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A Review on Noises in EMG Signal and its Removal

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Abstract- Electromyography (EMG) is the study about the function of muscles, and today it have many applications in biomedical and clinical purposes. The EMG signal contains two sources during the myoelectrical simulation which are the useful electrical response of the muscles and the noise in the signal. The noises can occur from either technical sources (power line noise) or from biological sources (ECG). The noises in the system must be carefully studied, as this will interrupt the analysis of the muscular activity. This paper discuss about various types of noises that affects EMG signal and also some of the basic noise removal techniques.

Index Terms- Artifact , Electrodes, EMG, Noise removal .

I. Introduction

Electromyography (EMG) is a process of recording the electric activities of muscles. It is used to assess the health of muscles and nerve cells. Today it is used in many applications and most commonly for research purposes. When the muscle fibres contract, it generates a small electric current, which can be measured using EMG. It will convert this electrical signal into graphs, sounds or/and numerical values. The signal is known to be Electromyogram and it can be measured using two techniques. There are invasive methods in which the electrodes like needle electrodes are inserted into the person's body and non invasive method in which the surface electrodes are used to collect the EMG from the person's facial tissue. Electrodes are used to measure the electric current generated due to the muscle contraction. The muscle activity is measured using electrodes. It converts the ionic currents generated by the muscle contractions into electric currents so that it can be easily be used by electronic circuits. In both engineering and medical fields, EMG is a very useful signal that have a wide range of applications. The different conditions of human body can easily be understand from accurately recorded EMG signal. But like any other signal, EMG signals are also susceptible to various types of noises.EMG contains mainly two sources, which are muscular electrical activity and artifacts. When passing through various tissues, EMG signal acquires various noises. Noise is the unwanted electrical signal in an EMG signal. This noise and artifacts in the signal is a serious issue to be considered, as this will adversely effects the quality of the signal. Also the analysis of EMG signals are difficult due to this. So a filtering is done on the received signal inorder to remove the unwanted signal before it is being used by the system. Thus the signal to noise ratio can be improved by reducing the noise in the signal. Several filters like low pass filter, high pass filter and notch filter can be used for this purpose. Apart from these, there are several other techniques.

II. ELECTROMYOGRAPHY

Electromyography is the process of recording the electrical potential from the muscles. The electrical potential is represented in the form of time varying signal.

A simple model of the EMG signal [1]:

$$x(n) = \sum_{r=0}^{N-1} h(r)\, e(n-r) + w(n) \quad \text{..................................(1)}$$

Where, x(n) is the EMG signal, e(n) is the firing impulse, h(r) represents the MUAP, w(n) is the zero mean additive white Gaussian noise and N is the number of motor units firing.

EMG is also called as myoelectric signal (MES)[2] . It provides very important and useful information of neuromuscular activities. EMG signals are non stationary, non linear and complex signals. The information from the EMG is extracted from the features taken from it. For that there are several feature extraction techniques available.

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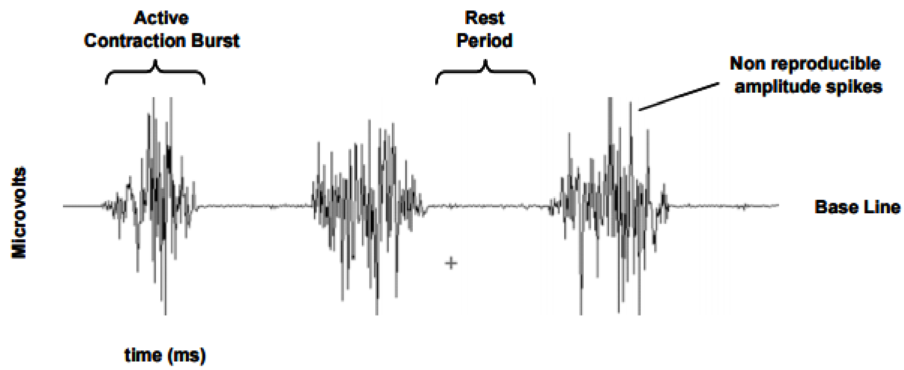

Figure 1: The raw EMG recording [6]

The muscle movement is made under the control of our brain [3]. Thus the electric activity of muscles are very closely related with the nervous system. An action potential is produced from the brain which passes through the nerve fibres. This action potential that passed through the nerve fibres will stimulate the muscle fibres. Motor neurons transmit electrical signals that cause muscles to contract. This causes the movement of the muscles. The electric potential from the muscles which is represented in the form of time varying signal is known to be the EMG signal.

