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A quick survey of filtering techniques for surface electromyography signals

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Abstract

Electromyography (EMG) represents the electrical activity of muscles, and it has a wide range of usage in biomedical and clinical tasks. During myoelectrical stimulation, the EMG signal has two sources: the meaningful electrical response of the muscles and signal noise. Technical noise (such as power line noise) and biological noise (ECG). The noises in the system must be efficiently rejected, as this will disturb the analysis of the activity of the muscle. This paper presents different types of noise that corrupt the EMG signal and the main denoising approaches for minimizing the noise effect.

Keywords: EMG; Artifact; Denoising; Adaptive Filtering; NLM; DWT and MSE

1. Introduction

Electromyography (EMG) signals are becoming increasingly important in many applications, including clinical/biomedical, prosthesis or rehabilitation devices, human machine interactions, and more. However, noisy EMG signals are the major hurdles to be overcome in order to achieve improved performance in the above applications. Detection, processing and classification analysis in electromyography (EMG) is very desirable because it allows a more standardized and precise evaluation of the neurophysiological, rehabitational and assistive technological findings [1-4]. Varieties of noises originated from measurement instruments are major problems in the analysis of surface electromyographic (SEMG) signals. Therefore, methods to eliminate or reduce the effect of noises have been one of the most important problems [5]. Nervous System every time controls activity of muscle (contraction/relaxation). For this reason, Electromyogram signal is a complex signal that is controlled by nervous system and depends on anatomical and physiological muscle characteristics. The electromyogram signal makes noise when traveling with different tissues. Moreover, if the electromyographic detector is located on a particularly deep surface, it picks up signals from different engine units that can produce the interaction of the individual signals. EMG, powerful and advanced methodologies and perception signals become a very significant necessity in biomedical engineering. Primary reason in order to interest in analysis of electromyogram signal is biomedical implementations and clinical diagnosis. Up to now, research and intensive efforts have been made in field, the improvement of better algorithms, and the development of existing methodologies, the development of detection techniques for noise reduction, and the acquisition of correct Electromyogram signals. EMG is a technique utilized to evaluate and record electrical activity generated by skeletal muscle. The electromyogram is performed utilizing a device named an electromyograph, to make a record. Two types of electrodes have been used to acquire muscle signal: invasive electrode and non-invasive electrode. When EMG is acquired from electrodes mounted directly on the skin, the signal is a composite of all the muscle fiber action potentials occurring in the muscles underlying the skin [6-8]. These action potentials occur at random intervals. So at any one moment, the EMG signal may be either positive or negative voltage [9]. It is widely acknowledged that noise contamination of EMG signals is an unavoidable problem involved in the recording data. In other words, raw EMG signals typically contain not only useful information but also some irrelevant or confounding information that adds

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ambiguity. The raw signal cannot, therefore be used directly, and data pre-processing is necessary to reduce the effect of noise and to improve the spectral resolution of the EMG signal [10].

2. Various Types of noises in EMG Signal

There are many types of noises are added with the input EMG signal; they are ECG noise, baseline wander (BW) noise and PLI noise, Inherent noise in electronics equipment, Motion artifact, Inherent instability of signal, Cross talk, Electrode contact, Transducer noise, Baseline shifts.

2.1. Base-line wanders (BW)

Spectral content with less than 1 Hz appears as a long-term drift in the EMG signal. Herewith, the least square procedures, polynomials are estimated, which mentions that within the PLI model. At the mean PLI frequency f_0, modulation of sine and cosine is done from the second-order polynomials with recall and PLI coefficients. In the same way, BW [11] signals are modeled from the low-order polynomials. Therefore, we can describe the signal with f_0=0:

$$S_{\mathrm{BW}}(t) = (a_0 + a_1 n + a_2 n^2)\sin(2\pi 0 t) + (b_0 + b_1 n + b_2 n^2)\cos(2\pi 0 t) = (b_0 + b_1 n + b_2 n^2)', \quad (1)$$

Where f_0 is aimed to stress the relationship between BW and PLI model [11].

2.2. Power-line interference (PLI)

Depending upon the geometric location frequency range of the PLI signal varied which is 50 or 60 Hz and also due to some unstable power sources, time deviations in the available frequency happen. So, this may produce 3–4% variation in frequency and also reduces the energy with some harmonics. Due to the harmonics in the PLI, an information loss happens in the real signal [12].

2.3. 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 [13].

2.4. 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 [14].

