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TECHNIQUES FOR ELIMINATION OF NOISE IN BASELINE OF EMG SIGNAL

Jeet Singh[1], Jitendar yadav[2]

[1]Invertis University, Department of Electronics and Communication Engineering,
Invertis village, NH-24, Bareilly 241323, India
rvjrathour@gmail.com

[2]Invertis University, Assistant Professor Department of Electronics and Communication Engineering,
Invertis village, NH-24, Bareilly 241323, India
jksliet@yahoo.com

***Abstract*: *Electromyography (EMG) is the study of the muscle function through analysis of the electrical signal emanated during skeletal muscle contraction and it from get information in the diagnosis of neuromuscular disorders. The EMG is very importance and used for the diagnosis and treatment of the different neuromuscular disorders and to study the neuromuscular control mechanism and muscle weakness, the quality of EMG signal may be degrade by baseline fluctuation or low frequency oscillations. Due to baseline fluctuation of EMG signal Disturbing the process of MUAP extraction, study and classification. Appropriate removal of noise present in the baseline of EMG signal is an important issue when recoding EMG signal using the electrodes, as it may be reduce quality and quantitative analysis and an adequate remove of noise in the baseline can enhance the quality of EMG signal. The present work focus on different techniques and their comparative study for elimination of noise present in the baseline of the EMG signal. These techniques on real and simulated EMG signal give their advantages and drawbacks in term of both visual inspection and merit figures. We use three methods to cancellation the noise present in the baseline of EMG signal named as Digital filter designing, statistical approach and moving average method. Segmentation of EMG signal is used in all techniques. Segmentation is required to classify the motor unit action potentials composed by the EMG signal. We analyzed EMG signal from the skeletal muscles in a healthy subjects at low force level, using the needle electrode.*

Keywords: *EMG signal, Baseline fluctuation, segmentation, MUAP*

1. INTRODUCTION

The electromyography (EMG) signal is a biomedical signal that measures electrical currents generated in muscles during its contraction representing neuromuscular activities. The EMG signal is a complicated signal, which is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles.

Electromyography (EMG) is the study of function through analysis of the electrical signal emanated during muscular contractions. And the study of electromyography (EMG) signal is a study of the properties and activities of the tissue. EMG signals are detected by placing and detecting the extracellular voltage produced by the electrical activity of the muscle fibers. The analysis of EMG signals detected during muscle contraction provides important information to aid in the diagnosis and characterization of neuromuscular disorders. In general , the characteristics of EMG signals are dependent on a number of factors, including the anatomical and physiological of the muscle contraction, the types of electrode used and the location of the electrode relative the contracting muscle fibers. The analysis of the Electromyography (EMG) signals are based on its constitute i.e. motor unit action potential (MUAPs). It consists of a group of muscle fibers, which are innervated from the same motor nerve. The shape of motor unit action potential (MUAP) reflects the pathological and functional states of the motor unit (MU). If increasing muscle force then the EMG signal an increase in the number of activated MUAPs recruited at increasing firing rate, making it difficult for the neurophysiologist to distinguish individual MUAP waveforms. In most of the clinical EMG examinations, it is the shape of the action potential that is analyzed for 30 diagnostics. For this purpose, clinical examinations are carried out with the EMG signal recorded at low contraction level of the muscle; usually such individual motor unit action potentials are distinguishable.

The motor unit action potential (MUAP) expresses the electrical activity of the muscle fibers of a motor unit recorded from a electrodes. The shape of motor unit action potential (MUAPs) waveforms and the degree of similarity in consecutive firings contain valuable information about the nature and state of a muscle and It helps to distinguish normal from pathological conditions and to measure the degree of abnormality [6].The motor unit action potential (MUAP) analysis is a routine procedure in clinical electromyography (EMG). In the usual clinical procedure, different MUAP discharges are extracted from the continuous electromyography (EMG) recorded. Conventional electromyography (EMG) presents a manual or automatic selection of several discharges from a motor unit, which are then aligned and averaged [3, 8], to form the MUAP waveform. After that, qualitative (visual-based) and quantitative (parameter-based) analysis are carried out. The quality of the EMG signal may be reduced by baseline oscillations, disturbing the processes of MUAP extraction, classification and analysis. An adequate cancellation of the baseline fluctuation (BLF) would enhance quality of the EMG signals. Electromyography (EMG) signals can be used for variety of applications like clinical, biomedical and human machine interaction, prosthetic hand control, grasp recognition etc.

