journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Neural network and wavelet average framing percentage energy for atrial fibrillation classification

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ARTICLE INFO

Article history:
Received 13 July 2012
Received in revised form
7 December 2013
Accepted 9 December 2013

Keywords:
Average framing
Wavelet
Percentage energy
Atrial fibrillation
Probabilistic neural network
Noise

ABSTRACT

ECG signals are an important source of information in the diagnosis of atrial conduction pathology. Nevertheless, diagnosis by visual inspection is a difficult task. This work introduces a novel wavelet feature extraction method for atrial fibrillation derived from the average framing percentage energy (AFE) of terminal wavelet packet transform (WPT) sub signals. Probabilistic neural network (PNN) is used for classification. The presented method is shown to be a potentially effective discriminator in an automated diagnostic process. The ECG signals taken from the MIT-BIH database are used to classify different arrhythmias together with normal ECG. Several published methods were investigated for comparison. The best recognition rate selection was obtained for AFE. The classification performance achieved accuracy 97.92%. It was also suggested to analyze the presented system in an additive white Gaussian noise (AWGN) environment; 55.14% for 0 dB and 92.53% for 5 dB. It was concluded that the proposed approach of automating classification is worth pursuing with larger samples to validate and extend the present study.

1. Introduction

The electrocardiogram (ECG) is the electrical activity signal of the working heart which is very important in analyzing heart disease because every arrhythmia in ECG signals can be related to a variety of diseases of the heart. The main challenge in diagnosing heart disease using ECG is that the normal ECG may differ for each person and consequently one disease may show dissimilarly from one patient's ECG to the next. Furthermore, two distinct diseases may have almost identical effects on normal ECG signals. These obstacles complicate heart disease identification. Therefore, utilization of pattern classifier techniques can improve new patients' ECG arrhythmia diagnoses [1].

Atrial fibrillation (AF) has in recent years been the subject of intense investigation, namely in the context of obtaining a better understanding of its mechanism and improving its management. It is the most commonly experienced cardiac arrhythmia, occurring in 1–2% of the overall population. Over 6 million Europeans suffer from this arrhythmia, and its prevalence is estimated to at least double in the next 50 years as the population ages and average life expectancies continue to increase. AF is an arrhythmia in which electrical activity in the atria is disorganized. Instead of the sinus node providing normal electrical signals to the atrium, fast circulating waves of abnormal electrical signals continuously excite the atrium. The atrial rate may exceed 400 beats per minute. In AF, electrical signals from the atrium regularly bombard the AV node. The AV node passes on a large number of these rapid signals

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http://dx.doi.org/10.1016/j.cmpb.2013.12.002