2.5. Inherent Noise in the Electrode

All types of electronic equipment generate electrical noise, otherwise known as “inherent noise”. This noise has frequency components that range from 0 Hz to several thousand Hz. Two kinds of EMG signals in widespread use include surface EMG, and intramuscular (needle and fine-wire) EMG. To perform intramuscular EMG, a needle electrode or a needle containing two fine-wire electrodes is placed within the muscle of interest (invasive electrode). However, the use of surface electrodes has become more accepted in clinical and physiological applications [4].

2.6. Motion artifact

When motion artifact is introduced to the system, the information is skewed. Motion artifact causes irregularities in the data. There are two main sources for motion artifact: 1) electrode interface and 2) electrode cable. Motion artifact can be reduced by proper design of the electronic circuitry and set-up [15].

2.7. Inherent Instability of Signal

The amplitude of EMG is random in nature. EMG signal is affected by the firing rate of the motor units, which, in most conditions, fire in the frequency region of 0 to 20 Hz. This kind of noise is considered as unwanted, and the removal of the noise is important [16].

2.8. Inherent noise in electronics equipment

This type of noise is inherent in all electronic equipments. 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 [17].

3. Noise removal techniques

The electromyographic signals are effected by different elements including muscle life and different physiological procedure and furthermore by numerous outer elements [18]. So the EMG signals are defenseless to different commotions. The EMG signal is distorted by various interference voltages. There are some characteristic commotions in the system that corrupts the output of the system. It is illogical or even difficult to extricate the helpful data from the EMG signal when the signal to noise ratio is exceptionally poor. There are a few noise expulsion systems used to diminish the noise in EMG signal [18].

3.1. Median Filter

Median filter reduces the random noise when the large tails occur in noise amplitude probability density. It is a nonlinear filter in which the input signal is sampled into individual windows and each output is consider as median value. The median filter is a non-linear digital filtering technique, often used to remove noise from an image or signal. Such noise reduction is a typical pre-processing step to improve the results of later processing. Present information and globalizes in different patterns. If a resolution of signal is too high, then the window size will be the main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal. For one-dimensional signals, the most obvious window is just the first few preceding and following entries, whereas for two-dimensional (or higher-dimensional) data the window must include all entries within a given radius or ellipsoidal region (i.e. the median filter is not a separable filter) [19].

3.2. EMD-based Filter

In this method, the complex data are decomposed into a finite and often small number of oscillatory components, called intrinsic mode functions (IMFs). An IMF must provide two conditions [20]:

- In the whole data set, the number of extreme and zero crossings must be equal or differ at most by one;
- At any point, the mean value of the envelope defined by the local maxima and the local minima must be zero.

3.3. Wavelet-based Filtering Method

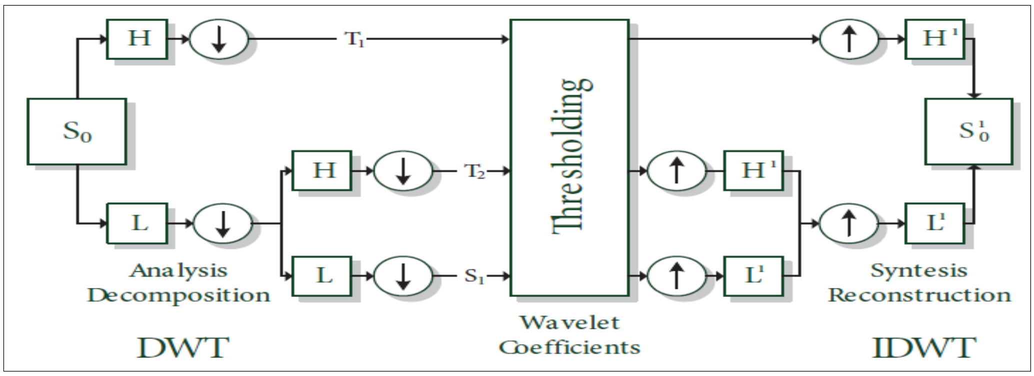

Figure 1 Typical DWT denoising application using filter banks

The discrete wavelet transform (DWT) is a convenient way to represent and manipulate signals featuring sharp transients. It splits the signal into its "low-resolution" parts and a series of details at different resolutions. This process is described in terms of filter banks. In filter banks, the signals under analysis are divided into two components, S(n) and T(n), by digital filters L and H. L stands for the low-pass filter while H stands for the high-pass filter. For the signal reconstruction, the filtering process is simply reversed. One common application of the DWT is denoising, which has received considerable attention in the removal of noise in biomedical signals [21].