The objective of the present work is to cancellation the baseline fluctuation (BLF) present in the EMG signal. In this thesis, digital filter designing technique is devised for removal of baseline fluctuation.

2. METHODS

Three techniques are used for elimination of noise present in the baseline of the EMG signal, which are listed below.

1. Statistical technique based on threshold
2. Digital filter designing for removal of baseline fluctuation (BLF)
3. Moving average method

2.1 Statistical Technique Based On Threshold

Statistical technique used for cancellation of baseline fluctuation (BLE) is based on the threshold, which is calculated on the basis of mean absolute value of whole EMG signal. This technique can easily remove the low frequency oscillations or noise presents in the baseline of EMG signal and thus it may enhance the quality of EMG signal. It is generally based on the threshold values, which can be calculated with the help of a simple algorithm. This technique is comprises the following sequential steps, which are listed below.

1. Calculation of threshold
2. Segmentation of EMG signal
3. Removal of baseline signal
4. EMG signal without BLF

2.1.1 Calculation of threshold

To characterize the baseline fluctuation, MUAP free segments or the baseline segment (BLS) must be distinguished from MUAP segments of the Electromyography (EMG) signal. It can be accomplished that the threshold calculation is the most significant part in the cancellation of BLF of EMG signal in the statistical technique. The threshold is used in the activity level of the EMG activity, segmentation and classification of whole EMG signal. The value of threshold is calculated on the base of mean absolute value of each samples present in the EMG signal X (t).

A simple algorithm used for the calculation of threshold T is given as

If maximum X (t)>30* mean (abs X (t))

Then

Threshold = 5 * mean (abs X (t))

Else

Threshold =maximum X (t)/5

The value of threshold will be different for different EMG signal.

2.1.2 Segmentation of EMG signal

The process to cut the EMG signal into segment of possible MUAPs segment (active segment) and baseline segment (MUAPs free segment) is known as segmentation. Segmentation of EMG signal can be performed using by discrete wavelet transform (DWT) [1]. The discrete wavelet transform (DWT) decay the EMG signal into active segment and baseline segment with the help of defined algorithm, which is given in the Matlab toolbox. In the present paper segmentation is performed into two stages. In first stage active segment (AS) are obtained and in second stage BLS are obtained. In the first step segmentation algorithm calculates the threshold, peaks over the calculated threshold are considered as candidate MUAPs. Now a window of constant width of 120 points is applied centered at the identified peak. If a greater peak is originated in the window, the window is centered at the greater peak otherwise the 120 points are saved as a candidate MUAP waveform. In second stage to obtain the BLS of EMG signal, second threshold, named T1 is also calculated. In this step a windows of constant width of 30 points is taken and calculates T1, then selects the next window of 30 samples and calculate the value of T1 again. Thus the complete length of the EMG signal is divided into the window of 30 samples and threshold is calculated each time. The value of threshold (T1) is change for every next window. The threshold T1 is also calculated on the basis of mean absolute value of complete samples present in a window of 30 samples. Now the BLS is performed by the comparison of this threshold T1 with first threshold T, which has been calculated in last section. If threshold T1 is greater than the threshold T then the samples is again considered as the candidate of MUAPs waveform i.e. the active segment, otherwise the segment is baseline segment. The value of second threshold T1 is calculated as:

T1=mean [abs(X (w))]

Where w is the size of window.

