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A Wavelet Transform based SVM Analysis of ECG Signals - Detection of Cardiac Abnormality

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ABSTRACT

This paper presents a new approach to the Automatic detection and classification of electrocardiogram (ECG) signals is of huge importance for diagnosis of cardiac abnormalities. A method is proposed here to classify different cardiac abnormalities like Ventricular Arrythmias, Myocardial infarction,Myocardial hypertrophy and Valvular heart disease. Support Vector Machine (SVM) has been used to classify the patterns inherent in the features extracted through Continuous Wavelet Transform (CWT) of different ECG signals. CWT allows a time domain signal to be transformed into time-frequency domain such that frequency characteristics and the location of particular features in a time series may be highlighted simultaneously. Thus it allows accurate extraction of feature from non-stationary signals like ECG. Then the support vector machine (SVM) with Gaussian kernel is used to classify different ECG heart rhythm. In the present work, SVM in regression mode has been successfully applied for the classification of cardiac abnormalities with good diagnostic accuracy.

Introduction

The electrocardiogram (ECG) is routinely used in clinical practice, which describes the electrical activity of the heart. In physical checkups at hospitals, physicians record the ECG after the patient has exercised to check his/her cardiac condition. The Holter ECG device is used most frequently for recording the ECG. Physicians apply the device to a patient when they need to monitor his/her ECG to find the few abnormal cycles in the ECG throughout the day. Physicians then interpret the shapes of those waves and complexes. They calculate parameters to determine whether the ECG shows signs of cardiac disease or not. The parameters are the height and the interval of each wave, such as RR interval, PP interval, QT interval, and ST segment. Recognition of the fiducial points and calculations of the parameters is a tedious routine for the physician. Therefore, there is an urgent need for an automatic ECG recognition system to reduce the burden of interpreting the ECG.Various studies have been done for classification of various cardiac arrhythmias [1][2][3][4]. In this paper, we propose the combination of wavelet transform and AR model as the feature extraction method, then use the SVM to classify the ECG heartbeat. The proposed approach is validated in the MIT-BIH Arrhythmia Database[5]. Fig.1 shows an ideal ECG wave form.

Filtering of Ecg Signal

ECG signals ofthe above mentioned diseases along with the ECG signal of healthy persons have been collected from the PTB Diagnostic ECG Database www.physionet.org. The ECG signals have been recorded for 2 minutes and 30 seconds, with a sampling frequency of 1 kHz for the 12 ECG leads. ECG signals are always affected by noise, baseline drift and artifacts. Therefore it is difficult to use them in the raw form for classification of disease. Filtering of the ECG signals are thus necessary. In order to reduce very low frequency as well as the high frequency noises, an FIR band pass filter with the pass band 0.1 -Hz to 90 Hz has been used. The main advantage of using an FIR filter is that it minimizes waveform distortion and it also has nearly linear phase relationship. The magnitude and phase responses of the proposed FIR filter are shown in Fig.2. Fig.3 shows the original ECG signal taken from the PTB database and the output signal of the mentioned FIR filter.

