EMG signals. Myoelectric based prosthetics is the widely used process for amputees. Fig.1 shows the control mechanism for EMG based arm-prosthetics and its sequences [6].

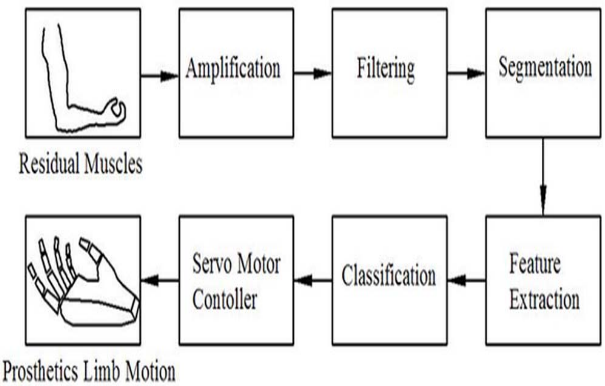


Fig.1: EMG based human arm prosthetics and its sequences.

Electrodes can be positioned onto the skin owing to the electrical activity adjacent to the skin surface results from muscle shrinkage. The contact area of the electrode is called the detection surface and the physiological data logged by a surface electrode is termed as surface EMG (sEMG). Fig. 2 shows the design & construction of an EMG system. The EMG detection scheme takes input from three electrodes: two adjacent electrodes located on the biceps of the upper arm and one reference electrode positioned on the elbow.

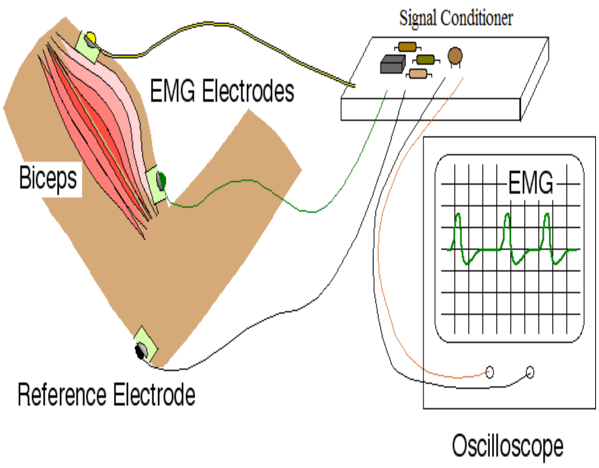


Fig 2: Method of detecting EMG signals

The formal structure for acquisition& analysis of the EMG signal to control prosthetic arm is shown in Fig. 3. The important parts are:

- Signal conditioning
- Feature extraction
- Envelope detection

The data monitoring and acquisition devices may cause interference to the captured EMG signal. To avoid this problem all the monitoring and acquisition devices need to be optically isolated to the data processing system. When EMG is captured by electrodes which are directly connected to the skin, the captured EMG signal is a mixture of all muscle fiber action potentials found in the muscles. These action potentials arise at arbitrary intermissions. Hence, the EMG signal can fluctuate as any positive (+ve) or negative (-ve) voltage.
Motor unit action potential (MUAP) denotes the summation of the muscle fiber action potentials of a single motor unit. MUAP can be collected by a surface electrode injected into the muscle. Equation (1) demonstrates a general model of the EMG signal [7]

$$x(n) = \sum_{i=0}^{N-1} h(i)e(n-i) + w(n)\,; \qquad (1)$$

where, $x(n)$, EMG signal, $e(n)$, denotes the firing impulse, $h(i)$, symbolizes the MUAP, $w(n)$, indicates zero mean additive white Gaussian noise and N mentions the number of motor unit firings.
It is known that RMS value of EMG signal holds the data of muscle power along with the envelope of the signal.

$$\text{RMS value} = \sqrt{\frac{1}{N}\int_{i=1}^{N}[x(n)]^2}\,; \qquad (2)$$

Where N is the number of samples and $i=1, 2, 3, \ldots\ldots, N$.
It is known that, the raw EMG signals contain noise. Thus it is essential to extract the envelope from the raw EMG signal. According to the position of the electrode, the magnitude of the RMS signals may vary. The normalization method is employed to bargain the direction vector of the EMG activations. After signal acquisition, the signals are ready to convert into a pulse signal and then amplification is done. Envelope detection system comprises with a full wave rectification circuit followed by a low pass filter. It reduces the frequency content for smooth and proper detection of the EMG signal.