2.1.3 Removal of baseline signal

The cancellation of baseline fluctuation present in the BLS of the EMG signal can be performed. In this step the AS of the EMG signal will remain unchanged, only the correction is required in the BLS of the signal, The low frequency oscillations or disturbance present in the baseline segment of EMG signal are removed by subtracting the value of threshold T1 from the absolute value of the each samples present in the BLS of the first window of the size of 30 samples then taken the next window and subtract the value of respective threshold T1 from the absolute value of each samples of this window. This sequential procedure is applied to the whole windows of BLS of the EMG signal. After applying all the above procedure, a new BLS is obtained, which is free from the baseline fluctuation (BLF) or low frequency oscillations. Now the whole EMG signal with AS and BLS (without BLF) is achieved. Then the EMG signal without BLF can be further used for required applications such as clinical, biomedical and human machine interaction. In this way sufficient cancellation of BLF can be obtained, that can enhance the signal quality and accordingly make the process of extraction and analysis of EMG signal easier and reliable.

2.1.4 EMG signal without baseline fluctuation (BLF)

The EMG signal without BLF has been obtained with the help of above explained sequential steps. Since the noise and low frequency oscillations free signals usually do not exist in real environment, but the low frequency baseline oscillations can be reduced, which has been discussed in the above section. From the above in order steps it can be concluded that the AS of EMG signal will remain same throughout the whole process, all the techniques are applied only into the

BLS, Then new BLS of the EMG signal without BLF and same AS are obtained. Now the EMG signal without BLF can be used for different tasks. The EMG signal with and without baseline fluctuation respectively is shown in Figure 1 and Figure 2, the flat baseline of the EMG signal can be simply observed from the Figure 2.

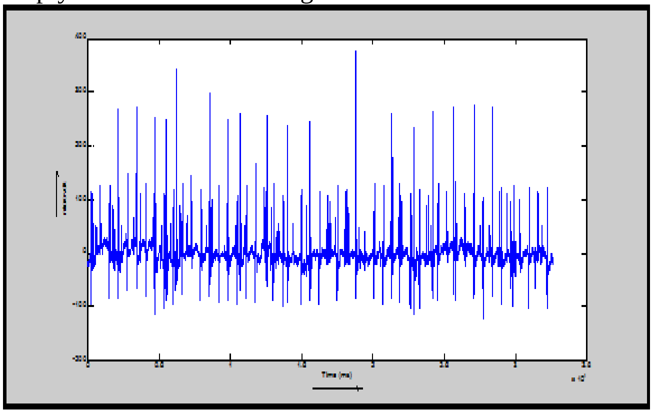

Figure 1: EMG signal with BLF

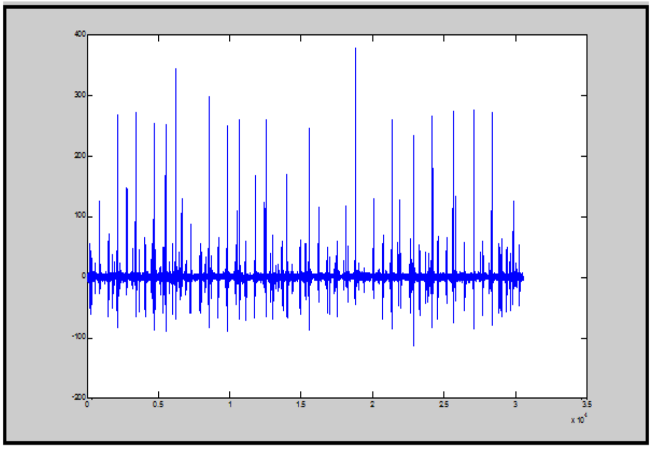

Figure 2: EMG signal without BLF

2.2 Digital filter designing for removal of baseline fluctuation (BLF)

Digital filter designing is another approach for removal of baseline fluctuation present in the EMG signal.

In this method, an EMG signal passed through high pass IIR (Butterworth) filter for the removal of the low frequency oscillations or the fluctuations present in the baseline of EMG signal. This technique is comprised the following steps.

