Signal Processing 88 (2008) 2927–2935

Contents lists available at ScienceDirect

Signal Processing

journal homepage: www.elsevier.com/locate/sigpro

Multi-features fusion diagnosis of tremor based on artificial neural network and D–S evidence theory

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ARTICLE INFO

Article history:
Received 30 January 2008
Received in revised form
26 June 2008
Accepted 26 June 2008
Available online 3 July 2008

Keywords:
Tremor diagnosis
Bispectrum
Empirical mode decomposition
Discrete wavelet transform
Back-propagation neural network
D–S evidence theory

ABSTRACT

With respect to three kinds of familiar tremor, including essential tremor (ET), Parkinsonian disease (PD) tremor, and physiological tremor (PT), which are subjected to frequent clinical misdiagnosis, a new fusion diagnosis method for tremor based on multi-features extraction, back-propagation neural network (BPNN), and Dempster–Shafer (D–S) evidence theory is proposed to overcome the clinical misdiagnosis. First the features of hand acceleration signals of subjects with ET, PD, and PT were extracted using bispectrum, empirical mode decomposition (EMD) and discrete wavelet transform (DWT) analysis methods, respectively. Second the resulting features were subsequently recognized by three independent BPNNs, respectively, the outputs of which were further processed and acted as basic probability assignments for tremor. Finally, the basic probability assignments were fused by the D–S evidence theory and decision-making analysis was performed. The experimental analysis results indicate that the accuracy of fusion results of the D–S evidence theory is markedly higher than the independent diagnosis of BPNN. The method proposed in this paper is able to adequately utilize the complementary multi-features information for accurately recognizing tremor types, thus providing practical guiding significance for diagnosing tremor types in clinic.

1. Introduction

Tremor is an involuntary movement characterized by regular or irregular oscillations of one or several body parts [1]. It can be of the physiological or pathological nature. Three types, including pathological Parkinson's disease (PD) tremor, pathological essential tremor (ET), and physiological tremor (PT), are often observed. Head, limb, and voice and even the whole body are affected by tremor, posing severe impact on the work and life of patients. It has been reported that there are 120–180 PD victims and 5000 persons are affected by ET per 100,000 people [2]. Treatment of tremor often depends on types of tremor. At present, the pathogenesis is still not completely disclosed so that the diagnosis of the tremor types depends mainly on doctor's experience, patients' symptoms, etc. The misdiagnosis rate amounts to 15%. In particular, the misdiagnosis rate for PD and ET has been reported to be higher than 25% [3]. Consequently, the accuracy for diagnosing the tremor types based on clinical diagnosis alone is not high enough and hence, it is imperative to perform assistant diagnosis with other methods.

Currently, it has become a very important research technique for the assistant clinical diagnosis to identify the tremor types by extracting feature information from the non-invasive hand acceleration signals or the upper limb electromyogram (EMG) signals. Chwaleba et al. [2] and Engine et al. [4] have extracted feature information from the hand acceleration signals of the PD, ET, and PT subjects with the higher order spectra, wavelet, and linear predication coefficients methods and then conducted

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doi:10.1016/j.sigpro.2008.06.018

classification diagnosis with the back-propagation neural network (BPNN) classifier. Milanov [5] has identified seven types of tremor by using the statistical methods to extract features from the time and frequency domain with EMG signals. Wharrad and Jefferson [6] have employed hand acceleration signals spectra and the *K*-means value clustering analysis to distinguish ET from PT. While these methods have quantitatively processed the tremor types and got relatively satisfactory results, the diagnosis results are limited because the feature extracted methods all have the same information expression limitation. In Refs. [2,4], the neural network structure is inevitably made complicated and the diagnosis results are limited as much feature information is input into the independent BPNN identification diagnosis simultaneously. In addition, as the PD and ET pathology are complex and there are similar clinical manifestations, the ability to accurately diagnose tremor is limited. As a result, only by making the diagnosis analysis to extract multiple features from many aspects and by fusing them with many independent BPNN structures can the more effective and reliable diagnosis of tremor types be realized.

