CARDIAC ARRHYTHMIA DETECTION BASED ON SIGNAL DECOMPOSITION WITH SINGULAR VALUE DECOMPOSITION (SVD) APPROACH–TIME PROPERTIES AND NEURAL NETWORK ERROR BACK-PROPAGATION (BP)

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ABSTRACT

Until a few years ago, the automatic classification of electrocardiogram signals has received great attention from the biomedical engineering. Recorded ECG signal has useful information about the rhythm and functioning of the heart. ECG signal analysis can show different kinds of cardiac diseases. Correct classifications of ECG heart beats are essential for Clinicians. In this paper, a new method is proposed for the automatic detection of arrhythmias that utilizes ECG signal decomposition using Singular Value Decomposition to extract features from input signal and neural network Back Propagation for classification of properties accompanied with temporal characteristics. In this article, twenty files from standard MIT-BIH database in a format of 420 signal samples are used. Each file contains several types of heart disease. As experimental results show, the proposed method is more accurate than other methods, so that it has the capability of four-class arrhythmia classification with accuracy of 98.82 %.

KEY WORDS
ECG Signal, decomposition using SVD, neural network error back-propagation, cardiac arrhythmias. , traditional medicine, Mus musculus, Toxoplasmosis.

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INTRODUCTION

ECG signal is indicative of cardiac activity. Important components of this signal can be divided into atria, complex QRS, ventricular depolarization and U wave. Figure 1 shows the various parts of the [Fig.1].

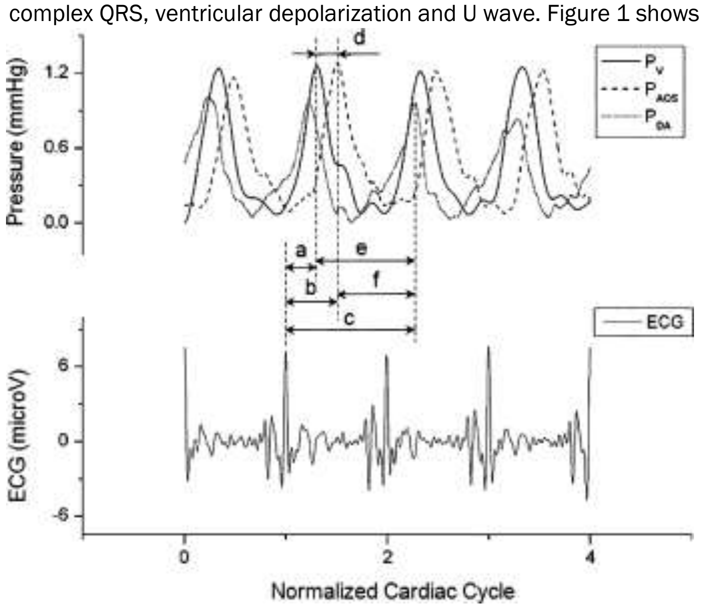

Fig.1 : Normal ECG signal.

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As the World Health Organization statistics show, heart related diseases are major causes of death. Accordingly, diagnosis and appropriate treatment of heart diseases, largely avoids sudden death.
There are many approaches to monitor heart activities. One of the known ways to evaluate the performance of the heart muscle system is ECG (Electro Cardio Gram) signal analysis. The advantages of this signal analysis are its ease and low cost [2].
Signal changes and obvious distortions found in ECG signal contain the message of a cardiac arrhythmia. Smart methods can be used to detect these distortions. But a question that arises is that which characteristic of ECG signal should be used to detect distortion since the whole signal does not contain valuable information.
In [3, 4], the morphological features of the ECG signal are utilized. Also, using specified and organized timescales is a technique that is utilized in [3-5]. Due to the inherent properties of the Hermite polynomials, the method presented in [6] has also used the same features.
To classify these distortions, various methodologies are used. For example, linear classifications [4], artificial neural networks (ANN) in [3,4,7,8].