1. Calculation of threshold
2. Segmentation of EMG signal
3. Interpolation of baseline points
4. Analysis of power density spectrum
5. Filter designing & filtering of raw EMG signal

(2.2.1) Calculation of threshold and (2.2.2) Segmentation of EMG signal steps are same as discussed in section (2.1.1) & (2.1.2) respectively.

2.2.3 Interpolation of baseline points

Interpolation is the process of estimation of values between the data points. The previously averaged points are interpolated by means of cubic splines, which closely follow the BL through (along) its fluctuations. Now a peak of the amplitude of threshold T1 is marked at the centre of the window of 30 samples in the BLS of the EMG signal, the whole BLS of the EMG signal are centered with the peaks of respective threshold T1. After obtaining these peaks the interpolation techniques are applied to all peaks of baseline segments. The cubic spline interpolation is used to obtain the smooth baseline segment. The cubic splines technique interpolates signal points by means of concatenated cubic polynomials such that the obtained interpolation curve and its time derivative are both continuous throughout the whole time span, and the signal points to be interpolated are exactly on the curve Figure 4.

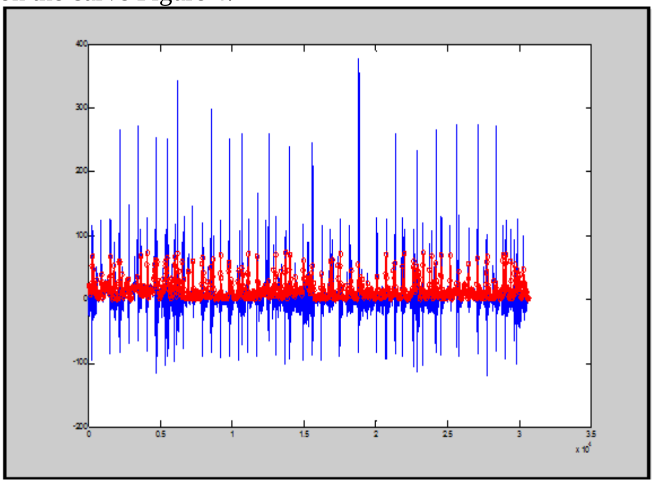

Figure 3: Interpolation points

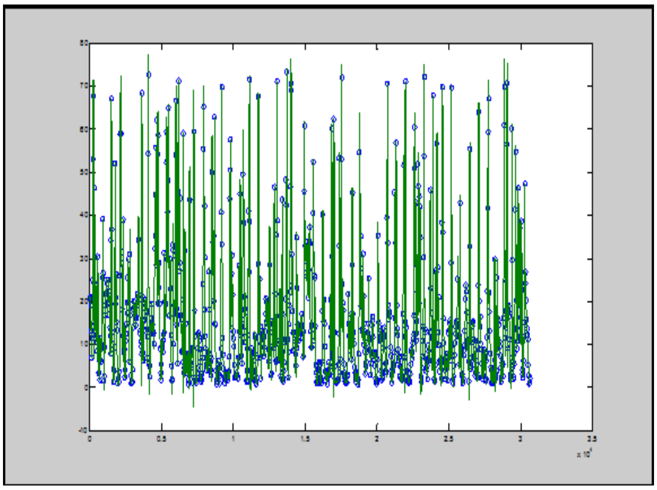

Figure 4: Interpolated BLS

2.2.4 Analysis of power density spectrum

The power spectrum density of the interpolated baseline segments will be obtained to find out the frequency range of the baseline, so that the filter would be designed for the specified cut off frequency. AR spectral estimation can also be used on the interpolated signal to obtain a smooth and high-resolution power spectral density. Other hand discrete Fourier transforms and Fast Fourier transform are also the efficient and simplest methods of power density spectral analysis. In this present paper Fast Fourier transform is used to obtain the Power density spectrum of interpolated baseline segment. From the PDS analysis, the cut off frequency of the BLS is 15Hz.

