Muscle fatigue detection in EMG using SVM

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Abstract- In this work, we present the design of a system implemented in Matlab for the detection of muscle fatigue. it is an effect on the muscles of the human body that produces inability or lack of strength to carry out a physical activity. For the detection of this disability, support vector machines (SVM) are used for the classification process, the acquisition, analysis, and classification of electromyographic signals is performed. The tests were performed on one hundred test subjects, analyzing characteristics in the signals in the time and frequency domains. The results show a high correlation (90%) between the indicators of sensitivity, specificity and accuracy of the classifiers in the detection of muscle fatigue in the designed system contrasted with the moment in which the test subjects indicated lack of strength to carry out a physical activity.

Keywords – EMG, Principal Component Analysis–PCA, Support Vector Machines–SVM, Matlab®.

I. Introduction

Muscle fatigue is a non-voluntary and unexpected attenuation due to exhaustive muscle work, without considering the loss of strength due to damage or factors that are not related to muscle activation [1]. Muscle fatigue can be estimated by different methods. Some are by measuring blood lactate level, blood oxygen levels, muscle pH, and electromyogram (EMG) [2]. The EMG is a method of recurrent use by high-performance athletes because it is easy to measure and it is possible to analyze in real time.

In [2], surface EMG is used to detect fatigue and the recovery process objectively. The muscle fatigue characteristic makes the transition from the high frequency spectrum to the low frequency spectrum and amplitude increases. In the experiment they used weights of 8 kg and 6 kg as load, and measured surface EMG of the biceps brachii and triceps brachii. The movement used was the dumbbell curl.

Some works such as [3], different indicators of muscle fatigue were studied from the electrical signal produced by the muscles when contracting, such as mean frequency of the power spectrum, mean frequency, Dimitrov spectral index, mean square root and zero crossings. They selected the most reliable features to develop a detection algorithm to calculate muscle fatigue. The developed system is divided into two processes, training, and validation. During training, the algorithm learns the distribution of data regarding the evolution of fatigue, then the algorithm is validated with data that has not been used for training. By studying the characteristics of surface EMG signals, strength can be predicted, human movements recognized, and muscle disorders diagnosed effectively. Systems for studying EMG signals are widely used in rehabilitation medicine, artificial limb, prosthetic control, and other fields [4].

In [4] a four-channel wireless EMG acquisition system is designed with high precision, low latency, portable, lithium battery and wireless data transmission. The noise interference from this system is small, has a high SNR that prevents interference, and can provide EMG signal processing with a suitable platform.

Work presented in [5], develops a low-cost EMG signal acquisition system with two-channel input applied to physiotherapy. In the acquisition system, both input signals are amplified with a differential amplifier and pre-processed by the signal to obtain the linear envelope of the EMG signal. The obtained EMG signal is digitized and sent to the computer for tracing.

In [6] the design of a multichannel EMG signal acquisition system is shown, using the least number of electronic components to avoid noise. A set of electrodes are used for differential acquisition and two references to reduce the area and noise of the set. The system is 16 channels and is connected through a microcontroller USB interface for data storage. Each unique acquisition channel is made up of a buffer, a preamplifier, and filters. These provide a low-cost acquisition stage as well as a low noise system that retains information at a frequency of 50 Hz. Their application is for the measurement of specific arm and forearm movements at the same time.

In [7] a comparative analysis is performed between the SVM and K-Nearest-Neighbor (KNN) classifier for the classification of signals using elementary time domain characteristics such as mean absolute value, mean square value, simple square integral, wavelength, average amplitude change, difference from absolute value of standard deviation and log detector. In this work, we present a novel design of an implemented system for the detection of muscular fatigue that uses the training of vector support machines to be used in used in amateur athletes and high-performance athletes.

II. Methodology

The designed system is implemented in Matlab, performing the acquisition of electromyographic signals, filtering of the signals, segmentation of the EMG signals, creation of a matrix of characteristics, reduction of dimensionality and classification of the signals to determine if they correspond to an EMG signal with presence or not of muscle fatigue.

2.1 EMG signal acquisition

To acquire electromyographic signals from the arm muscles of 100 test subjects, the g.MOBIlab + device manufactured by [8] is used, because this equipment has within its intended functions. The acquisition of surface EMG signals in humans for research purposes, considering the characteristics documented in Table 1.

Table -1 g.MOBIlab + device features.