3.4. Adaptive Filtering based Method

An adaptive filter uses iterative computations to minimize the error "in modelling the relationship between two signals in real time". Fig. 2 shows a basic diagram of an adaptive filter. Here, the input s_1 represents the EMG which is observed with the additive noise n. The reference signal s is either a pure noise generator or a signal related to n. Since the n and s_1 are uncorrelated, then $E[e^2] = E[(n-y)^2] + E[s_1^2]$ [22].

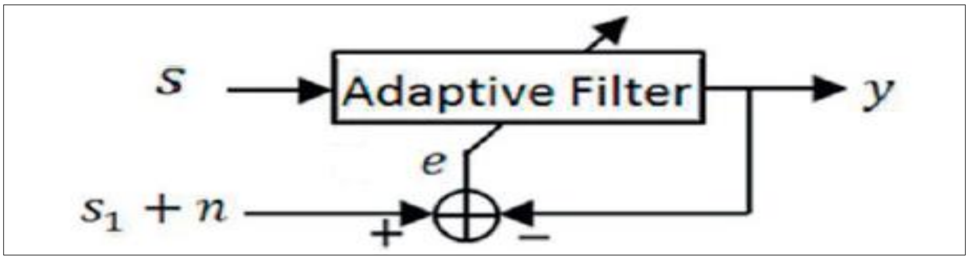

Figure 2 A general diagram of an adaptive filter [22]

3.5. Non-Local-Means (NLM)-Based Filtering Method

The NLM algorithms were originally developed for image denoising. However, the algorithms have evolved and have been applied to EMG signal denoising due to their repetitive characteristics similar to that of the EMG. The NLM method calculates an estimate for each sample in the noisy EMG signal [23]. The goal of the NLM algorithm is to solve the issues with local smoothing filters by computing the smoothed value as a weighted average of other values in the signal based on the similarity of the neighborhoods [23].

4. Performance Metrics of EMG Signal Filtering Approaches

There are three benchmark metrics for the analysis of different denoising methods. These are root-mean-square error (RMSE), percentage-root-mean-square difference (PRD), and improvement in signal-to-noise ratio (SNRimp). RMSE is the root of the squared error difference between the denoised and original EMG signals. It is used for determining the variance between the output predicted by the denoising model and the actual signal. A smaller value of RMSE implies the better performance of the model. PRD computes the total distortion present in the denoised signal. A lower PRD represents a better quality of the denoised signal. SNRimp is the improvement in the SNR levels between the input and the output. The performance evaluation criteria can be defined as follows [5]:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{n=0}^{N-1} [x(n) - \hat{x}(n)]^2} \qquad (1)$$

$$\mathrm{SNR_{imp}} = \mathrm{SNR_{out}} - \mathrm{SNR_{in}}$$

where $\mathrm{SNR_{in}}$ and $\mathrm{SNR_{out}}$ are as follows:

$$\mathrm{SNR_{out}} = 10 \times \log_{10}\left(\frac{\sum_{n=0}^{N-1}[x(n)]^2}{\sum_{n=0}^{N-1}[\hat{x}(n)-x(n)]^2}\right) \qquad (2)$$

$$\mathrm{PRD} = \sqrt{\frac{\sum_{n=0}^{N-1}[x(n)-\hat{x}(n)]^2}{\sum_{n=0}^{N-1}[x(n)]^2}} \times 100 \qquad (3)$$

Where N is the number of data points

5. Conclusion

A raw EMG signal includes more significant information about the nervous system in worthless form. The objective of this research is to review the recent techniques for reducing noises and artifacts that corrupt the EMG signals. This paper focused on the methods and algorithms used for denoising EMG signals, which is a crucial step in several applications, such as prosthetic arm control, end-user, and diagnosis of neurological problems, biochemical and biomedical research. Also, this article presented a clear and comprehensive view of EMG processing techniques for reducing noise, which will be a solid foundation for improving the existing pattern recognition algorithms.

References

[1] Pérez-Reynoso F, Farrera-Vazquez N, Capetillo C, Méndez-Lozano N, González-Gutiérrez C, López-Neri E. Pattern Recognition of EMG Signals by Machine Learning for the Control of a Manipulator Robot. Sensors. 30 Apr 2022; 22(9): 3424.

[2] Tuncer SA, Alkan A. Classification of EMG signals taken from arm with hybrid CNN-SVM architecture. Concurrency and Computation: Practice and Experience. 28 Feb 2022; 34(5): e6746.