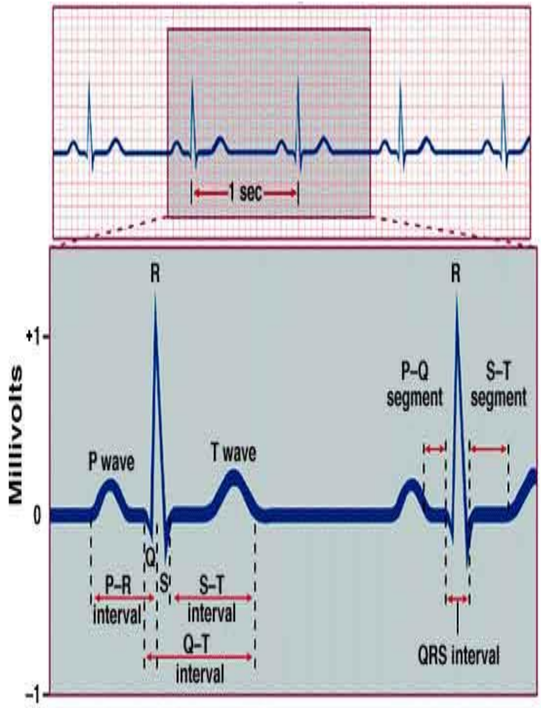

Fig 1. Ideal ECG wave form

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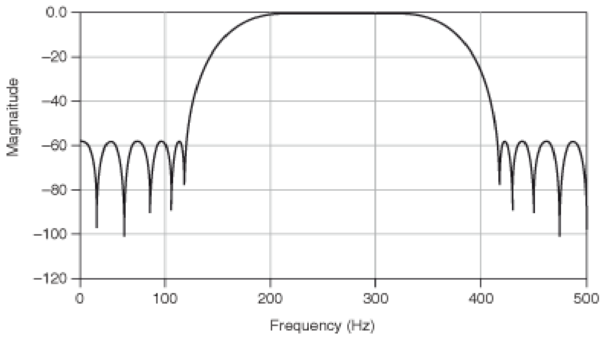

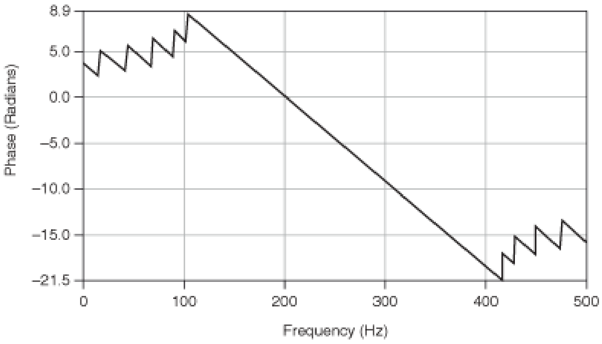

Fig 2 & Fig 3. Magnitude and phase responses of the proposed FIR filter

Wavelet Transform

The ECG signals are considered as representative signals of cardiac physiology, which are helpful in diagnosing cardiac disorders. The absolute way to display this information is to perform spectral analysis. The Wavelet Transform (WT) gives very general techniques, which can be implemented to many tasks in signal processing. The ECG signal, consisting of many characteristic points, can be compressed into a few points. These points characterize the behaviour of the ECG signal. This feature of using a lesser number of parameters to represent the ECG signal is particularly important for recognition and diagnostic functions. The WT can be thought of as an extension of the classic Fourier transform, but instead of working on a single scale (time or frequency), it works on a multiple-scale basis. This multiple-scale feature of the WT allows the decomposition of a signal into a number of scales, every scale representing a particular coarseness of the signal under this study. The procedure of multiresolution decomposition of a signal $x[n]$ is schematically shown in Fig 4. Every stage of this scheme consists of two digital filters and two down samplers by 2. The initial filter, the discrete mother wavelet is g[n], high pass in nature, and the second, h[n] is its reflect version, low-pass in nature. The down sampled outputs of first high pass and low-pass filters give the detail, $d1$ and the approximation, $a1$, respectively. The first approximation, $a1$ is more decomposed and this process is continued as shown in Figure. 2 [11,12].

ECG Database

PhysioBank database is a large and growing archive of well-characterized digital recordings of physiological signals and related data for use by the biomedical research community. The databases of MIT-BIH Arrhythmia Database, MIT-BIH Atrial Arrythmia Database and Malignant Ventricular Arrhythmia Database were used for the analysis.

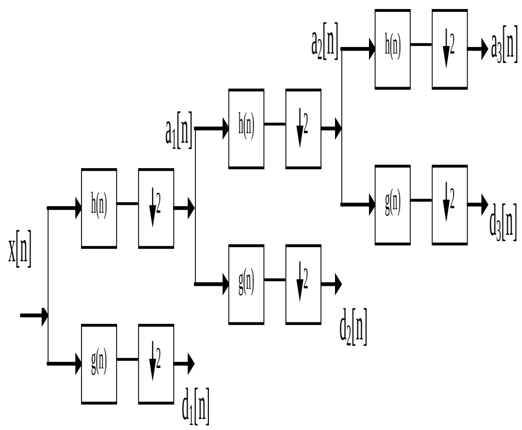

Figure 2.Three level wavelet decomposition tree

Theory of Svm

The SVM technique, was originally proposed essentially for classification problems of two classes but was found to be useful to deal with non-linearly separable cases too. Given a set ofpoints which belong to either of two classes, a linear SVM finds the hyperplane leaving the largest possible fraction of points of the same class on the same side, while maximizing the distance of either class from the hyperplane[5-10].