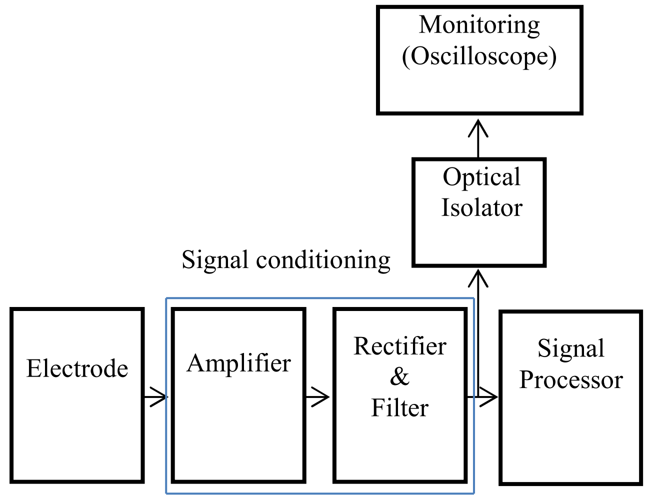


Fig 3: EMG signal capturing & conditioning

The step by step signal conditioning process of a typical EMG signal is shown Fig. 4. Raw EMG signals can be achieved by using a surface electrode positioned on arm for different actions such as pick, drop, left movement and right movement.

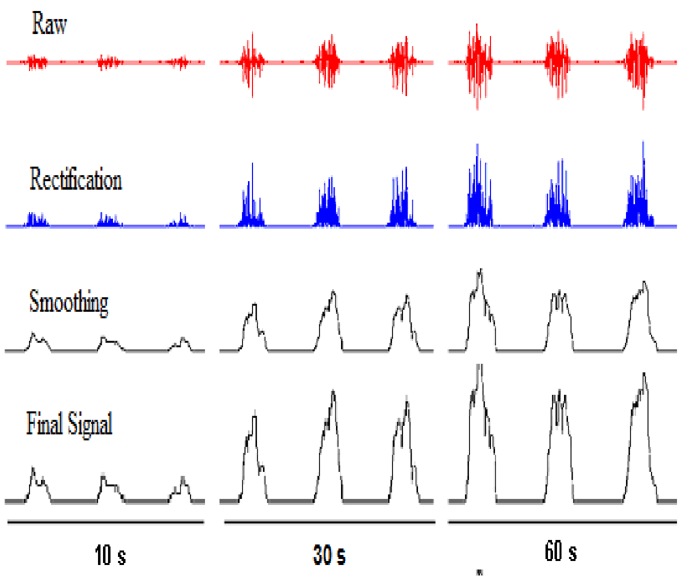


Fig. 4: Typical EMG signal conditioning.

III. PROSTHETIC ARM CONTROL TECHNIQUE

Specific set of muscle is responsible for actuating the specific peripheral. Frist the specific muscle is targeted corresponding to the damage peripheral and the EMG signal of that muscle is captured. The captured EMG signal then conditioned for processing and extraction. The artificial arm is controlled by the extracted meaningful command signal. Fig. 5 shows the prosthetic arm control technique.

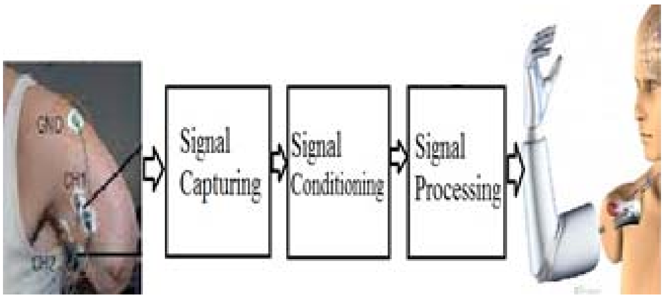


Fig 5: Prosthetic arm control model

The signals coming from the brain through the nervous system in order to control a specific peripheral by the means of stimulation of the corresponding muscle generate EMG signal over that muscle. As the amplitude of EMG signals varies with the stimulation of muscle, the amplitude of the EMG signal represents the force acting on the associated peripheral. If the muscle stimulation increases then the amplitude of EMG signals also increases. But at relax condition the amplitude of EMG is very low. EMG signals are shown in Fig. 6 at different stimulated conditions. When the arm flexes and relaxes, then the EMG signal amplitude varies over a range. Typically, the range of EMG signal amplitude varies from 0 to 10 mV prior to amplification.

Fig 6: Biceps EMG signal at different stimulated conditions

So it can be considered, there is no force acting on peripheral if the amplitude of EMG is very low. Otherwise, there is a movement exists due to high amplitude of EMG signals. Depending on this logic, the amplitude range of EMG can be divided into two states. These two states interpret two position of peripheral. It is necessary to set the boundary condition as a threshold level of EMG signal amplitude. The threshold value depends upon the noise level. Double threshold method gives better result than single threshold method for EMG detection [8]. Fig. 7 shows the feature extraction process from filtered EMG signal.

