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Classification of Electromyogram Using Recurrence Quantification Analysis

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Abstract

Clinical analysis of the electromyogram is a powerful tool for diagnosis of neuromuscular diseases. Therefore, the classification of electromyogram signals has attracted much attention over the years. Several classification methods based on techniques such as neuro-fuzzy systems, wavelet coefficients, and artificial neural networks have been investigated for electromyogram signal classification. However, many of these time series analysis methods are not highly successful in classification of electromyography signals due to their complexity and non-stationarity. In this paper, we introduce a novel approach for the diagnosis of neuromuscular disorders using recurrence quantification analysis and support vector machines.

Electromyogram signals are transformed into recurrence plots and a set of statistical features are extracted using recurrence quantification analysis. Support vector machine employing radial basis functions is used for classifying the normal and abnormal of neuromuscular disorders. Examining the acoustic patterns in electromyogram, we classify the signals into one of the three categories: healthy, neuropathy, and myopathy. The results show that the proposed method classifies these signals with 98.28% accuracy; it is a significantly better accuracy than what has been reported in the literature thus far. The accurate results indicate that proposed diagnosis method of neuromuscular disorders is very effective.

Keywords: Classification; Dynamical System; Electromyogram; Recurrence Quantification Analysis

1. Introduction

There are more than 100 neuromuscular disorders that affect the brain, spinal cord, nerves, and muscles [1]. Neuromuscular disorders are related to pathological changes in the structure of motor units and can be divided into muscular (myopathy) and neuronal disorders (neuropathy). Myopathy is neuromuscular disorders in which the primary symptom is muscle weakness due to dysfunction of muscle fibres [1]. Neuropathy describes damage to the peripheral nervous system which transmits information from the brain and spinal cord to every other part of the body. Myopathy is neuromuscular disorders in which the primary symptom is muscle weakness due to dysfunction of muscle fibres [1].

Motor unit morphology can be studied by recording its electrical activity which is electromyogram (EMG). In clinical EMG, motor unit potential (MUPs) are recorded using a needle electrode at slight voluntary contraction [2].

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A MUP reflects the electrical activity of a single anatomical motor unit. Moreover, they are used to detect and describe different neuromuscular diseases. Therefore, intramuscular electromyogram is commonly used as a diagnostic tool in clinical practice.

Modern electromyogram analysis has been used for some decades. It is focused on signal processing and graphical representation of the signals [3] [4]. In the last decade, many applications were introduced. In 2005, Nihal implemented an artificial neural network to diagnose neuromuscular disorders [3]. His results showed 91.6 - 94.4% classification accuracy. In 2006, Subasi [4] introduced a wavelet coefficient method to classify the EMG signals. In 2010, Sabri [5] introduced a neuro-fuzzy system to classify EMG signals. Its performance showed 83.3 – 90% classification accuracy.

Analyzing nonlinear time series through recurrence quantification analysis has been investigated for many years [6] [7]. To test whether electromyogram is a nonlinear signal or just random noise, we analyze EMG signals of neuromuscular diseases using recurrence plot (see Figure 1). From all the results, we conclude that EMG obeys a certain nonlinear deterministic law and non-stationarity is significant within these signals. It is therefore possible to study and analyze these signals as a non-linear system using recurrence quantification analysis.

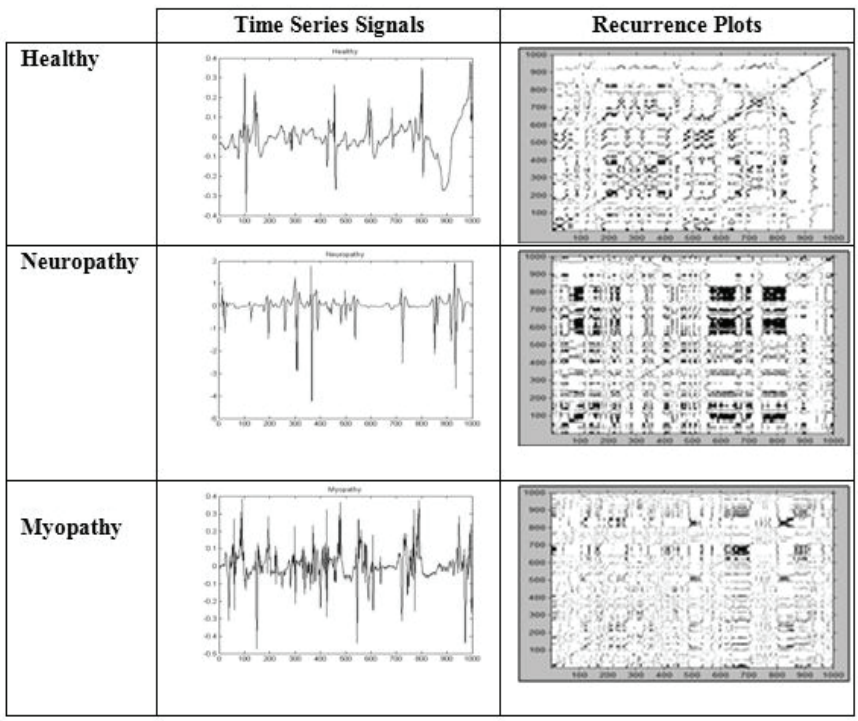

Fig. 1 Electromyogram signals of neuromuscular diseases

In this paper, we introduce a novel diagnosis and classification method for neuromuscular disorders; this method uses recurrence quantification analysis and a support vector machine. Our proposed method is evaluated using electromyogram signals corresponding to three different neuromuscular disorders: healthy, neuropathy, and myopathy. In order to extract their features, we apply recurrence quantification analysis as feature extraction. The classification of neuromuscular disorders is obtained from support vector machine learning. Furthermore, electromyogram signals of myopathy, neuropathy, and healthy subjects are used for analyzing the diagnostic performance of neuromuscular disorders.

2. Recurrence Quantification Analysis

The recurrence statistics, which is called recurrence quantification analysis (RQA), has been introduced for measuring quantitative information within recurrence plots [8]; subsequently it was extended with new measure of