Electrodes type	**Actives**	**-**
Dispositive type	**Wireless**	**-**
Rate Wireless Data Transmission	**Bluetooth 2.0**	**-**
Nominal Voltage	**3**	**V**
Nominal Power	**0.18**	**VA**
Channels In	**8**	**-**
Sensibilization (min)	**+/- 500**	**μV**
Sensibilization (max)	**+/- 250**	**mV**
Bandwidth	**0.5 – 100**	**Hz**
Sample frequency	**256**	**Hz**
Resolution	**16**	**bit**

The acquisition of the input signal was carried out by recording with the electrodes of the g.MOBIlab + device on the biceps of the 100 test subjects, in 10 sessions of 100 seconds, performing bicep curls. The basic exercise is to lift a 10 kg weight, by hand as shown in Figure 1. Each recording per test subject was performed on different days, 1 recording of EMG signals per subject each day.

2.2 Filtering signals

Two Butterworth filters of order 4 are used. A band reject filter is designed to eliminate 60 Hz electrical noise from the public power grid. Subsequently, 1 bandpass filter is designed between 10 Hz and 100 Hz to eliminate motion artifacts and filter the relevant information from the electromyographic signals (See Figure 2).

Figure 1. Acquisition of signals in biceps curl method.

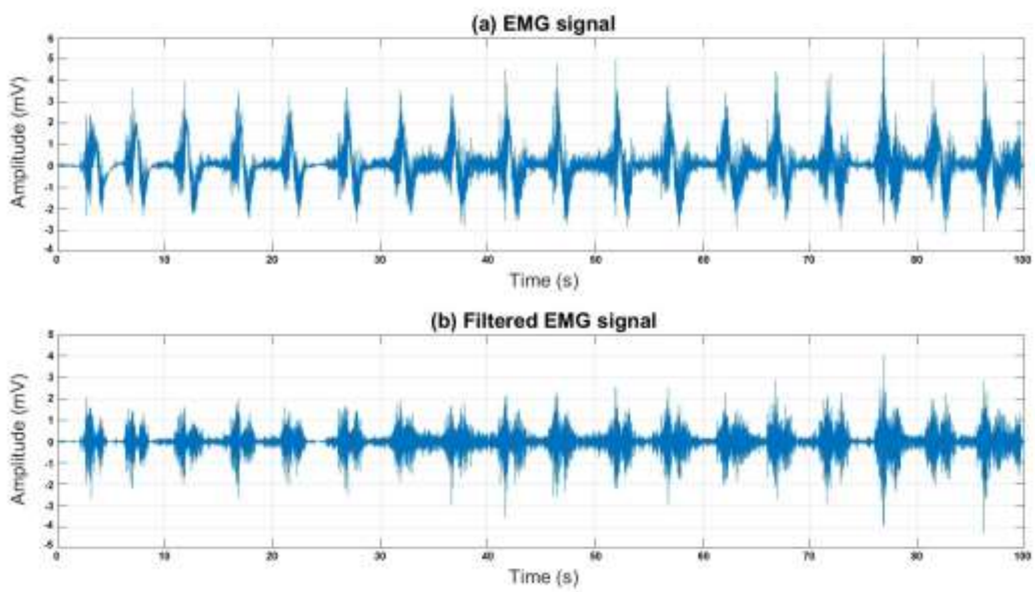

Figure 2. (a) Original and (b) Filtered EMG signals.

2.3 Segmentation

Since it is identified that in 99% of the recorded EMG signals, the events generated by a flexing exercise with the biceps are framed in 5-second windows, they proceed to segment the signals in windows of this period of time, to analyze the characteristics of each generated event.

2.4 Characteristic matrix

In order to create a matrix of signal characteristics, a Continuous Wavelet Transform was initially performed in order to analyze the signals in both the time domain and the frequency domain, to identify changes in characteristics of signals when muscle fatigue appears, by means of amplitudes, thresholds, time of occurrence and frequency bands as shown in Figure 3.

To create the characteristic matrix, the maximum amplitude, minimum amplitude, RMS voltage, peak-to-peak voltage, average voltage, average and standard deviation of the frequency are taken into account in each 5-second segment. That is generated for each window containing the events of the EMG signals by an exercise with the biceps.

