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Automated Muscle Fatigue Diagnosis using EMG Signal

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ABSTRACT

One of the major causes of injuries in athletes is related to muscle fatigue and is normally detected after the muscle is already injured. To prevent future injuries it is important to detect muscular fatigue before it is visible, so that the athletes' performance is improved. The main objective of this thesis is to detect and characterize muscular fatigue. The signals under study are electrical impulses produced by the muscle (electromyography). Analysing these signals allows us to evaluate if fatigue is present. The amplitude of EMG signals increases progressively as a function of time when the fatigue increases. EMG signal will be acquired from clinical database. Signal generated the main muscles during particular task will be analysed for fatigue assessment. In recent research paper many EMG indices have been suggested and compared in muscle fatigue assessment, including root mean square (RMS), the median (MF), and mean power frequencies (MPF) based on Fourier Transform. Feature obtained from the signal is given to Classifier which is identified category or class Label of EMG signal, two different class labels used is Fatigue and non-fatigue.

Keywords: Muscle Fatigue Analysis, Electromyography, Support Vector Machine (SVM), K-nearest Neighborhood (KNN)

I. INTRODUCTION

Muscle fatigue is a condition in which muscle' ability to perform decreases over time. It is a common non-specified health symptom experienced by many people and is associated with many health conditions. It is associated with a state of exhaustion, often following strenuous activity or exercise. When fatigue is experienced, the force behind the muscles' movements decreases resulting a neuromuscular symptom in which the muscle fails to maintain the required or expected force. To overcome this problem Electromyography is used. To evaluate and record the electrical activity produced by the skeletal muscles, Electromyography commonly known as EMG technique is used. When muscle cells are electrically or neurologically activated, the electrical potential generated by muscle cell is detected by an EMG.

Electromyography (EMG) recordings can be divided into two types depending on the place of the recording electrodes; if the electrodes are placed on the skin, the procedure is considered surface electromyography (sEMG), and if the electrodes are inserted in the muscle, it is referred to as intramuscular electromyography. The results obtained from both techniques may differ in some aspects. For example, the evolution of the amplitude of the recording during fatigue differs because the

RMS value of intramuscular EMGs decreases, whereas the RMS of the sEMG increases. Both these techniques are useful for studying muscle fatigue. The invasiveness of the Intramuscular EMG results in discomfort of the subject, therefore surface EMG is more preferred.

In this work, surface electromyography is performed for analysing muscle fatigue. Due to the non-invasiveness and real time applicability surface EMG or sEMG is widely used for muscle fatigue diagnosis, sEMG signal is a non-stationary and weak bioelectrical signal and is ranges from 20Hz to 500Hz. EMG signals contains motor unit action potentials (MUAPs) from several Motor Units (MU). The characteristics and shape of the motor unit action potential (MUAPs) is affected with the changes in neuromuscular diseases. For the classification of fatigue muscle and non-fatigue muscle, the DWT based feature extraction scheme is used in this procedure. The DWT of the dominant motor unit action potential (MUAP) gives the statistical features. SVM is used as base classifier for designing the multi classifier. The base classifiers consist of different kinds of classifiers such as adaptive certainty-based, the adaptive fuzzy k-NN, and the adaptive matched template filter classifiers. here in this work the K-nearest neighbourhood (KNN) is employed. The comparative analysis of EMG signals presents the experimental result for muscle fatigue analysis.

II. METHODS AND MATERIAL

2.1 Signal Acquisition and Pre-processing

The EMG signals obtained from the sensor contains noise or unwanted electrical signal. It is important to filter the signal taken from EMG sensor to attenuate unwanted electrical signal. First of all, the EMG signal of 10Hz to 3KHz is filtered by a band pass filter in MATLAB. The filtered signal contains inactive and active segments with motor unit action potentials (MUAPs). For the extraction of MUAPs around this inactive segment, window function is used. The threshold parameter ($\pm\lambda$) is been set around baseline of the sample between $+\lambda$ and $-\lambda$ for removing the inactive segment. At the identified peak of MUAPs, a window of 180 sampling points is centered where the size of window depends on the sampling rate. Depending upon the temporal energy of the dominant MUAP, MUAPs is been extracted from the EMG signal. When the dominant MUAPs for different datasets are acquired then they are used for the feature extraction.

2.2 Feature Extraction

Feature extraction converts the input data to a set of features for extracting the information relevant from the data. The changes in EMG parameters shown by the sEMG signal analysis helps to detect muscle fatigue. The morphological features of the MUAPs for the Time Domain extraction used for visual assessment.

