

Electromyography based Detection of Neuropathy Disorder using Reduced Cepstral Feature

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Abstract

Background/Objectives: Neuropathy is a disorder which will be detected using Electromyography (EMG) signals. A new transformation based wavelet decomposition method is proposed in this work to categorize normal EMG signals from abnormal neuropathy disorder signals. **Methods/Statistical Analysis:** Transformation technique is applied to convert the signals into frequency map. Wavelet decomposition method decomposes transformed signal into set of various levels of coefficients. Cepstral feature have been applied to extract meaningful properties and Minimum Redundancy Maximum Relevance (MRMR) method has been applied to reduce dimensionality of cepstral features. **Findings:** The KNN classifier is used to discriminate neuropathy disorder from healthy Electromyography signals. The results shows better classification accuracy using cepstral feature set. Entire signal has been subdivided into 20 and 40 sub segments for better features. Coefficients for five levels have been extracted where 40 sub segment features shows better classification accuracy than 20 sub segments. In some cases, 3rd and 5th level coefficients of 20 sub segments shows better classification. **Application/Improvements:** This study helps to detect abnormal EMG signal from normal patterns which helps radiologist for better prediction of various disorders based on EMG signals.

Keywords: Cepstral Feature, EMG, Hilbert Transform, KNN, MRMR, Neuropathy

1. Introduction

Electromyography (EMG) signals are one of the familiar modalities used to diagnose the neuromuscular disorder which will affect muscles, brain, spinal cord and nerves. Electromyogram is a device to measure the electrical potentials generated by muscle contraction and recorded from the surface layer of the skin through varying electrodes. An Electromyogram (EMG) signal can have neuromuscular activities of all the motor unit potentials which are recorded with varying depths and lengths of electrodes¹. EMG helps to identify abnormal activity of the muscle and nerves that will cause many neuromuscular disorders which include muscle spasms, lower back pain, pinched nerve, cervical pain, epilepsy and dystonia. Neuropathy is one of the nerve disorders due to the damage of peripheral nerve system. It is associated with sensory changes like loss of sensation and balance².

The general workflow of EMG signal architecture

consists of four phases such as pre-processing, feature extraction, dimensionality reduction and classification. Pre-processing is the initial phase which removes all the noise contaminations from the acquired EMG signal. Feature extraction is an important phase in classification system which always depends on the accurate selection of relevant features. Dimensionality reduction is a technique used to preserve the significant features by reducing the redundant features. Classification also plays a major role for predicting the disorder signal through various machine intelligence algorithms.

In³ proposed a method for prosthetic arm movement based on EMG signals which has been classified using Artificial Neural Network and KNN. In⁴, compares two classification methods such as SVM and KNN for Amyotrophic Lateral Sclerosis disorder detection where KNN produce higher classification result than SVM. In⁵ discussed that autoregressive coefficient along with neuro fuzzy system has been used to discriminate neuropathy, Myopathy and healthy signal. In⁶, applied PCA based

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dimensionality reduction and compared SVM and MLP classifiers for discriminating EMG signals. In⁷, proposed a new method Hilbert-Huang transform to classify neuromuscular disorder. In⁸, proposes wavelet packet method for denoising and threshold methods for discriminating Myopathy and neuropathy EMG signals.

2. Proposed Method

Architecture of proposed method is shown in Figure 1. EMG signals have been acquired and transformed in the pre-processing stage. Cepstral features and reduced feature set have been obtained for decomposed EMG signal. Classification has been done based on these features in post-processing stage.

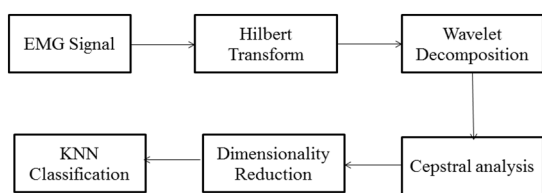


Figure 1. Proposed method for neuropathy disorder detection system.

2.1 Dataset Description

The data set have been collected from physionet site where the set consist of three classes of data such as healthy subject without the history of neuromuscular disease, a subject with long lasting history of polymyositis and a subject with chronic low back pain and neuropathy due to right L5 radiculopathy. Data were collected with a Medelec Synergy N2 EMG Monitoring system. These signals have been band passed with the frequency range from 20 Hz to 50 KHz. In this work, healthy and neuropathy classes have been considered for EMG signal analysis⁹.

2.2 Transformation

Transformation is the process of converting signal from time domain into frequency domain for understanding spectral properties of the signal. Hilbert transform is one of the transformation techniques which uses amplitude and frequency components of the signal. It makes change in the phase value and not in magnitude. It transforms all the frequency components by $-\pi/2$ radians¹⁰. It can be defined as

$$H(t) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{H(x)}{t-x} dx$$

where, integral adopts the Cauchy principal value of signal 'x' at defined time 't'.

2.3 Wavelet Decomposition

Wavelet decomposition is to decompose the spectral transformation of EMG signal into set of approximation and detail coefficients. These coefficients are acquired by convolving EMG signals with low pass and high pass filter for approximation and details respectively with the help of downsampling¹¹.