to the ventricles which, therefore, beat rapidly and irregularly. The ventricular rate may vary from 50 to 200 beats per minute depending on the level of AV conduction [41,42]. Actually, the overall ventricular rate varies enormously depending on the age of the patient, the health of the AV node, and whether medications such as calcium-channel blockers or beta blockers are present to slow AV conduction [2,3]. Three common atrial fibrillation cases have been clinically diagnosed. The first case is paroxysmal atrial fibrillation, which is a self-terminating arrhythmia that persists for less than one week. The second case is known as a persistent atrial fibrillation when the arrhythmia continues for more than one week. Permanent atrial fibrillation occurs when the arrhythmia has been persisting for more than 1 year [37–39]. Scientists who previously tried to detect AF mostly utilized time-frequency analysis techniques, statistical tools and sequential analysis methods. For instance, Stridth et al. have performed time-frequency analysis to produce trends of AF frequency. The Wigner–Ville distribution technique and Choi–Williams distribution were used for short-term and long-term time-frequency analysis. They have found that chronic AF has time varying characteristics [4]. Tateno et al. have analyzed AF in order to detect the AF based on RR intervals. Their method utilizes standard density histograms and test density histograms of RR intervals and the time difference between successive RR intervals. When two histograms are not significantly dissimilar from each other, the ECG is classified as AF [5]. Further work on detection of AF was conducted by Christov et al. [6]. They employed sequential analysis to check for the absence of a P wave, existence of ventricular arrhythmia and atrial activity. Stridth and Sornmo have tried to distinguish AF based on time-frequency distribution of the QRST canceled ECG signals (after QRST waves elimination to get a P-wave only) [7]. Data regarding temporal variations in fibrillation frequency and waveform shape was extracted and explored. Cerutti et al. examined the dynamics of RR intervals in normal SR and AF ECGs by using parameters resulting from autoregressive modeling and corrected conditional entropy methods [8]. Guler et al. proposed an ECG beat classifier using the Physiobank database and combined artificial neural network (ANN) model, with a higher accuracy that reached 97%, better than the use of a stand-alone neural network model [9,3]. ANN is a famous classifier that may be used for the classification of ECG arrhythmias. Multilayer perceptron (MLP) is introduced to more accurately recognize and classify ECG signals as compared to other ANN methods. Still, MLP with backpropagation (BP) training algorithm suffers from slow con-vergence to local and global minima and from random settings of weights and initial values [10]. Progress of ANN's performance has been the subject of intense research on ECG arrhythmias classification. Several groups have accomplished this using various feature extraction techniques. For example, Ozbay et al. compared the competence of fuzzy clustering neural network architecture with multilayered perceptron in addition to backpropagation training algorithm for classification of arrhythmias. The study proved the superiority of the presented system in terms of the classification time which is a result of decreasing the number of segments by grouping similar segments in training data with fuzzy *c*-means clustering [3]. Discrete wavelet transform (DWT) is used to improve the quality of MLP with (BP) training algorithm comparing with other feature extraction algorithms and data reduction methods [11]. Many researchers have combined the MLP neural network with DWT for better accuracy [12]. Instead of an ECG beat classification system based on DWT, a probabilistic neural network (PNN) is proposed to differentiate six ECG beat types [13]. The ECG recordings were treated by means of wavelets in an effort to predict the maintenance of sinus rhythm after cardioversion in patients with detected atrial fibrillation [14,1]. Several classic methods of system analysis have been used to morphologically classify the P-wave. Both ANN [15,20], and system modelling [16] have shown to be superior over conventional frequency domain and signal-averaged ECG methods (achieving an accuracy of about 85%). In the study [19], authors found good reasons for examining the effectiveness of a wavelet-linear discriminant analysis P-wave classification system. First, while the use of wavelets for analysis and classification of biomedical signals, including some components of the ECG are well documented [17,18], wavelet analysis specifically of the P-wave has not received much attention. Wavelet Transforms (WT) in its three forms; discrete, continuous (CWT) or packet (WP), offer a significant information-rich parameterization method for data reduction of the ECG time-series. Secondly, neural networks functionally different from linear discriminant analysis (i.e. those with a hidden layer) require large samples due to the large number of parameters to be estimated. This is often not practical. Third, unlike model-based approaches, linear discriminant analysis is relatively assumption free. The results for the individual P-wave approach generally outperformed the standard cardiological measures and the signal-averaged P-wave approach.

In this paper, the AF classification system is studied in the context of recognition rate for the noisy environment. This work studies several methods for improving arrhythmias diagnosis systems [21]. Our intent is to examine the performance of AFE technique utility for AF arrhythmia classification. For this reason, many techniques such as feature fusion with DWT or Shannon entropy are investigated. For the structure of this paper, we present the wavelet packet transform feature extraction method followed by classification techniques. The results and discussion will then be presented followed, finally, by the conclusion.

2. Wavelet packet transform feature extraction method

The wavelet packet is used to extract additional features to guarantee a higher classification rate. In this study, WPT is applied at the stage of ECG feature extraction, but these data are not proper for classification due to a great amount of data length (for example, an ECG signal with a number of 2300 samples will reach 4602 after WPT decomposition at level two). Thus, we have to seek a better representation of the speech features. Avci et al. [26] proposed a method to calculate the entropy value of the wavelet norm in digital modulation recognition. In the biomedical field, Behroozmand and Almasganj [21] presented a combination of genetic algorithm and wavelet packet transform used in the pathological evaluation, and the energy features are determined from a group of