III. NOISES IN EMG SIGNAL

The range of the EMG signal amplitude is between 0-10mV [1] . When passing through various tissues, EMG signal is contaminated by various noises. It is very important to understand the properties of these unwanted electric signals. We can classify the electrical noises affecting the EMG signal into the following

A. Inherent noise in electronics equipment

This type of noise is inherent in all electronic equipments [4]. This noise cannot be eliminated. This can only be reduced by using components of high quality and using intelligent circuit design. It have frequency components in range from 0 Hz to several thousand Hertz. An adequate signal-to –noise ratio can be acquired when the EMG signals are recorded using the silver/silver chloride electrode. This is electrically very steady. As the electrode size increases, the impedance decreases.

B. Ambient noise

The main source of this noise is the electromagnetic radiation. The amplitude of this kind of noise will sometimes one to three times greater than the desired EMG signal. The surface of human body is constantly exposed to electromagnetic radiations. It is not that easy or is impossible to avoid this exposure on the surface of the earth. Power line interface (PLI) is the ambient noise causing from the radiation of power sources of 60Hz or 50Hz. If the frequency of this interference is high, then it can be removed by using a high pass filter. It is necessary to realize the nature of the EMG signal, if the frequency content of PLI is within the EMG signal.

C. Motion artifact

The frequency range of this type of noise is normally between 1-10 Hz. The voltage range is comparable to the amplitude of the EMG signal. The information is distorted when motion artefacts are introduced into the system. This causes irregularities to the data. This is mainly due to the changes in the muscle due to relative motion. There are chances that the electrodes can move from the skin with respect to each other. Also, when the muscle is activated, the length of muscle gets decreased. Thus electrodes will cause movement artefacts. The main sources of this artifact is electrode interface and electrode cable. Proper design of the electronic circuitry is the only way to reduce this artefact. The motion artifact can be removed significantly by using recessed electrodes. In this, between the surface of the skin and the electrode- electrolyte interface, a conductive gel layer is applied.

D. Inherent instability of signal

This is affected for signals with frequency components ranging between 0- 20 Hz. The EMG signals are quasi- random in nature. Firing rate of the motor units affect the signal and hence they are unstable. This unstable nature causes noise. The information in the EMG signals are changed with the number of active motor neurons, motor firing rate and mechanical interaction between muscle fibres.

E. ECG artifacts

The process of recording the electrical activity of heart is referred to as the electrocardiography. The ECG is an interfering component in the EMG signal taken from the shoulder girdle, which is known as ECG artefact. The EMG taken from the muscles in the trunk are often gets affected by ECG artefacts. The EMG electrode placement is an important factor that determines the extend of ECG contamination in EMG signal. As the frequency spectra of ECG and EMG signals gets overlap and also as the characteristics such as non-stationarity and varied temporal shape are relative to each other, the removal of ECG artefacts from EMG signals are so difficult.

F. Cross talk

It is a type of noise occurs when an EMG signal that is not desired to monitor at a point of time gets interfered with the desired signal to be monitored. This contaminates the signal and will cause misinterpretation of the information. Even though this can be due to various parameters, by carefully choosing the electrode size and inter-electrode distances, this can be minimized.

G. Electrode contact

The electrode-electrolyte-skin contact will influence in the signal to noise ratio of an EMG signal. So the skin needs to be get ready before the recording of EMG signal so as to ensure the proper electrode-skin contact.

H. Transducer noise

This noise is produced at the electrode-skin junction[5]. Electrode converts the ionic currents generated by the muscle contractions into electric currents. So this can be easily stored in either analog or digital form as a voltage potential. The main two noise sources are DC voltage potential and AC voltage potential. The impedance effect is the main cause for this noise and this can be decreased by using Ag-AgCl electrodes.

I. Baseline shifts

The EMG rest -line remains at constant zero and the regular EMG burst returns to zero within a few milli-seconds[6]. When the cables shake too much, there is a visible shift of baseline which is greater than 5ms indicating the artefact. This problem can be solved by correct fixation of electrodes.

The factors affecting the EMG signal can mainly be classified into three basic categories.

1) Causative factors : It affects the signal directly. This can be classified into extrinsic and intrinsic factors. The extrinsic factors are related to the electrode structure and its placement. Intrinsic factors are due to the physiological and anatomical factors which depends on the number of active motor units, blood flow, amount of tissue between the surface of the muscle and the electrode, etc.
2) Intermediate factors : These are physical and physiological phenomena that are affected by one or more causative factors. This can be due to band-pass filtering of the electrode alone with detection volume, superposition of action potentials of the EMG signal, etc. Intermediate factors can even cause from the crosstalk from nearby muscles.
3) Deterministic factors : Intermediate factors are the cause for deterministic factors. There is a direct connection on the information in the EMG signal with the number of active motor units, motor firing rate and mechanical interaction between the muscle fibres. Also the amplitude, duration and shape of motor unit action potential are causes for this.

