Noises Removal in EMG Signal

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Abstract:- Electromyography is the technique of recording and interpreting the electrical activity of muscle's action potential. EMG is drawn using an instrument called an electromyograph, to produce a record called an electromyogram . The EMG potentials from a muscle or group of muscles produce a noise like waveform that varies in amplitude with the amount of muscular activity. It has frequency component ranging from 10 Hz to 3000 Hz and peak amplitude of 50 μV to 1 mV, depending on the location of the measuring electrodes with respect to the muscle and its activity.. Noises that commonly disturb the basic electromyograph are power line interference, instrumentation noise, external electromagnetic field interference, noise due to random body movements and respirational movements. These noises can be classified according to their frequency content. It is essential to reduce these disturbances in EMG signal to improve accuracy and reliability Different types of adaptive and non-adaptive digital filters have been proposed to remove these noises. In this thesis, window based FIR filters, adaptive filters and wavelet filter bank are applied to remove the noise

IndexTerms— Denoising, FIR filter, adaptive filter, wavelet decomposition, PSNR

I. INTRODUCTION

The traditional use of surface myoelectric signal (SMES) in physiological and biomechanical research was extended to applied research: SMES achieved a well established value as an evaluation tool in surgery planning , rehabilitation [4], biofeedback , sports medicine and training , and ergonomics research .Among other innovative applications, it is gaining interest the development of advanced human–machine interfaces in which SMES has a key role to play. In particular, myoelectric control is an advanced technique concerned with the detection, processing, classification, and application of SMES to the active control of prosthetic limbs, human-assisting robots, or rehabilitation devices. The vast majority of the above mentioned applications evaluates muscle activity in dynamic conditions and, in particular, during cyclic or repetitive motor tasks , e.g. walking (gait analysis) or biking . The movements of the corresponding body segments imply cyclic contractions of muscles. As a consequence, SMES detected from a specific muscle results in a sequence of pseudo-periodical activation bursts . In the time elapsed between the end of a muscle burst and the beginning of the successive one, the muscle under study is silent. However, the probe detects a background noise that is unavoidable in any dynamic test. This background noise is mainly due to crosstalk from neighboring muscles: it is a 'physiological' noise, more relevant than that due to instrumentation. . 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.LITERATURE REVIEW

EMG signal interpretation is a growing and modern research domain today. Lot of research works have been carried out by different scientists in this domain from the previous decade. Some of the biomedical engineering labs in our country also have shown their interests in this research domains and started work. Still ergonomics has not been carried out on this research field. The brief literature survey towards EMG signal related to interdisciplinary work and signal interpretation techniques are characterized below. Documentation of experiments were beginning with discovering the generation of electricity from specialized muscle of electric eel by FranescoRedi's initiative research proposal in 1666. In research field, a new chapter was released with his noble work. Different scientists, research workers proposed and demonstrated various innovative and creative articles and objects with an influence of Redi's work. In 1890, Marey introduced the term 'electromyography' and its activity behind actual reading. In the short review consideration it proceed to conclude that though the actual idea originated from Redi's work but the term EMG was introduced by Marey. A new era became started with the visualization of electrical signals from muscles by oscilloscope in 1922 by Gasser and Erlanger. Though improvement of science and technology more new little inventions regarding electromyography signal was done, but the important work began in 1960 with clinical usage of surface EMG. Hardyck and his research group were the first practitioners to use of Surface EMG. J.G. Kreifeldt of Tufs University was represented a method to identify the signal-tonoise ratio characteristics of surface detected electromyography for amplify, rectify activities [5]. A common method of initially processing surface-detected electromographic (EMG) activity was to differentially amplify, rectify, and then smooth (using a low-pass filter) the rectified activity .The SNR depends, at least, upon the contraction level, type of smoothing filter, and the amount of smoothing for the particular filter. This defined SNR is important in signal communication problems of both a design and a theoretical nature. In 1975, D. Graupe et al. mentioned an approach to overcome the recognition prob-lems using autoregressive-moving-average parameters and the kalman filter parameters of the EMG time series apply-ing on prosthesis control purpose [6]. It was shown that the resulting identified parameters yield sufficient information to discriminate between a small numbers of upper extremity functions. After that proposed work, the characteristics of surface EMG signals from different stepping of human locomotive activities were represented by Cecil Hershler and M.Milner [7]. Emphasizing consistency and repeatability of acquired data, it was presented the characteristics of sur-face EMG signals from m. vastus lateralis and m. rectus femoris during several steps of level walking under controlled repeatable gait conditions at three different speeds for several subjects. The statistical analysis and the pattern classifi-cation of electromyographic signals from the biceps and triceps of a paralyzed person generated by discrete lower arm movements. The contribution of this work was to enlighten the controlling purpose of prosthetic or amputee arm with minimal mental effort [8].The idea of prosthesis using surface EMG gradually began from the year 1975

III. METHODOLOGY

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. .

Figure 1. Electromyogram Signal

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.

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.