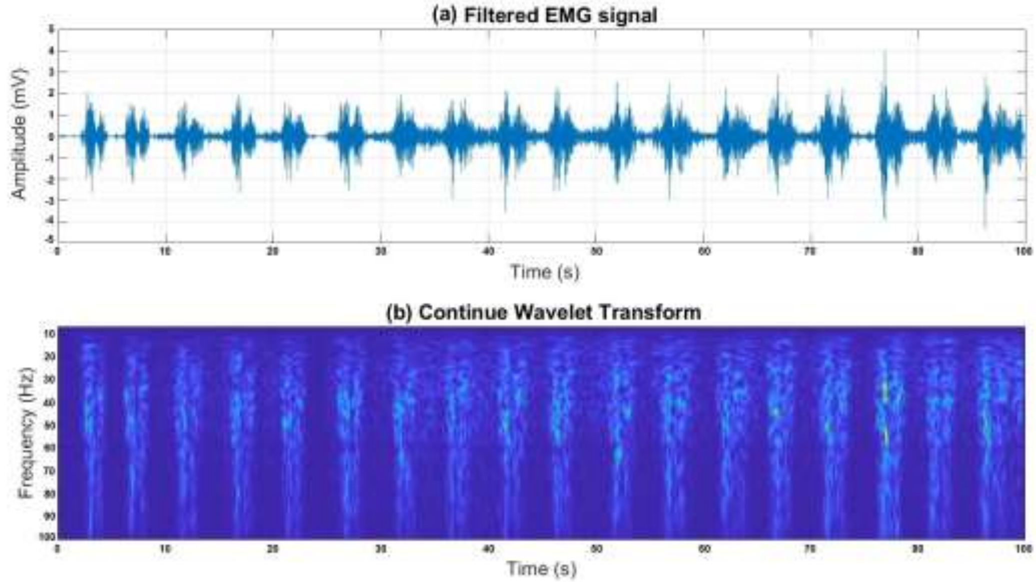

Figure 3. (a) Filtered EMG signal. (b) Identification of Characteristics of EMG Signals.

2.5 Dimensionality reduction

Using Principal Component Analysis (PCA), q2 components of the 7 defined characteristics are determined. Thus, it is possible to analyze the EMG signals by performing a non-linearly correlated principal dimensionality reduction. It is possible to appreciate the order by the variance described by the components in Figure 4.

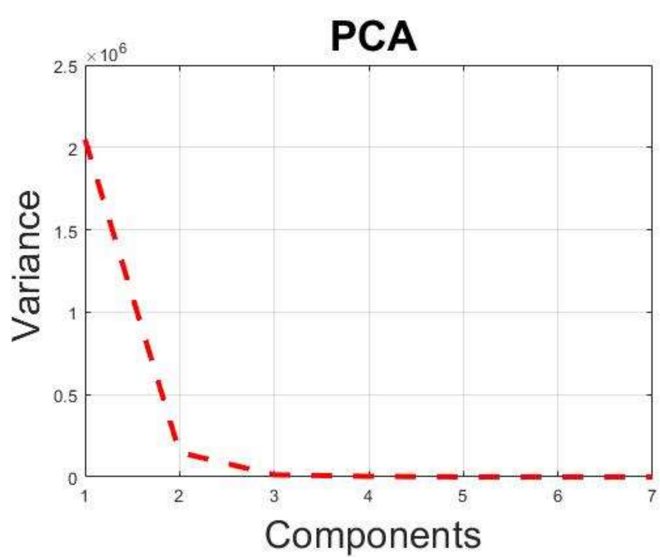

Figure 4. Principal component analysis

2.6 Classification

To carry out the EMG signal classification process, the component matrix resulting from the dimensionality reduction process is taken using Principal Component Analysis (PCA) [9][10]. Subsequently, a Vector Support

Machine (SVM) is implemented for each of the test subjects, each of the SVMs was trained using 70% of samples for training and 30% for evaluation.

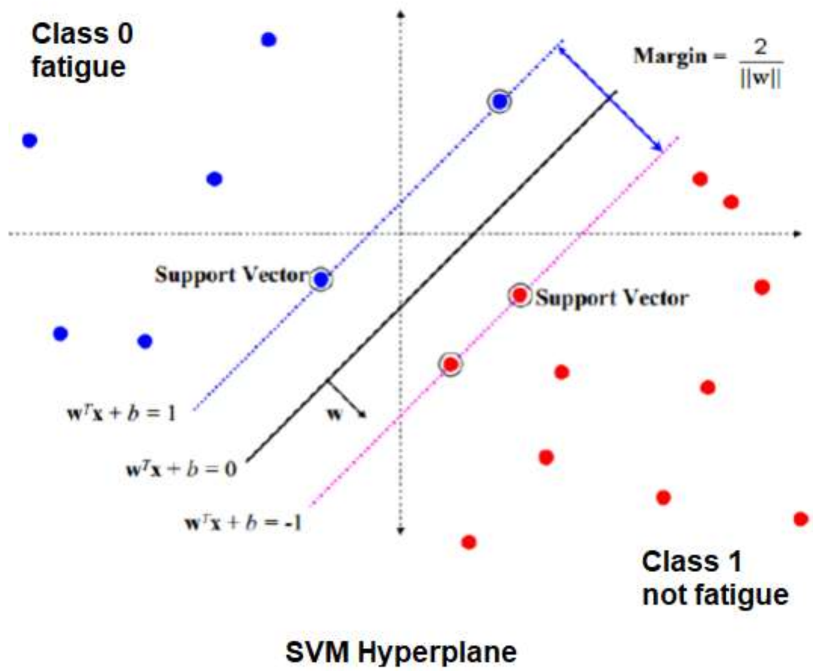

Figure 5. SVM hyperplane [9].