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SVD decomposition

SVD decomposition or SVD transformation is one of important methods to extract the fundamental components of the signal. If A is an input signal which has dimensions of m × n, then applying SVD one can write:

$$A_{m\times n} = U_{m\times m} \times S_{m\times n} \times V_{n\times n}$$

So one can write:

$$\mathrm{U} \times U^T = I$$
$$V \times V^T = I$$

Matrices U and V are the left and right singular vectors of a matrix respectively and the matrix S is called singular values matrix. Note that I is the identity matrix.
Also, the matrix S only has non-zero values on the main diagonal. Direct correspondence exists between the columns of the matrix U and V with these diagonal elements of matrix S. Another important point that needs special attention is the order of these components, that if column components of singular vectors matrix and the diagonal components of singular values matrix have smaller subscript then, they worth more. It means precisely that components with smaller indexes have important information than others.

Proposed method

Here, first input signal pre-process to remove noise is done, then feature extraction using SVD decomposition method is performed and finally, classification with the aid of back-propagation neural network is done. Figure 2 shows the diagram of the method presented in this paper.
As shown in this diagram, first a pre-processing is performed on the input signal to eliminate high-frequency noises and Base Line that contains error. This is performed by a Gaussian low-pass filter and a Gaussian window. Then, in the processing stage, SVD transformation is applied to the filtered signal to extract the signal characteristics which contain important information. Then, these extracted features with time features are used to construct feature vectors. It should be noted that this vector should be normalized.

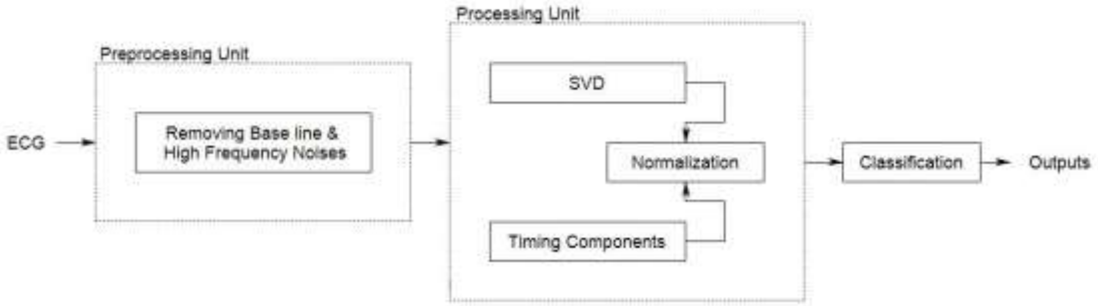

Fig.2 : Diagram of the proposed method for the diagnosis of cardiac arrhythm

The final step is to use the error back propagation neural network that should be trained for good input feature vectors.

In this paper, 22 records of the MIT-IBH database (Reference 13) are used that Table 1 is devoted to review these records completely.

Table 1 - used files from MIT-IBH database and their classes

Class	Record number in the database
Normal	100, 101, 103, 112, 115, 117, 121, 122, 123, 202, 220, 222, 234
RBBB	118, 212, 231
LBBB	109, 111
PB	107, 217

I. Extraction of signal features:

As mentioned earlier, to extract feature from the input signal, SVD decomposition method is used. First, the input signal is decomposed to the vectors U, S and V. As mentioned earlier, there exists a direct correlation between columns of the matrices U and V with the diagonal elements of the matrix S, so the elements of the singular values diagonal matrix are candidates for singular vectors of the input signal. In this paper, the singular values are used as features.
If A is the input signal, to extract feature, the following algorithm is presented:

1. $Compute\ [U, S, V] = SVD(A)$
2. $for\ i, j = 1: size(S)$
   $if\ (i == j)$
   $Val(i) = S(i, j)$
3. $Return\ Val$

In this situation, matrix Val contains features extracted from the A signal. This is a very good result because using this process, not only the key features of the input signal are extracted, but also the dimension reduction is done. One important feature of signal decomposition using SVD method like PCA is to reduce the dimensions of features.

For mentioned time features, the distance of the peak QRS of the current heart rate and the previous heart rate are considered [9].

II. Classification of Features:

Classes based on neural network are considered the best classification methodologies that are inspired from characteristic of the living organisms' nervous system. As we know, there are several methods exists for classification using neural networks. BP or the back-propagation neural network is used in this paper for classification.