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

yk = k+n-xk-n) ……………………….(2)

Where xk is the discrete input time series and yk 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

. Description of the algorithm

In order to estimate e_{noise}, SNR and DC of an SMES generated during cyclic movements we use the following algorithm:

1) Consider the time series $\{x_i\}$, i = 1,…, N, being N the number of samples. In the following, we refer to a time series with a duration equal to 30 s sampled at sampling frequency equal to 2 kHz. It follows that the number of samples N is equal to 60000.

2) Divide $\{x_i\}$ into M = N/r epochs. Considering r = 10 we have:

$$\{X_{kj}\} = \{X_{1j}, X_{2j}, \dots, X_{Mj}\}, j = 1, \dots, 10$$

3) Obtain the auxiliary time series of the normalized sum of squares:

$$C(k) = \sum_{j=1}^{10} \frac{X_{kj}^2}{10}, \quad k = 1, \dots, M.$$

4) Obtain the histogram of the series Log10 C. The bins of the histogram are defined as:

$$bins(m) \equiv m \cdot \frac{\max(Log_{10}C) - \min(Log_{10}C)}{2 \cdot Nbins} + \min(Log_{10}C), \quad m = 1,3,\ldots,2 \cdot Nbins - 1.$$

where Nbins is the number of bins. Since in our case M = 6000, to have a sufficient sample numerosity for each bin we choose Nbins = 60. In general, a number of bins in the range 50-100 is an acceptable choice.

5) Search for local maxima of the curve that interpolates the frequencies of the histogram. Locate the absolute maximum and the highest relative maximum. The leftmost point of maximum is associated to noise (Inoise), the rightmost is associated to signal (Isignal)

6) Estimate the mean power of the noise, averaging five bins around I noise:

$$P_{noise} = \frac{\sum_{i=I_{noise}-2}^{I_{noise}+2} bins(i) \cdot Freq(i)}{\sum_{i=I_{noise}-2}^{I_{noise}+2} Freq(i)}.$$

7) Estimate the mean power of the signal, averaging five bins around I_{signal}:

$$P_{signal} = \frac{\sum_{i=I_{signal}-2}^{I_{signal}+2} bins(i) \cdot Freq(i)}{\sum_{i=I_{signal}-2}^{I_{signal}+2} Freq(i)}.$$

8) Estimate the root-mean-square value of the background noise e_{noise}: signal

$$e_{noise} = \sqrt{P_{noise}}.$$

9) Estimate the SNR (in dB):

$$SNR = 10 \cdot Log_{10} \frac{P_{signal} - P_{noise}}{P_{noise}}.$$

10) Estimate the duty cycle (%):

$$DC = 100 \cdot \frac{\sum_{i=I_{signal}-2}^{I_{signal}+2} Freq(i)}{\sum_{i=I_{signal}-2}^{I_{signal}+2} Freq(i) + \sum_{i=I_{noise}-2}^{I_{noise}+2} Freq(i)}.$$

IV. CONCLUSION

This work presents an algorithm for the estimation of background noise, signal-to-noise ratio and duty cycle of SMES generated during cyclic movements. The algorithm was tested on synthetic and real SMES and the obtained results show that, in most practical situations, it provides accurate and stable measures of the aforementioned parameters.

We adopted this method to choose the parameters of a double-threshold statistical detector we previously developed and that we have been using in the past years to carry-out a user independent analysis of the SMES detected during walk. Results we obtained in that field are fully satisfactory and we believe that the approach herein presented could be beneficial also in other applications, when dealing with operator independent processing of SMES or other biomedical signals with similar characteristics.

V. REFERENCES

[1] R. Acharya, J. S. Suri, J. A.E. Spaan and S .M. Krishnan, "Advances in Cardiac SignalProcessing", 2007 edition, Springer Berlin Heidelberg, New York , ISBN: 3-540-36674-1.

[2] J. Moss and S. Stern., "Non-invasive electrocardiology: Clinical aspects of holter monitoring", 1st edition, 1996, W.B. Saunders, Philadelphia, ISBN: 9-7020-1925-9.

[3] S.K. Jagtap, M.S. Chavan, R.C. Wagvekar and M.D. Uplane, "Application of the digital filter for noise reduction in electrocardiogram". Journal of Instrumentation, vol.40, no. 2, pp. 83–86, June 2010.

[4] Dr. K. L. Yadav and Sachin Singh, "Performance evaluation of different adaptive filters for ECG signal processing", International Journal On Computer Science and Engineering, vol. 40, no. 5, pp. 1880–1883, 2010.

[5] Muhammad ZiaUrRahman, Rafi Ahamed Shaik and D.V.RamaKoti Reddy, "Efficient sign based normalized adaptive filtering techniques for cancelation of artifacts in ECG signals: Application to wireless biotelemetry", Journal of signal processing, vol. 91, no. 2, pp. 225–239, February 2011.

[6] Ching-Haur Chang ,Kang-Ming Chang ,and Hsien-Ju Ko, "Cancellation of highfrequency noise in ECG signals using Adaptive filter without external reference", Proceedings of International Conference on Biomedical Engineering and Informatics, pp. 787–790, Yantai, October 2010.

[7] K. Daqrouq, "ECG base line wander reduction using discrete wavelet transform", Asian Journal of Information Technology, vol. 4, no. 11, pp. 989–995, 2005.