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Surface Electromyography (sEMG): Signal Propagation, processing and their Analysis

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ABSTRACT

Electromyography is the specialized technique comes under Biomechatonics which is one of the biomechanical methods. This technique detects and analyzes the bioelectrical signals which were generated due to the exchange of ions across the muscle membranes. During signal propagation the signal is originated, acquits, filters, amplified and converted to digital signals. Various techniques like rectification, averaging, smoothing, normalization and electrocardiography signal reduction were used for the processing of EMG signals which were finally analyzed for their validity and quality analysis. The objective of this paper is to understand various methods which are used forthe processing and analysis of EMG signals.

Keywords: Electromyography, CNS, MUAP

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INTRODUCTION

"Electromyography is concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the muscle fiber membranes. In human body all the muscle works under the action of Central Nervous System (CNS) [1]. During any movement of human body there is generation of electrical activities across the muscle membrane. An ionic equality between inner and outer surface of muscle cell creates a resting potential (-80mV) in the sarcolemna. This create negative intracellular environment inside the sarcolemna as compare to external surface of muscle cell. Whenever there is any movement in the body muscle, brain generates excited signals through Central Nervous System.

When these excited signals move along the motor nerve, active ion pump comes into the action. Na+ ion starts to flow inside the muscle membrane and thus cases Depolarization. During depolarization an action potential of muscle membrane changes to 30mV which is consequently followed by repolarization.An action potential which initiates from the motor end plates moves across the muscle fiber and thus causes the release of calcium ions in the intra-cellular space.Motor unit is a junction point where the motor neurons and muscle fibers meet and produces Motor Unit Action Potential (MUAP) [2].

EMG signal is generated as a result of action potential across the surface of muscle fiber which results in the development of electric dipole. Electric dipole induces potential difference between the electrodes on the basis of distance between them. Due to interference phenomenon all active motor unit action potential superimposed and thus generate a bipolar signal with both equal positive and negative amplitude. This signal is called a raw EMG Signal.This process is repeated and combined to produce EMG Signals.

These signals are generated continuously and thus form a chain of signals which were stored temporarily. For differentiating the signals among each other trigger value can be used.A Signal display only when its value is more than the trigger value otherwise not.

EMG SIGNAL ACQUISITION:

EMG signal acquisition depend on mainly two parameters i.e. skin preparation and placement of electrodes. For getting qualitative signal the skin should be prepared in such a manner so that there is low skin impedance with proper setting of electrodes [3]. Various skin preparation method like removal of hair over the skin, scrubbing of skin with various abrasives for removing dead cell, cleaning of skin with alcohol [4].

The selection of electrode is depending on the test condition as no same electrode is used for various different tests. The selection of an electrode for a particular test is supported by an EMG pre amplifier. The signals obtained from the EMG surface are collected with respect to reference electrode which is generally earthed (act as a ground). The electrodes which were used for acquiring EMG signals are of various types depending on form which muscles the signal is to be acquired [5]. Electrodes which are used for obtaining signals from surface muscles like masseter muscles are called surface electrodes while those which are used for obtaining signals from deeper muscles are called needle or finewire electrode.
For commercial purposes surface electrodes with wet or adhesive pre-gelled were used. They have an advantage of being easy in use, hygiene, repositioned in case of error and dispose after use. Fine wire electrodes are thin and flexible, so mobilized to the concern position for study deeper muscles covered by bones or other muscles. The proper position of fine-wire electrode is governed by ultrasound imaging [6].
Both surface and needle electrode measure and process the signals in similar manner. Generally high pass filter (20Hz) is usedwith fine wire electrode to eliminate the artifacts within the muscles and noise signals.

EMG Signal Filtration

During acquisition of EMG signal various noise signals, ECG artifacts and other disturbances like interfering power hum, baseline offset and baseline shift occurred. Frequencies which may contaminate the raw EMG signal can be of low value or high value. Noise with low frequency may be caused due to amplifier offset and due to sensor drifting which lead to inaccurate temperature fluctuations while noise with high frequency is caused from nerve conduction and frequency interference from other equipment's like computer, phone etc. To remove these problems electric grounding of equipment, offset correct function, proper placement of electrode with good skin preparation is to be used [7].
High pass filter is used to remove frequency of low value form the raw signal. All low frequencies below the cut off value were eliminated while other allowed moving forward.Signals transmitted through this filter come under pass band region while those which were attenuated come under stop band region. Low pass filter in opposite allowed transmission of frequencies below the cut off frequency value and removed all frequencies above this value [8].