In this study, we proposed to extract features by using various methods to analyze the hand acceleration signals of the subjects, to use the BPNN diagnosis results as the belief function, and to fuse the BPNN diagnosis results with the Dempster–Shafer (D–S) evidence theory in order to realize the fusion diagnosis of the PD, ET, and PT tremor types. Fig. 1 shows the multi-features fusion diagnosis flow chart of the hand tremor acceleration signals based on BPNN and the D–S evidence theory. The fundamental consideration is as follows. First, acquire the hand acceleration signals of the voluntary subjects. Extract the features using the methods like bispectrum, empirical mode decomposition (EMD), discrete wavelet transform (DWT), etc. Obtain the classification results of three types of tremor by inputting the features to independent BPNN. Fuse the neural network diagnosis results of three types of tremor. The purpose of doing the above is to achieve more important, accuracy, and reliable diagnosis results of tremor types, to form a basis to make satisfactory clinical decision.

The paper is organized as follows. Section 2 introduces the acquisition and preprocessing of hand tremor acceleration signals. Section 3 describes the features of hand acceleration signals of voluntary subjects. The features are extracted by bispectrum, EMD and DWT analytic approach, respectively, and diagnosed by the independent BPNN, respectively. Section 4 introduces the D–S evidence theory. Section 5 presents the experimental results and discussion, followed by conclusions in Section 6.

2. Acquisition and preprocessing of hand tremor acceleration signals

Forty voluntary subjects participated in the experiment. Ten of them were ET subjects (7 males and 3 females in an age group from 29 to 80 years), 15 of them were PD subjects (10 males and 5 females in an age group from 27 to 74 years), 15 of them were PT (10 males and 5 females in an age group from 27 to 74 years). All subjects were diagnosed before the experiment. The PD and ET patients came from the clinical department of neurosurgery of Xi'an Tangdu Hospital. The PT recruits were patient family members.

The subject was asked to sit comfortably in a chair with backrest with the two feet resting on the ground. The sensor was fixed to the middle finger of the tremoring hand of the subject. To acquire the tremoring acceleration signals of the hand, the subject was required to extend the arm straightly, keeping it parallel to the ground at a 90° included angle with the shoulder, and making the palm face downward. A block of three acquisition trials in total was recorded. The duration of each acquisition trial was 60 s.

The hand tremor signals were registered by an MMA7260Q 3-axis low-g accelerometer of Freescale at first, then were amplified, filtered and converted to the digital form in the analog–digital (A/D) converter and finally saved on the computer with a ASCII formatting. The sampling frequency was 512 Hz. When acquiring actual signals, the sampling frequency was reduced to 128 Hz, and the signals were subjected to the normalization treatment by making 10 s data of the *z*-axis signal perpendicular to the ground act as a data segment, causing each person to find four data segments with 160 sets of data segments from 40 subjects for the analytic purposes.

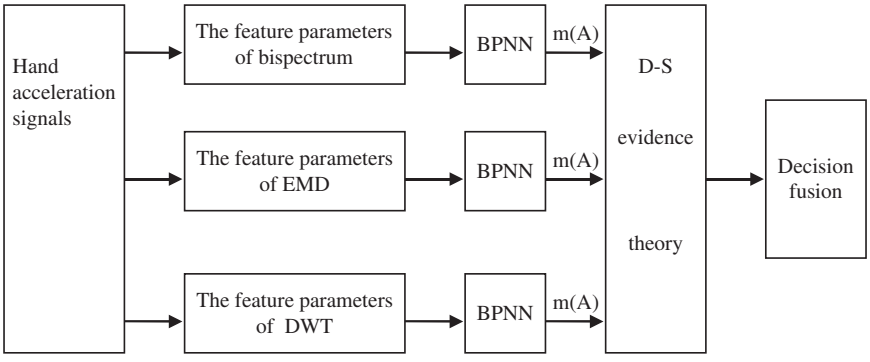

Fig. 1. A graphical overview of hand tremor acceleration signals diagnosis based on BPNN and D–S evidence theory.