Biomedical Signal Processing and Control 25 (2016) 12–23

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

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

A new personalized ECG signal classification algorithm using Block-based Neural Network and Particle Swarm Optimization

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ARTICLE INFO

Article history:
Received 20 April 2015
Received in revised form 23 August 2015
Accepted 27 October 2015
Available online 18 November 2015

Keywords:
Block-based Neural Network (BbNNs)
Particle Swarm Optimization (PSO)
Electrocardiogram signals (ECG)
Patient specific
ECG signal classification

ABSTRACT

The purpose of this paper is the classification of ECG heartbeats of a patient in five heartbeat types according to AAMI recommendation, using an artificial neural network. In this paper a Block-based Neural Network (BBNN) has been used as the classifier. The BBNN is created from 2-D array of blocks which are connected to each other. The internal structure of each block depends on the number of incoming and outgoing signals. The overall construction of the network is determined by the moving of signals through the network blocks. The Network structure and the weights are optimized using Particle Swarm Optimization (PSO) algorithm. The input of the BBNN is a vector which its elements are the features extracted from the ECG signals. In this paper Hermit function coefficient and temporal features which have been extracted from ECG signals, create the input vector of the BBNN. The BBNN parameters have been optimized by PSO algorithm which can overcome the possible changes of ECG signals from time-to-time and/or person-to-person variations. Therefore the trained BBNN has an unique structure for each person. The performance evaluation using the MIT-BIH arrhythmia database shows a high classification accuracy of 97%.

1. Introduction

Electrocardiogram (ECG) signals show the electrical activities of heart using some electrodes which are connected to special points of body. Some of these electrodes apply electrical signals and some of them readout the output signal. Any change in the appearance of the signal might show a heart disease. Medical specialist just can see these appearances but in some cases, two signals have similar patterns but show different diseases (Fig. 1(a) and (b)), and in some other cases, two signals have different patterns but indicate the same disease (Fig. 1 (a) and (c)). In these cases medical specialist cannot easily diagnose the diseases. Therefore only using the ECG signals appearance is not an accurate approach to detect the possible diseases. Using another features of these signals might be helpful to detect the diseases. A number of ECG signal feature extraction methods have been presented in the literature such as morphological features [1], heartbeat temporal intervals [2], frequency domain features [3], and wavelet transform coefficients [4,5]. Only for a day, ECG records are composed of thousands of heart beats and it is extremely difficult for medical experts to follow all the signals to detect the possible diseases. Therefore we need an automatic monitoring system which can follow and study all these heart beats very fast. Linear discriminant analysis [6], support vector machines [7], artificial neural networks (ANNs) [8], mixture-of-experts method [9], and statistical Markov models [10] are examples of the methods for studying and classification of the heart diseases that have been proposed in the literature.

Artificial neural networks by mimicking brain function are one of the powerful tools for automatic diagnosing the disease. ECG signals vary significantly for different individuals (because of gender, age, etc.) [11]. Also some physical conditions cause ECG signals to change for the same individual over the time. Therefore because of dynamical nature of ECG signals, a fixed structure ANN cannot be used.

In this paper an artificial neural network is used which its parameters (structure and internal configuration) are modified based on the changes of ECG signals. For designing an artificial neural network, two issues must be considered. First issue is optimization of the structure and corresponding weights, simultaneously. Another issue is hardware implementation of ANN. For tackling with these issues we have used a Block-based Neural Network [12] that has been trained using Particle Swarm Optimization (PSO) algorithm [13,14]. The internal weights and overall structure

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http://dx.doi.org/10.1016/j.bspc.2015.10.008
1746-8094/