2.7 Experiments

The experiments designed to evaluate the classification system implemented for the detection of muscle fatigue consist of storing EMG signals using the g.MOBIlab + device with its electrodes connected on the biceps of each of the 100 test subjects. Then, the signals are sent to the computer where the Matlab system is implemented. For each test subject, for 10 days, signals were recorded in 10 100-second sessions, performing 10 kg bicep curls. To create the signal labels, test subjects were asked to indicate when they felt pain in muscle and inability to exercise or loss of strength.

III. Experiment and Result

For the SVM classifiers created, values of 1 for sensitivity, specificity, and accuracy were achieved for each of the 100 test subjects. The moment of detection of muscle fatigue in the designed system was compared with the moment when the test subjects indicated lack of strength to carry out a physical activity. Finally, with all the recorded EMG signals, a vector support machine was trained, reaching an accuracy of 90% at the time of detecting muscle fatigue.

IV.CONCLUSION

Through the classification of electromyographic signals, it was found that it is possible to detect muscle fatigue, by observing significant changes in the amplitude and RMS voltage of these signals. The Principal Component Analysis is useful to obtain a better performance of the Vector Support Machines in the classification of electromyographic signals to detect muscle fatigue.

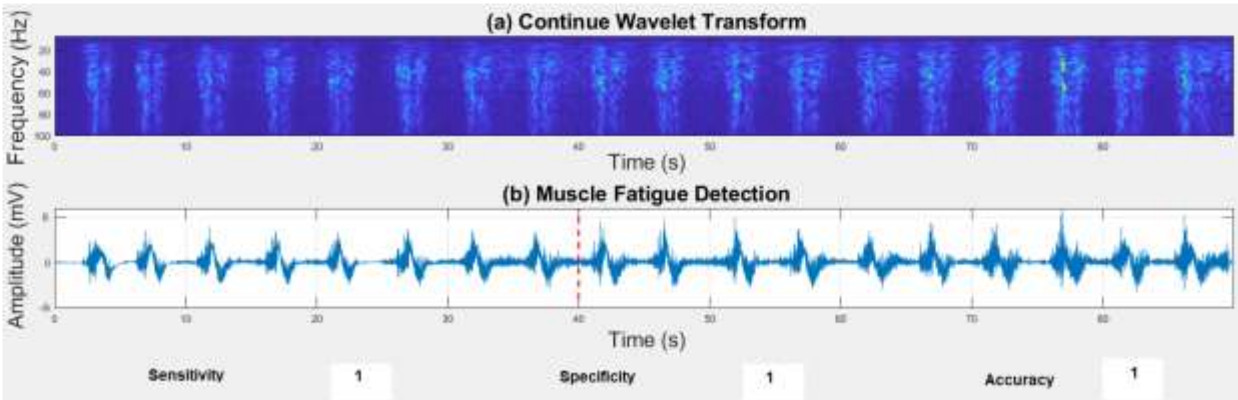

Figure 6. Muscle Fatigue Detection Subject 1

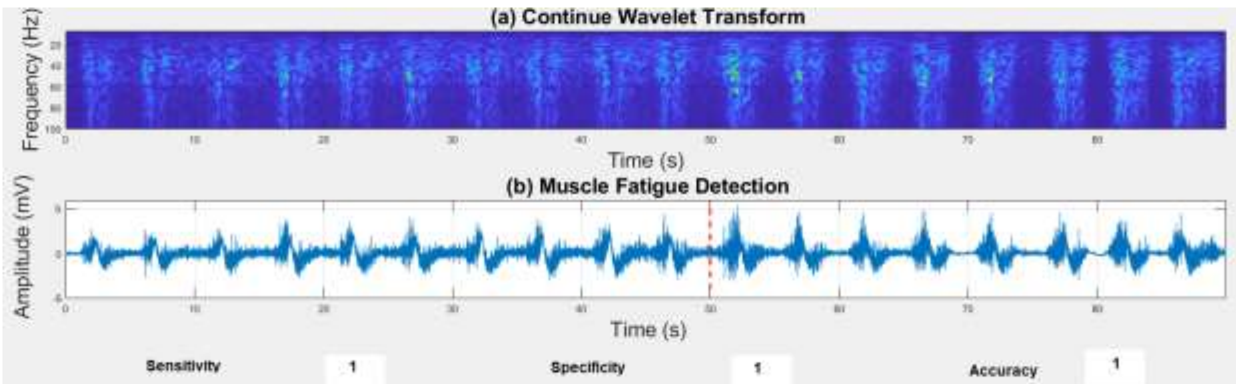

Figure 7. Muscle Fatigue Detection Subject 2

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