IV. NOISE REMOVAL TECHNIQUES

The electromyographic signals are influenced by various factors including muscle anatomy and various physiological process and also by many external factors [7]. So the EMG signals are susceptible to various noises. They are interfering voltages that causes distortion to the measured signal. There are some inherent noises in the system that degrades the performance of the system. It is impractical or even impossible to extract the useful information from the EMG signal when the signal to noise ratio value is very poor. There are several noise removal techniques used to reduce the noises in EMG signal.

A. Low pass differential filter

The low pass differential (LPD) filter is widely used in EMG signal processing. The filer is implemented in time domain as

$$y_k = \sum_{n=1}^{N}(x_{k+n} - x_{k-n}) \quad \text{.........................(2)}$$

Where x_k is the discrete input time series and y_k is the filtered output. N is the window width. This N is used to adjust the cut-off frequency.

There are some drawbacks in this method such that in low signal-to-noise ratio conditions, the high frequency noises will be noticeable. Also, as the LPD filter is not ideal low pass filter, there will be leakage of energy frequency out of the filter pass band. So there are chances that high frequency noise gets pass through the filter. Apart from these disadvantages, the main advantage is that the LPD filter is easy to implement and also is fast for real-time applications.

B. Adaptive noise cancellation

This technique is used to reduce the effect of noise on the signal adaptively, so as to obtain the desired signal. Adaptive noise cancellation is an alternative technique of estimating signals corrupted by additive noise or interference. The 50Hz and 150Hz components are signals localized on frequency band of the EMG signal. Different digital filtering techniques can be used to eliminate them. Least mean square (LMS) algorithm is the basis for adaptive noise cancellation. It requires a reference input signal which is correlated with the interference signal. From the noisy signal, the reference input is adaptively filtered and subtracted. A fixed delay is inserted in the reference input and this delay must have a sufficient length to cause the EMG signal components in the reference input to become decorrelated from the primary input. When a signal is corrupted by a noise and resulted in a corrupted signal, the algorithm for adaptive noise cancellation will evaluate the parameters for the filter to attenuate the unwanted components.
LMS filter based technique will find out the filter coefficients which minimizes the mean square of the error .The error is the difference between the desired signal and the error signal. The undesired 50 Hz component can be attenuated by this method. As EMG signals also have 50Hz components , it is impractical to practically eliminate the noise completely.

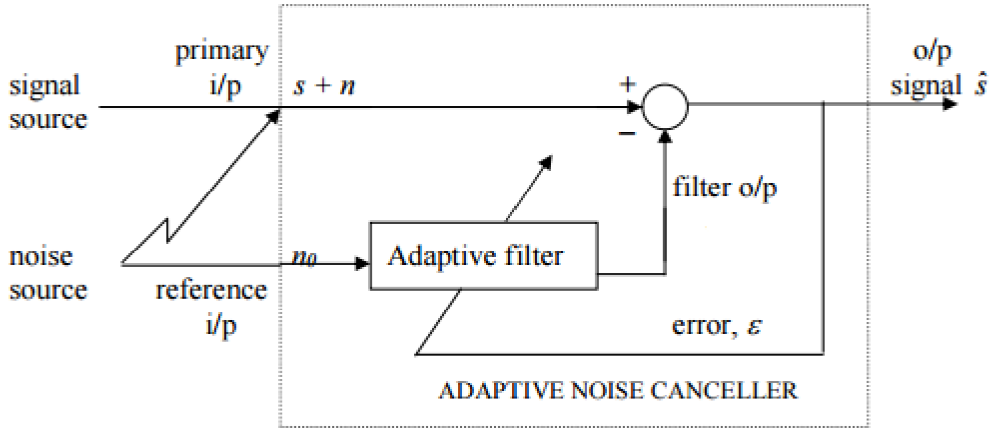

Figure 2: Adaptive Noise Canceller

To obtain the optimum filter weights in LMS filter, the algorithm starts by assuming small weights (zero) and in each step, it finds a gradient of mean square error and then updates the weights. If the mean square error is positive, error increases positively and the filter weights needs to be decreased. If the gradient is negative, then the filter weights needs to be increased.

In figure 2, there are primary input and reference input. The primary input comprises of a signal s from the signal source which is corrupted by noise n . this noise is uncorrelated with the signal. The reference input is a noise n_0. This noise is uncorrelated with the signal but correlated with the noise n. T he noise n_0 is given to an adaptive filter. This produces a filter output which is a close estimate of the primary input noise. This estimate of noise is subtracted from the signal corrupted with noise and produces an estimate of the signal which is denoted by $\hat{s}$. The noise cancellation system will produce an output $\hat{s}$ which is the difference between the signal $s+n$ and the noise estimate $\hat{n}$ that suits the least mean squares of the signal. This can be done by feeding back the system output to the adaptive filter and at the same time adjusting the filter by the LMS adaptive algorithm in order to minimize the system output power. The system output resembles the error signal for the adaptive process.