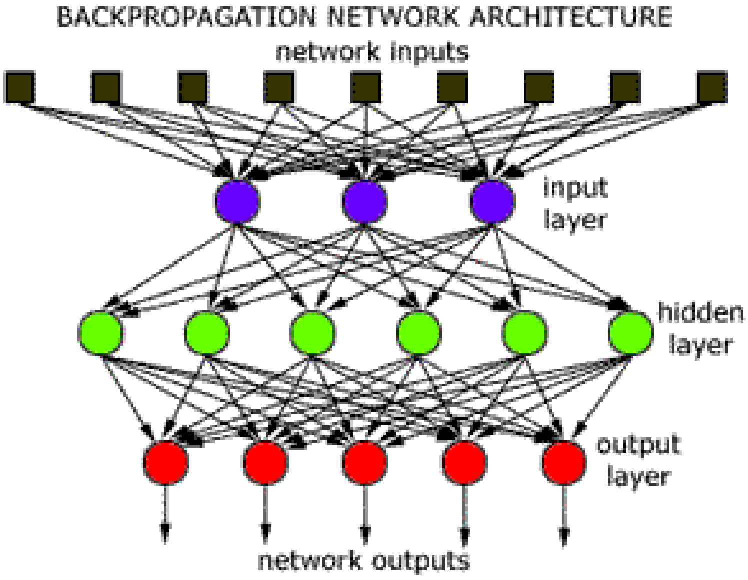

Figure 3 - Overall architecture of the back-propagation neural network

Neural network used in this paper is composed of an input layer, three intermediate layers and an output layer that thirty neurons for the hidden layer are considered. The activation function used in this paper is a bipolar sigmoid function and output layer neurons have linear function.

III. Test Results:

In this article, the following criteria is used to determine the efficiency of the method:

$$Accuracy = 100(1 - \frac{\#Error}{\#Total})$$

Accuracy represents the percentage of system efficiency; #Total is total number of samples and #Error is the number of examples that are not classified correctly. Table 2 demonstrates simulation results of the presented method in this paper, network efficiency is 98.82%.

Table 2 - Details of the performance of the presented method in this article

Classes	Number of Test Samples	Number of Test Samples	Error	Efficiency(%)
Normal	20	100	1	**99**
RBBB	20	80	1	**98.75**
LBBB	20	80	0	**100**
PB	20	80	2	**97.50**
Total	80	340	4	**98.82**

The above table compares the performance efficiency of the method presented in this paper with other known methods. It is obvious that, considering the number of files used from MIT-BIH database and the number of classes, proposed technique in this paper has higher performance efficiency than most other methods.

Table 3 - performance comparison of different methods for the diagnosis of cardiac arrhythmias

Method	Database	Classes	Efficiency(%)
Multi-Stage Neural Network [7]	10 files MIT-BIH arrhythmias database	Normal, PVC, PB, RBBB, atrial premature beat, fusion of paced and normal beat	**88.33**
Wavelet combined with time features and neural network [8]	22 files MIT-BIH arrhythmias database	PVC, Normal, Other beat	**95.16**
Wavelet and neural network [10]	7 files MIT-BIH arrhythmias database	PVC, Non PVC	**97.04**
PCA, Wavelet and neural network [11]	40 files MIT-BIH arrhythmias database	PVC, Normal, Other beat	**97**
Proposed method in this paper using SVD decomposition method and back-propagation neural network	20 files MIT-BIH arrhythmias database	Normal, PB, RBBB, LBBB	**98.82**

1- Conclusion:

In this paper, a new method was proposed for automatic detection of cardiac arrhythmias. Initially, using some filters, some input signal noises such as high frequency noises were removed, then using SVD signal decomposition method, not only convenient features were extracted from the input signal but also the dimensions of the features were reduced. Finally, using the back-propagation neural network, feature vectors were classified. The result was very high accuracy of this method in the diagnosis and classification of cardiac arrhythmias. Accuracy and the number of classes in the proposed method in comparison with other methods had superiority. This method could classify four classes: normal, Left Bundle Branch Block (LBBB), Right Bundle Branch Block (RBBB) and palpitations (PB) with an accuracy of 98.82%.

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