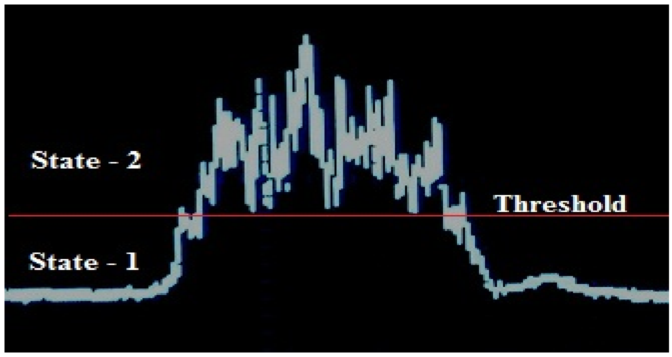


Fig 7: Feature extraction from filtered EMG signal

Filtered EMG signals have two state- state-1 and state-2. RMS value is taken as a feature for extraction due to its amplitude (envelope of the EMG signal) of muscle actions, and decreases the existence of noise.

IV. APPLICATION

A myoelectric prosthesis utilizes the electrical tension produced each time muscle contracts. This electrical tension can be taken from freely contracted muscles by electrodes. These electrodes are employed on the skin to control the activities of the prosthesis, i.e. elbow contraction/extension and opening/closing of the fingers. This type of prosthesis uses the residual neuromuscular scheme of the human body. It controls the tasks of an electric powered prosthetic hand, wrist, elbow or foot. In this research, the application of two state single degree of freedom prosthetic arm is performed which is shown below. Authors applied this artificial arm on a trans-humeral patient (16 years old) to control his elbow as shown in Fig. 8. The patient has been able to control his elbow of the artificial arm by thinking of his brain.

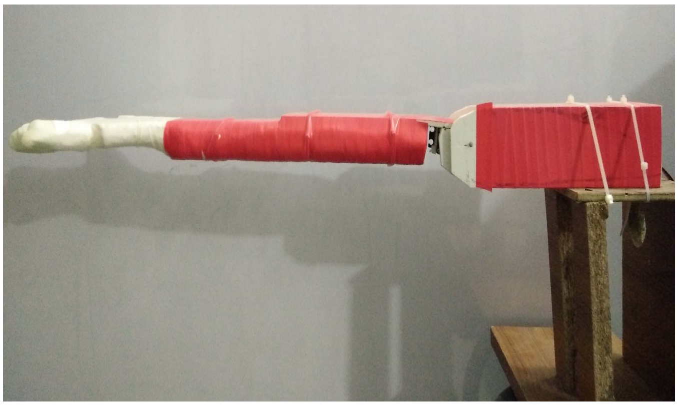
Fig. 8: The trans-humeral amputee patient on him we applied this method

V. RESULT AND DISCUSSION

As the patient has the trans-humeral amputation in our study, it is required to capture the EMG signals from his bicep for elbow controlling. The Fig. 6 shows the raw EMG signals associated with his bicep during experiment. There is a significant configuration in the myoelectric signals during muscle contraction. Furthermore, this configuration is dissimilar for contractions that yield unlike limb functions. Therefore, the actual configuration of the time varying myoelectric signal can be applied to differentiate limb function. Hence, variation of the limb actions can regulate the prosthetic limb function.

In Fig. 7 shows the EMG signals captured from the bicep of the experimental patient. Signal amplitude below and above threshold limit was found at relaxed and flexed condition of hand respectively of the experimental patient.
In Fig. 9 shows the artificial hand position when the experimental patient tries to make his hand relax and flex respectively. It expresses that the above method works successfully.

a)



b)

Fig. 9: a) Artificial arm model at flex position,
b) Artificial arm model at normal position

VI. CONCLUSION

This paper demonstrates that, how EMG signal is used for controlling prosthetic arm. In addition, experimental investigation is performed to the patient having trans-humeral amputation. The prosthetic arm controlling method is found successful. The features extraction method has employed, which is applicable for different patients because the controller has given the intelligence to be adaptive for any patient as in training session the controller detects the threshold value for new patients. As the raw EMG signal contains several noise and disturbing interferences, thus the feature extraction method should be more appropriate and efficient for effective controlling. Beyond this, the EMG signal can be used broadly as a control signal in robotics, rehabilitation and health care.

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