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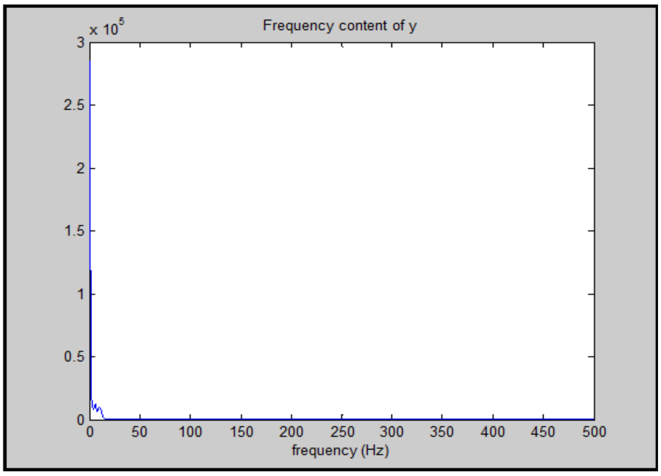

Figure 5: PSD of BLS

2.2.5 Filter designing & filtering of raw EMG signal

A high pass Butterworth filter of 3db cut off frequency with stop band of 15Hz is designed. Most commonly used method named; bilinear transformation can be followed for designing the IIR Butterworth filter. To eliminate of noise present in the baseline, the EMG signal is filtered out by the above designed high pass filter. The low frequency BLF are filtered out from the EMG signal and the active segment of high frequency pass through the filter thus it will remain same throughout the whole filtering process, almost linear phase characteristic of the Butterworth filter guarantees the preservation of MUAP shape as far as possible. The BLF filtering method using FFT spectral estimation followed by high pass Butterworth filter is found to be the best approach for baseline fluctuation filtering. An EMG signal with and without baseline fluctuation is shown in Figure 5.

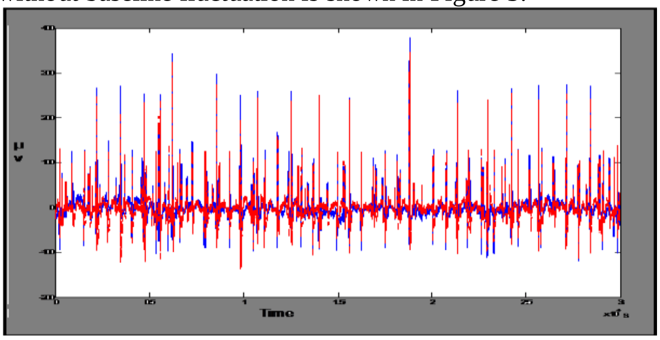

Figure 5: Original EMG signal and filtered BLF

2.3 Moving Average Method

Moving average method is one of the simplest technique for removal baseline fluctuation of EMG signals, because the algorithm used in this method is easier and smaller than other. In this techniques, one of the moving average techniques can be used such as, simple Moving average and Weighted moving average and Savitzky method. In this paper, simple moving average is used to filtering out the baseline oscillations. A direct function for smoothing a data of specified length is given in MATLAB, which can smooth the data easily. Moving average method devised for removal of baseline fluctuation present in the EMG signal is discussed below in four steps are below.

Select the data: The data that we want to smooth is loaded then specify the name of smoothed data set. Select the smoothing methods: One of the smoothing methods such as moving average method, locally weighted method and Savitzky method can be used to perform the smoothing.

Select the span: The span or the number of data points of the full length of data is selected, to compute each smoothed value. The processes of smoothing the original data set always produce a new data set containing new smoothed response value. For Moving average and Savitzky method, the span must be odd. In weighted method, if the span is less than one, it is interpreted as the percentage of the total number of data points. By default, the value of the span in Moving average method is five.

Select the degree: select the degree of polynomial used in only Savitzky method. The degree must be smaller than span.

The simple moving average method is used for smoothing the EMG signal with the span of 150 points from the full length of EMG signal. As the span will small, the accuracy of smoothed data will be increased. If the span is greater than data length, then it is reduced by the length of data. There is no need to select the degree of polynomial in the present work, due to the use of Moving average method

3. RESULTS

3.1 Quantitative Analysis

Quantitative explanation is required to compare the baseline removal techniques. Baseline fluctuation raises or lowers the mean level of a potential, so the degree of waveform variation in the discharge in a MUAP train is increased by BLF.