2.4 Feature Extraction

Feature Extraction plays a crucial role in classification system. Proper feature selection will improve performance and effectiveness¹². Cepstral analysis is one of the nonlinear signal processing technique which works only on the real part of the signal. Cepstral is calculated by taking inverse of the log magnitude of the DFT signal 'x'¹³. It is defined by

$$Ceps[n] = idft[\log [x(n)]]$$

2.5 Dimensionality Reduction

Minimum Redundancy Maximum Relevance (MRMR) helps to reduce the dimensions of the features¹⁴. Maximum relevance is defined by

$$\max_Q \frac{1}{|Q|^2} \sum_{x,y \in Q} I(x,y)$$

where, $I(x,y)$ is the mutual information between x and y , 'Q' is the set of features.

Minimum Relevance can be defined as,

$$\max_Q \frac{1}{|Q|^2} \sum_{x \in Q} I(x,g)$$

where, 'Q' is the feature set, 'g' is the group value. This method produces feature set which optimizes the maximum relevance and minimum redundancy.

2.6 Classification

Classification plays major role in EMG signal analysis system. Signal contaminated with noise, high dimension and small training dataset makes classification difficult. Better classification results can be produced only through the selection of proper features. K-Nearest Neighbourhood is familiar supervised classification algorithm which works based on the distance metrics. It

calculates the distance from each test point to every point in the signal, ranks them in ascending order and show the k points with the smallest distance^{15,16}.

3. Results and Discussion

In this work, neuropathy disordered and healthy EMG signals have been taken for analysis. Signal has been taken as 25 records with the sample size of 2000 each. Each record is further segmented into 40 and 20 subsegments with the size of 50 and 100 samples respectively. Hilbert transformation has been applied to transform the filtered signal into spectral domain. Daubechies 4th order wavelet decomposition method applied to the spectral signal in order to obtain various level of coefficients to enhance the depth of the analysis. Cepstral analysis has been applied to extract the coefficient from different levels of decomposition. These features have been feed into Knn classifier to obtain the classification accuracy of neuropathy signals.

Classification accuracy has been obtained for 40 and also 20 features without using dimensionality reduction technique as shown in Figure 2. All the five levels of coefficient of 40 sub-segment features produce higher classification accuracy than 20 sub-segment feature except 4th level coefficients. Both subsegments at 4th level produces similar classification accuracy.

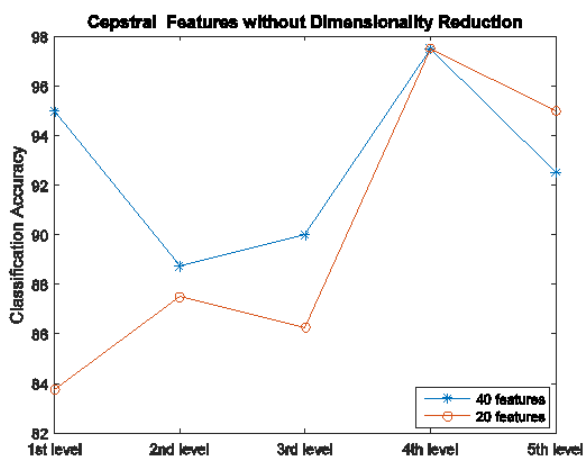


Figure 2. Classification accuracy of cepstral features without using dimensionality reduction method.

Minimum Reduction Maximum Relevance (MRMR) dimensionality reduction has been applied which reduces the redundant features. 1st, 2nd and 4th level coefficients

of 40 sub-segment feature produce higher classification accuracy than 20 sub-segment feature. 3rd and 5th level of 20 sub-segment yields better accuracy than 40 sub-segments of EMG signals as in Figure 3.

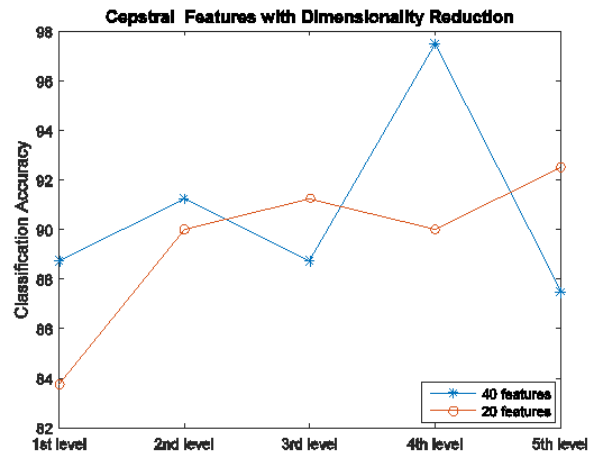


Figure 3. Classification accuracy of cepstral features using MRMR dimensionality reduction method.

4. Conclusion

EMG signals are primarily helpful for detecting neuromuscular disorders. Cepstral feature set have been used for neuropathy EMG signal disorder. In this study, impact of classification accuracy has been discussed by varying sample sizes with dimensionality reduction. Minimum redundancy maximum relevance feature has been used to detect closer feature set. Results shows classification accuracy varies with respect to selection of features and dimensionality reduction methods.

5. References

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