EMG signal Amplification:

After the signal is filtered, now it is to be amplified with the help of non-inverting amplifier. As EMG signal were generally weak, so it should be amplified to a suitable level. The process of amplification is to be performed in various steps i.e. cascading manner. Human subject shows both interas well as intra variation in respect to EMG signals. In human some muscles shows weak signals while some shows strong signals. Similarly, some subjects give weak response while some subjects give strong response [9]. Thus gain of amplifier is done on the basis of test muscle which is to be studied as well on the subject.
Amplifierused for EMG signal amplification acts as differential amplifier as they detect and amplify the difference of signal between the electrodes on the basis of their potential difference. Thus theyselectively amplify a particular signal while eliminate all other background noise, artifacts and frequency interference. EMG pre-amplifiers are the small amplifier which arebuildup in the cable or present on the top of the electrode called miniaturized amplifiers. They early pick up the signal, amplify and transmit it [10].

Computation of the EMG signal:

EMG signal after amplified is passing through ADC (Analog to Digital Converter). For a signal to be displayed and analyzed on computer screen it must be converted from analog to digital format. To study the complete frequency spectrum of a signal, the input voltage of the signal must be twice to the sampling frequency of the signal [11].

SIGNAL PROCESSING AND THEIR ANALYSIS

Signal Processing

Signal processing is done in two phases, first in which the raw signal is preprocessed for removing various sources of artifacts through various techniques performs at the time of recording the EMG signals [2]:

Rectification:

Rectification is the process which is used to avoid anti-aliasing effects with in the sample (raw EMG Wave). In this method all the negative amplitude get converted in to positive amplitude.

Averaging:

During EMG signals recording there are certain signals which bring some disturbance. These disturbances are caused mainly due to machine and biological error. By averaging the signals these disturbances may be minimized.

Smoothing:

In this step the non-reproducible section of the raw EMG Signal is removed using two algorithms named as moving average and root mean square. In Moving average method, a particular value of signal is averaged based on technique called gliding window. During this algorithm the average Rectified Value (AVR) is used for the measuring the information on the basis of area cover under the specific signal. While during root mean squarealgorithmcalculation are done on the basis of square root value which explained the mean power of the signal called rms EMG.

Normalization:

During this method the uncertainty of any EMG signal is removed based on the concept of normalization. In this step value of an EMG Signal is normalized to a specific reference value on the basis of physiological relevance. Two main effect of normalization were observed, first it eliminate the influence of any detection method on obtained EMG Signal and second it rescaled the data from very small value (microvolt) to specific reference value.

ECG Reduction:

Certain time while recording EMG Signals, the ECG values obtained from heart may interfere with the result. This error occurs mainly when we record EMG recordings from the upper part of the body. To minimize the effect of ECG, the adaptive filter with a pattern recognition mode is used.

While in second phase various techniques are used for processing of an EMG signals which are briefly describe here as follows [1]:

Wavelet Transform (WT):

Earlier both time and frequency domains were used for the analysis of EMG signal. Wavelet Transform is analternative to this approach, used for the analysis of non-stationary and fast moving signal. Wavelet analysis is used for studying multicomponent signals which are linear, represent in multi resolution manner and not affected by cross terms [12, 13, 14].

Artificial Neural Network (ANN):

Artificial intelligence is mainly based on the concept of neural network for processing EMG signal. Its give real time information regarding myoelectric signals based on Fourier analysis and fuzzy algorithm. It allows clustering of data from two or more clusters. The composition of ANN is based on network design, number of layers algorithm used for their analysis [15].

Higher-order Statistics (HOS):

This method is used for the analysis of a random process. HOS uses second and fourth order moments based on parametric model (probability theory). It has the advantage of suppressing Gaussiannoise and used for study non Gaussian and nonlinear signals. HOS is used for obtaining information regarding Motor Unit Action Potentials (MUAPs) [16].

Independent Component Analysis (ICA):

This method is based on statistics, where we assume that the final signal comes from the mixture of signals. In this method we transform multivariate random vectors into separate components which are independent of each other [1].

Empirical Mode Decomposition (EMD):

This technique is used for the analysis of non-stationary and nonlinear signals. Its provide information about signals based on time frequency features. This method decompose multi component signal into number of mono component signals for further analysis [17].

Analysis of Digital signal

While obtaining EMG Signals various steps are to be followed for their analysis. EMG technique is basically used for analysis of signals based on visual and auditory assessment. For a particular muscle, the quality of an EMG signal is based on position of the electrode, skin preparation etc. EMG Signal is visualized for the baseline noise (associated with some noise), baseline offset (away from the zero baseline) and baseline shifts (baseline before and after contractions must remain at zero line) [1, 17].

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