2.2.1 Time and frequency domain analysis

The obtained signal is analyzed in time domain where the amplitude/voltage of signal is represented as a function of time. The frequency of signal having greater value should be analyzed using frequency domain. The morphological features for representing each MUAP are as follows:

1. Within the main spike, rise time between the positive peak to the negative peak.
2. Ratio of Peak to Peak magnitude to RMS value
3. From first to the last positive peak, the spike duration.
4. ascending to descending slope positive spike of MUAP.
5. Positive to negative area of spike MUAP.
6. Phases: The number of baseline crossings where amplitude exceeds ±25 µV, plus one.
7. Thickness: The ratio of the area to the peak-to-peak amplitude.

8. Total samples between the minimum positive and the maximum negative peak called as peak-to-peak samples number.

2.2.2 DWT Based Feature Extraction

The wavelet transform decomposes signal into number of multi resolution components using wavelet function. The detection and classification of short time component within a non-stationary signal is performed using this function. For extracting the features from EMG signal, DWT is used because this technique offers localisation in both time and frequency.

Number of 'Mother Wavelets' are used for the purpose of signal decomposition. The properties of wavelet function and characteristics should be matched so that the most appropriate mother wavelet is selected for the particular application. Db4 is suitable for the signals using feature extraction with more than 4 samples.

2.3 feature selection

It is important to ensure the selected features should contain class relevant information as most features does not include such information. Therefore, feature selection is used for selecting the features of the required information. To enhance the comprehension of the produced classifier model, feature selection creates a model of generalised unseen dimensions. Feature selection is categorized into two types such as the wrapper approach and filter approach.

The evaluation of most optimal feature or sub-set is carried by the wrapper approach. This model is widely used in machine learning for improving the performance of the classifier. When classifier cannot be directly linked with the data set then the filtering approach is employed. It is linked with the data mining where data reduction is required.

2.4 Classification

In solving the statistics and computational problem where the individuals are grouped according to their characteristics, classification methods are used. In this method individuals having same characteristics are labelled in the same sets. There are many ways for classifying the sEMG signals. One of the popular methods is to measure the Euclidean distance among the waveform and MUAP.

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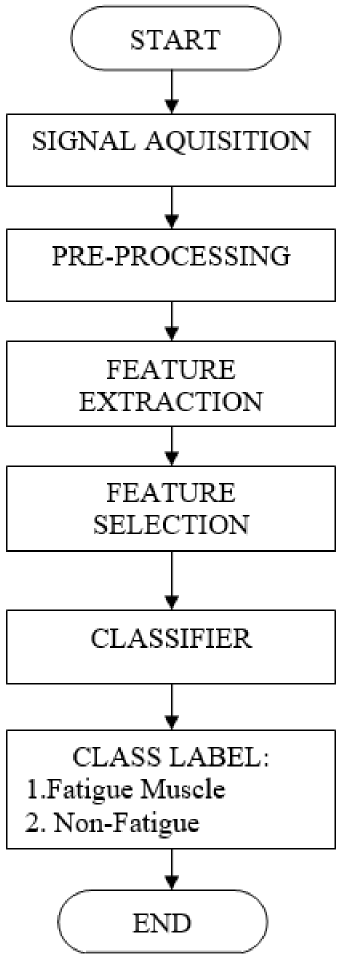

Multi-Classifiers Majority Voting (MCMV) classification strategy is used in the presented work. It contains two groups parallel to each other. The two non-parametric methods, k-nearest neighbour (kNN) and support vector machine (SVM) are used for classifying the signals of fatigue and Non-fatigue conditions. Using the predefined MATLAB functions, the classification is performed. The built in MATLAB function with radial basis function kernel is used for performing the classification with SVM. For better accuracy, all other parameters must be set to default.

III. RESULT AND DISCUSSION

It is seen that in the same class, the classification accuracy is high. In all the groups, the second highest accuracy for base classifier is taken from classification strategy one against all class label. For time-frequency feature, the multi-classifier provides an average accuracy of 97% whereas WKNN classifier achieves the accuracy of 95%. The data of 100 EMG signal, with 50 samples each has been tested for both the classes. The use of window function gives simple approach for MUAPs extraction. By removing the inactive region segmentation of EMG is carried out. The time and time-frequency domain selects the dominant MUAPs for feature extraction. The time domain feature fails to map spectrum behaviour therefore the time-frequency domain feature is selected. A number of changes occurring at both central and peripheral level are represented by the muscle fatigue phenomenon.

IV. CONCLUSION

This review paper focuses on classifying MUAPs into fatigue and non-fatigue class. Several base classifiers such as time domain features, time-frequency features are used for taking different MUAPs features. The limitation of single stage classifier with complexity and processing time is overcome with Multi-classifier. As it allows to segment big decision into many detailed decisions, this strategy can be used in other pattern recognition applications. This review paper shows that the approach to muscular fatigue diagnosis using sEMG is successful for getting the information about the skeletal muscles. Both types of time-frequency and time domain features gives promising results (97%) for the two classes. This research can be further extended if the influence of recording conditions on the classification accuracy is investigated.

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