$$u(x) = \sum_{i=1}^{N} \alpha_i y_i K(x_i, x) + b$$

$$F_i = \sum_{j=1}^{N} \alpha_j y_j K(x_j, x_i) - y_i$$

$$Case1 \;\; \alpha_i = 0 \qquad (F_i - b) y_i \geq 0$$

$$Case2 \;\; 0 < \alpha_i < C \quad (F_i - b) y_i = 0$$

$$Case3 \;\; \alpha_i = C \qquad (F_i - b) y_i \leq 0$$

And by further classification according to the possible combination of alpha and y_i. We can have:

$$b \leq F_i \;\; for\ \forall i \in I_0 \cup I_1 \cup I_2$$

$$b \geq F_i \;\; for\ \forall i \in I_0 \cup I_3 \cup I_4$$

Material and Methods

The block diagram of the proposed method for ECG beat classification shown in Figure 4. This method is separated into three steps: (1) preprocessing (2) ECG Preprocessing and (3) classification by SVM.

Pre-processing

Clinical ECG recordings undergo several stages of filtering in an attempt to decrease the noise. Each noise source resides in a characteristic frequency band. Poor conductance between skin and electrode creates slowly varying potentials which manifests as baseline wander in the ECG. The output function of this WT will be our filtered signal. Ψ (t) given in the equation (1). The parameters of this filtering are the attenuation factor β , and the basic frequency f .

$$\Psi\left(\mathrm{t}\right) = \exp\left(\frac{t^2}{\beta^2}\right)\cos\left(2\Pi \mathrm{ft}\right) - \lambda \tag{1}$$

β - Attenuation factor, f - base frequency, $\Psi(\mathrm{t})$ - WaveletTransform , λ - DC factor eliminator

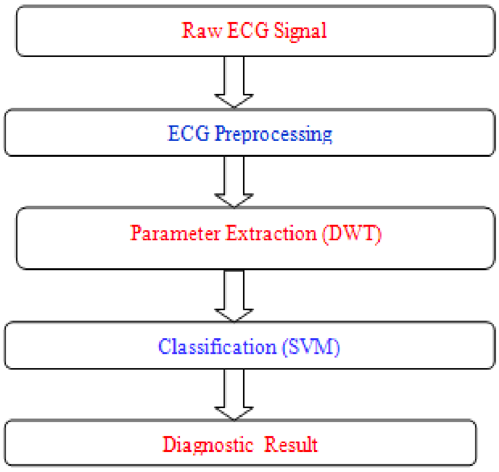

Figure 4. Proposed method for ECG beat classification

Our goal is to find those parameter values and contribute the most to a good QRS detection ratio. The value of these parameters will be chosen so that it assures all the significant parts of the sum defined in Equation (1), but it eliminates all additional calculations for the attenuated part of the signal, that hardly influences the result. Elimination of this low and high frequency components from the signal using the filters is the concrete effect of the wavelet filtering shown in Figure 5 and Figure 6,7.