C. Signal filtering based on wavelets

Wavelets can be used for noise removal from the corrupted signal. The denoising of the signal involves signal decomposition, detail coefficient thresholding and signal reconstruction. In signal decomposition, both a wavelet prototype and decomposition level (N) are selected and the wavelet prototype and the decomposition level (N) is performed. In detail coefficient thresholding, for each level from 1 to N, a threshold is selected and soft thresholding is applied detail coefficients. In the signal reconstruction, the signal denoising is estimated by using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

V. CONCLUSION

EMG signals have a wide range of application in many fields. Like any other signal, this signal is also disturbed by various types of noises. The removal of noise remains a vital factor for the analysis of the undeterministic signals. The various noises in EMG signal and some of the basic noise removal techniques are studied. In Adaptive filter system, it supports to provide stable system performance. The low computational complexity of LMS algorithm is an advantage of this technique. Also Adaptive Filters and LMS algorithm does not need statistical information like auto correlation for noise cancellation. LMS algorithm is easy to implement and is mathematically less complicated. There are several types of noises and we cannot completely eliminate all these noises. We can only reduce its effect in the system by using these techniques.

REFERENCES

[1] M. B. I. Reaz, M. S. Hussain and F. Mohd-Yasin, "Techniques of EMG signal analysis: detection, processing, classification and Applications" , Biol. Proced. Online 2006; 8(1): 11-35

[2] Sachin Sharma, Gaurav Kumar, Sandeep Kumar and Debasis Mohapatra, "Techniques for Feature Extraction from EMG Signal" , IJARCSSE, Volume 2, Issue 1, January 2012

[3] A. N. Norali, M.H. Mat Som, "Surface Electromyography Signal Processing and Application: A Review" , Proceedings of the International Conference on Man-Machine Systems (ICoMMS),11 – 13 October 2009, Batu Ferringhi, Penang, MALAYSIA

[4] Nurhazimah Nazmi , Mohd Azizi Abdul Rahman , Shin-Ichiroh Yamamoto , Siti Anom Ahmad , Hairi Zamzuri and Saiful Amri Mazlan, "A Review of Classification Techniques of EMG Signals during Isotonic and Isometric Contractions", Sensors 2016, 16, 1304

[5] Dr. Scott Day , "Important Factors in Surface EMG Measurement" , Bortec Biomedical Ltd 225, 604-1st ST SW Calgary, AB T2P 1M7

[6] Peter Konrad , "A Practical Introduction to Kinesiological Electromyography" , Version 1.4 March 2006 , ISBN 0-9771622-1-4

[7] Adriano O. Andrade, Alcimar B. Soares, Slawomir J. Nasuto and Peter J. Kyberd , "Computational Intelligence in Electromyography Analysis – A Perspective on Current Applications and Future Challenges",EMG Decomposition and ArtifactRemoval , InTech, http://dx.doi.org/10.5772/50819.

[8] Pallavi Patil, Gunjan Gujarathi, Geeta Sonawane, ''Different Approaches for Artifact Removal in Electromyography based Silent Speech Interface '',International Journal of Science, Engineering and Technology Research (IJSETR), Volume 5, Issue 1, January 2016

[9] Michael Wand, Matthias Janke, Till Heistermann, Christopher Schulte, Adam Himmelsbach, and Tanja Schultz "Application of Electrode Arrays for Artifact Removal in an Electromyographic Silent Speech Interface" In Proc. Biosignals, 2013

[10] KamyaDubey and Vikas Gupta ,"A Review On Speech Denoising Using Wavelet Techniques."

[11] Dr.Mahesh S.Chavan ., Mrs Manjusha N .Chavan,"Studies On Implementation Of Wavelet for Denoising Speech Signal."

[12] M. Knaflitz and R. Merletti, "Suppression of stimulation artifacts from myoelectric-evoked potential recordings," Biomedical Engineering, IEEE Transactions on, vol. 35, no. 9, pp. 758–763, 1988

[13] Maxime Yochum, Toufik Bakir, St´ephane Binczak, '' EMG artifacts removal during electrical stimulation, a CWT based technique'', 2014 IEEE Region 10 Symposium

[14] R. Roby and E. Lettich, "A simplified circuit for stimulus artifact suppression," Electroencephalography and Clinical Neurophysiology, vol. 39, no. 1, pp. 85–87, 1975.

[15] Michael Wand, Adam Himmelsbach, Till Heistermann, ''Artifact Removal Algorithm for an EMG-based Silent Speech Interface'', 35th Annual International Conference of the IEEE EMBS Osaka, Japan, 3 - 7 July, 2013

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