Two quantities (F and N) are devised to calculate the degree of BLF. They are calculated as follows.

- All the single potential are manually selected and classified, by eye, on the basis of wave shape into several classes corresponding to different MUAP trains.
- For each MUAP train, the corresponding discharges are time aligned so that correlation between them is maximized.

Let $Y_k = \{ y_k(1), y_k(2)......... ....y_k(n_k) \}$ be the discharge number k of the set of m discharges of a certain MUAP train, where $y_k(t)$ is the t sample of Y_k. Discharge in Y_k are normalized dividing their samples values by the maximum absolute value in the whole set. The two proposed quantities are defined below.

$F = S.D_k\,(mean_t(\,Y1)......... ....mean(Ym\,))\ Y$ (3.1)

First the temporal mean of every discharge is calculated; then standard deviation of all these means is computed.

$N = mean_t\,(s.d_k\,(y_k(t)................\ y_k(t))$ (3.2)

The standard deviation across various discharges is calculated for every sample time, the resulting set of values is then averaged.

Because of the above-mentioned normalization, F and N values will be in the range 0-1. F measures the variability of the mean of the different discharges pertaining to the same MU along the EMG signal. Ideally, if baseline fluctuation were not present, and if all discharges from the same MU were the same, F would be zero. When there is BLF, some discharges appear higher than others and the value of F increases accordingly. Other hand, N measures the variability of amplitude values of amplitude values of a

MUAP waveform throughout a MUAP train. N will be zero if no BLF is present and the discharges do not differ from each other. If the BL fluctuates, the amplitude of MUAP samples will vary from one discharge to another and N will increase according to this variation. Thus, the degree of BLF cancellation provided by a given technique on a certain EMG signal can be measured indirectly by looking at the decrement in the signal's F and N values. BLF removal techniques can be compared by direct computation of F and N parameters in the processed signal. For lower the F and N values, the lower the remaining BLF, and better the performance of method. The values of F and N are calculated here for three methods.

Table 1: Values of F and N of Raw EMG signal

MUs	Value of F for Raw EMG signal	Value of N for Raw signal
MU1	0.0257	0.207
MU2	0.0337	0.205
MU3	0.0388	0.1768

Table 2: Values of F and N without BLF, using Digital filter

MUs	Value of F for filtered EMG signal	Value of N for filtered EMG signal
MU1	0.0203	0.203
MU2	0.0230	0.2002
MU3	0.0320	0.1711

Table 3: Value of F and N without BLF, using Statistical technique

MUs	Value of F for filtered EMG signal	Value of N for filtered EMG signal
MU1	0.0195	0.122
MU2	0.0083	0.0204
MU3	0.0089	0.1640

Table 4: Value of F and N without BLF, using moving average technique

MUs	Value of F for filtered EMG signal	Value of N for filtered EMG signal
MU1	0.0196	0.1637
MU2	0.013	0.1539
MU3	0.017	0.1648

4. CONCLUSION

Three methods have been devised for cancellation of BLF named as statistical technique, digital filter designing and Moving average method. These makes use several signal processing, statistical and mathematical techniques in a sequential approach. Two merit figures have been devised to determine the degree of BLF present in an EMG signal. Tests with real and simulated signals show the validity of these merit figures and demonstrate that they are sensitive to variations in BLF amplitude and less sensitive to the BLF frequency distribution. To measure the activity level, segmentation and classification of EMG signal into the AS and BLS and threshold has been calculated based on mean absolute value of whole EMG signal. The degree of BLF cancellation provided by a given method on a certain EMG signal can be measured indirectly by looking at the decrement in the signal's F and N values. BLF removal methods can be compared by direct computation of F and N parameters in the processed signal all these techniques are promising for enhance EMG signal quality.

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