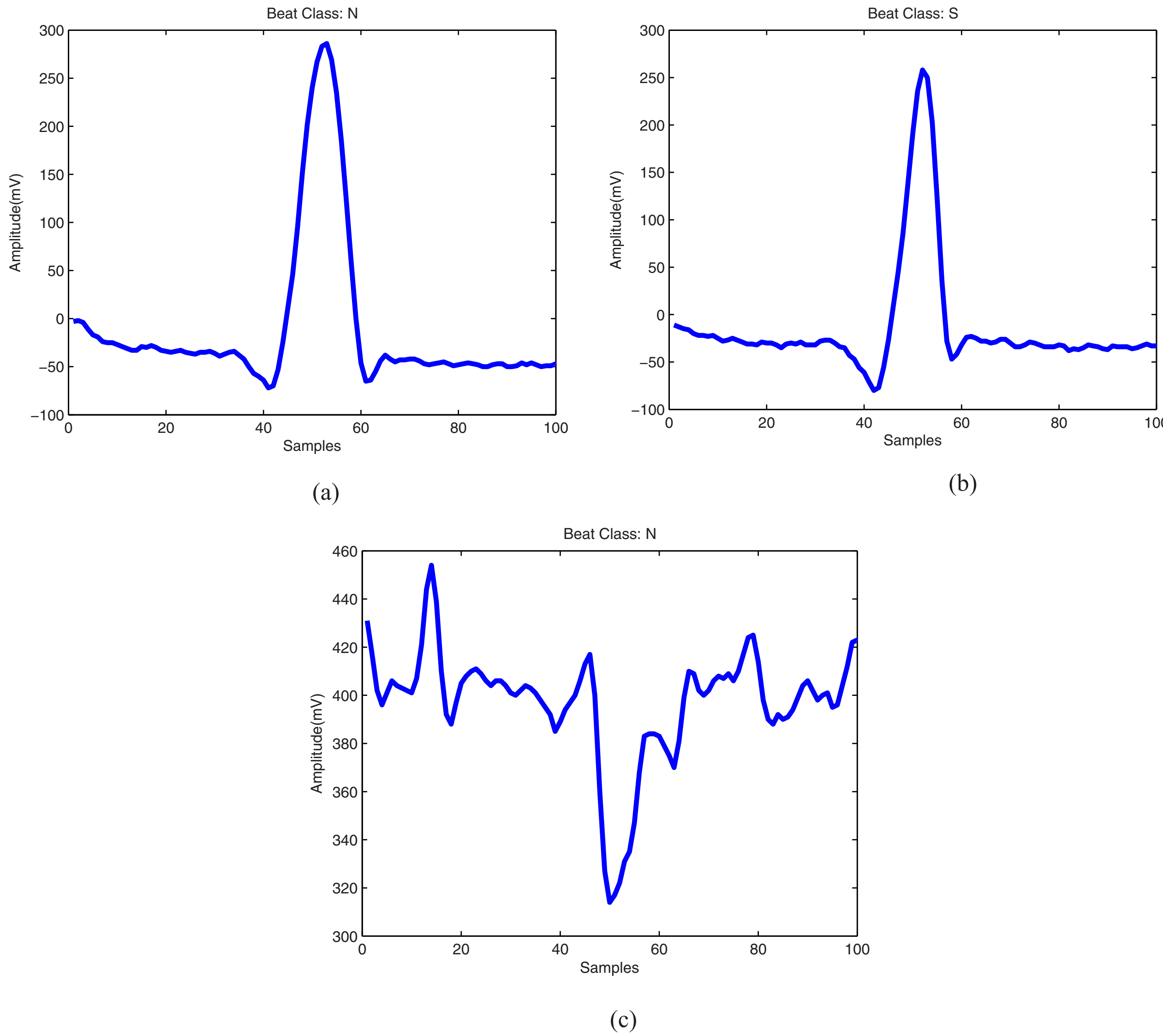

Fig. 1. Examples of AAMI beat classes from MIT-BIH Arrhythmia database: (a) Class N (beat #1 of record 100), (b) Class S (beat #8 of record 100), and (c) Class N (beat #1 of record 108).

of BBNN can be represented by a vector. Therefore by using this method the network structure and the weights can be optimized simultaneously.

In this research, Particle Swarm Optimization (PSO) algorithm is used for training and optimization purposes. This algorithm which is based on birds flocking behavior for finding food [13,14], uses swarm intelligence for finding optimal solution for problems. The birds flocking movement to find food is equal to create a swarm of solutions for a problem and the food resource is equal to the best solution. In this algorithm all members of swarm have two parameters; position and velocity. At first, these parameters are initialized with random values. The swarm of solutions is named particles. Each particle in this algorithm, changes its position and velocity until finding an optimal solution. All particles are in contact with each other. To achieve an optimal solution, they change their positions according to best position of each particle itself (local best) and population best position (global best).

In this research ECG signals which have been selected from MIT-BIH arrhythmia database [15], are classified in five groups (a normal group and four abnormal groups) according to AAMI recommendation [16]. The designed classifier has a unique optimal structure for each person. The BBNNs use the morphological (Hermit transfer function based features) and temporal (RR-interval ratio) features which extracted from the ECG signals. The overview of the proposed system for ECG signal classification have been shown in Fig. 2.

This paper is organized as follows: Section 2 represents the basic concepts of BBNN which has been used as the classifier. In Section 3 the ECG signals, pre-processing of ECG records and the method for extracting the features from the signals will be described. Section 4 will represent a new method for designing a BBNN in MATLAB and in Section 5 the new method for optimizing the designed BBNN and also classification of ECG records will be described, and at the end, in Section 6 the conclusions of this research will be presented.

2. Block-based Neural Network

A Block-based Neural Network [12] is represented by a structure of blocks in two dimensions. Each block is a small neural network with one input layer and one output layer (without any hidden layer). There are four neighboring blocks around each block and it is connected to them with signal flows. In other words, the outputs of each block are connected to the inputs of the neighbor blocks. The first block and the last block in each row are also connected to each other. The overall construction of network and internal structure