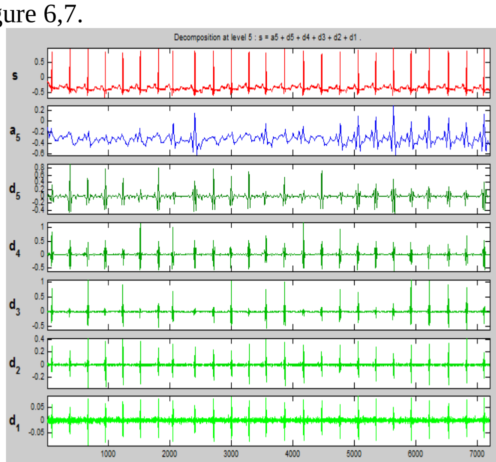

Figure 5. Decomposition of symlet Wavelet – Original Signal

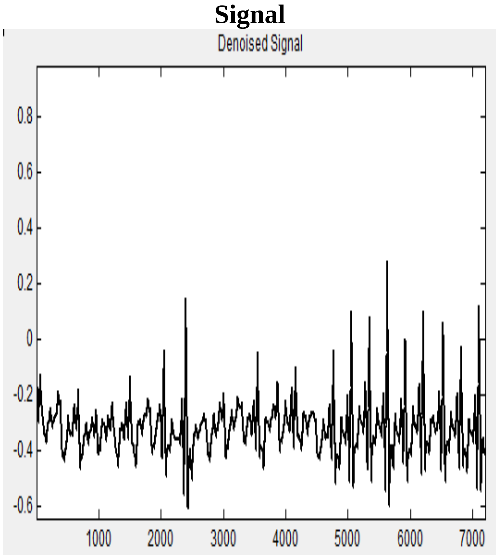

Figure 6. Denoised Signal

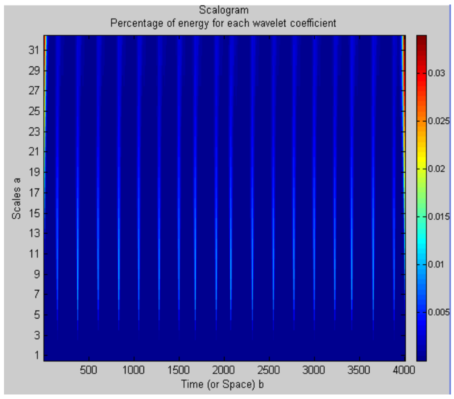

Figure 7. Scalogram from a clinical ECG recording using Symlet Wavelet

In this work, the Gaussian kemel is used as the kernel function. Classification consists of two steps: learning and testing. Our classifier is a learning machine of the supervised type and Multicategory SVM(MC-SVM). Firstly, all ECG segments that contain a special type heartbeat are mapped into feature space using wavelet and AR model which have been explained above. In the learning phase, SVM receives some patterns as input. These patterns are heartbeats represented by m feature parameters that can be seen as points in rn-dimensional space. Then the machine becomes able to find the labels of new vectors by comparing them with those used in the learning phase.

Results & Discussion

In the numerical experiments, we have used the ECG data from the MIT-BIH Arrhythmia Database corresponding to the normal heartbeat and 5 types of arrhythmias. Each type heartbeat was extracted from the record which contained most beats of this type. In this work five types arrhythmias were extracted respectively from the record 100, 109, 118, 107, 208 and 232. Then each type heartbeat has a data set that contains many heartbeats. Due to the scarcity of data corresponding to some beat types the number of data belonging to each heartbeat type was variable. We chosen 70% of data set to be training data and 30% of data set to be testing data. The total number of data used in training was equal 430. Another 185 data points have been left for testing.

Type of Arrhythmia	**Training Data**	**Testing Data**	**Mis classification**	**Classification Accuracy (%)**
VT	75	30	1	94.33
VF	95	40	1	97.00
VFLU	85	35	1	94.11
Myocardial infarction,	95	40	1	97.00
Myocardial hypertrophy	85	35	1	94.11
Total	430	185	7	98.24

The objective of this study is to model single-lead ECG signals for extracting classifiable features in order to improve the classification results using wavelet and AR modelling. The wavelet transform analysis provides robust features in presence of background continuous noise. Dominant and important features in the ECG data are extracted to provide robust information retrieval for classification. AR coefficients are also be used to extract the feature of ECG data. Because of the reduced dimensions of feature vectors, the classification can be done quickly. The experiment results show that usingwavelet and AR model together can result in high accuracy of classification.

Conclusion

This paper proposed a wavelet based feature extraction and SVM based pattern classification of different types of cardiacabnormalities.The method relies on high discrimination power and excellent generalization ability SVM in complex pattern recognition and classification tasks and is superior to conventional "expert" or "knowledge based" systems in the sense that it does not require a huge expert knowledge for recognition of a different input pattern, nor does it demand any rule to be described explicitly for discrimination of differentfault patterns. The accuracy of the -SVM predicted result can be improved by increasing number of training sets.

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