[3] Abbas EI, Rijab KS, Ahmed AF. Optimal Wavelet Filter for De-noising Surface Electromyographic Signal Captured From Biceps Brachii Muscle. Engineering and Technology Journal. 28 Jan 2015; 33(1 Part (A) Engineering).

[4] Chowdhury RH, Reaz MB, Ali MA, Bakar AA, Chellappan K, Chang TG. Surface electromyography signal processing and classification techniques. Sensors. Sep 2013; 13(9): 12431-66.

[5] Phinyomark A, Limsakul C, Phukpattaranont P. EMG feature extraction for tolerance of white Gaussian noise. InProc. International Workshop and Symposium Science Technology. 2 Dec 2008; 178-183.

[6] Reaz MB, Hussain MS, Mohd-Yasin F. Techniques of EMG signal analysis: detection, processing, classification and applications. Biological procedures online. Dec 2006; 8(1): 11-35.

[7] Wei C, Wang H, Hu F, Zhou B, Feng N, Lu Y, Tang H, Jia X. Single-channel surface electromyography signal classification with variational mode decomposition and entropy feature for lower limb movements recognition. Biomedical Signal Processing and Control. 1 Apr 2022; 74: 103487.

[8] Tuncer SA, Alkan A. Classification of EMG signals taken from arm with hybrid CNN-SVM architecture. Concurrency and Computation: Practice and Experience. 28 Feb 2022; 34(5): e6746.

[9] Stashuk D. EMG signal decomposition: how can it be accomplished and used? Journal of Electromyography and Kinesiology. 1 Jun 2001; 11(3): 151-73.

[10] Phinyomark A, Campbell E, Scheme E. Biomedical Signal Processing: Advances in Theory, Algorithms and Applications.

[11] Nagasirisha B, Prasad VV. Noise Removal from EMG Signal Using Adaptive Enhanced Squirrel Search Algorithm. Fluctuation and Noise Letters. 5 Dec 2020; 19(04): 2050039.

[12] Nazmi N, Abdul Rahman MA, Yamamoto SI, Ahmad SA, Zamzuri H, Mazlan SA. A review of classification techniques of EMG signals during isotonic and isometric contractions. Sensors. Aug 2016; 16(8): 1304.

[13] McManus L, De Vito G, Lowery MM. Analysis and biophysics of surface EMG for physiotherapists and kinesiologists: toward a common language with rehabilitation engineers. Frontiers in neurology. 2020: 1216.

[14] Amrutha N, Arul VH. A review on noises in EMG signal and its removal. Int. J. Sci. Res. Publ. May 2017; 7(5): 23-7.

[15] De Luca C. Electromyography. Encyclopedia of medical devices and instrumentation. 14 Apr 2006.

[16] Nazmi N, Abdul Rahman MA, Yamamoto SI, Ahmad SA, Zamzuri H, Mazlan SA. A review of classification techniques of EMG signals during isotonic and isometric contractions. Sensors. Aug 2016; 16(8): 1304.

[17] Schwartz M, editor. EMG methods for evaluating muscle and nerve function. BoD–Books on Demand. 11 Jan 2012.

[18] Ma S, Lv B, Lin C, Sheng X, Zhu X. EMG signal filtering based on variational mode decomposition and sub-band thresholding. IEEE Journal of Biomedical and Health Informatics. 15 Apr 2020; 25(1): 47-58.

[19] Erkan U, Gökrem L, Enginoğlu S. Different applied median filter in salt and pepper noise. Computers & Electrical Engineering. 1 Aug 2018; 70: 789-98.

[20] Liu BF, Sera Y, Matsubara N, Otsuka K, Terabe S. Signal denoising and baseline correction by discrete wavelet transform for microchip capillary electrophoresis. Electrophoresis. Sep 2003; 24(18): 3260-5.

[21] Gargour C, Gabrea M, Ramachandran V, Lina JM. A short introduction to wavelets and their applications. IEEE circuits and systems magazine. 5 Jun 2009; 9(2): 57-68.

[22] AlMahamdy M, Riley HB. Performance study of different denoising methods for ECG signals. Procedia Computer Science. 1 Jan 2014; 37: 325-32.

[23] Bhobhriya R, Boora R, Jangra M, Dalal P. An Efficient EMG Denoising Technique Based on the W-NLM Method.

[24] Chatterjee S, Thakur RS, Yadav RN, Gupta L, Raghuvanshi DK. Review of noise removal techniques in ECG signals. IET Signal Processing. Dec 2020; 14(9): 569-90.