ECG Feature Extraction and Classification using Discrete Wavelet Transform and Euclidean Classifier

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ABSTRACT

Several surveys have come up with the result that heart diseases are among the top five reasons of deaths worldwide. Conventional diagnosis of heart diseases relying on symptoms and standard tests like the ECG highly depends upon the experience of the physician and the fluctuations in the test data. Errors arising out of any of the above factors may have serious repercussions. In this paper, we present a technique in which consists of data pre-processing using the wavelet transform, classifying using the Euclidean Distance Classifier. It has been shown that the proposed technique achieves better performance compared to previously existing techniques.

Keywords: - Electrocardiogram (ECG), feature extraction, Discrete Wavelet Transform (DWT, Euclidean classifier.

1. INTRODUCTION

Several standard surveys have indicated that that, around 23.6 million persons may lose their lives due to Cardiovascular Diseases (CVD) by around 2030. Cardiac Arrhythmia is one of the key reasons of life threatening cardiac abnormalities.

Cardiac arrhythmia is the condition of irregular or abnormal heart speed or heart beat. It results in the heart running too fast or too slow i.e. to say in an irregular rhythm. In the case of arrhythmia, the heart is unable to pump requisite blood to the body. A lack of sufficient or regular blood flow may damage vital organs like the brain, heart, kidney etc and become fatal.

Classification of cardiac arrhythmia cases is substantially challenging and non-trivial. The electrocardiogram (ECG) signal is one of the basic signals that are used for the diagnosis of heart diseases as it provides crucial information about the functioning of the heart. The accurate classification becomes difficult due to[1]:

1) The enormous amount of data ECG signal contains.
2) Random fluctuations of the ECG signal.
3) Difficulty in detecting clear trends in the behavior of ECG signals.

These challenges can be overcome using sophisticated tools like artificial neural networks.

2. DESCRIPTION OF THE HUMAN CARDIAC CYCLE

The heart follows a regular pattern for pumping blood. This regular motion is periodic in nature. The presence of Sodium and Potassium salts in the blood stream results in the generation of weak electrical signals called electrocardiogram (ECG) signals. It can be seen from Fig.1that the ECG follows a regular pattern. Also the presence of some peaks can be observed. The peaks are named as P,Q,R,S,T waves and the separation between the peaks are named as PR segment, QT segment, QRS Complex, RR segment etc.[1] It is worth noting that these segments or intervals yield vital information about the functioning of the heart. Therefore these intervals or segments are called ECG parameters or ECG features. The calculation or estimation of these features is called **Feature Extraction.** It should be noted that a raw or unprocessed ECG signal contains different disturbances called noise. Prior to feature extraction, such disturbances need to be removed. This technique is called data pre-processing.

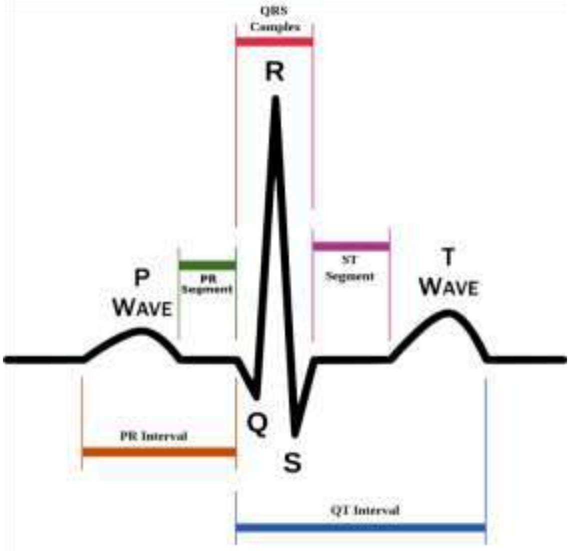

Fig.1 A Typical ECG Signal.

3. PRE-PROCESSING OF ECG DATA

Feature extraction, training and classification of ECG data will yield accurate results only when the ECG data fed to the neural network and classifier will be free from random fluctuations and noise. [7]The way the network trains is critical in its learning ability to follow a trend later and subsequently classify. In the present context, we have used the Discrete Wavelet Transform (DWT) to remove the irregularities in the ECG signal prior to training the neural network and classifying using the Euclidean Classifier.

The Wavelet Transform is rather a recent tool for the analysis of randomly fluctuating non-smooth signals.

While conventional Fourier methods like the Fourier Transform can analyze smoothly changing data, it is not capable enough to analyze abruptly changing data like ECG. The reason for this is the fact that the Fourier Transform has base signals as sine and cosine which are themselves smooth in nature. Whereas the Wavelet Transform has abruptly changing base signals. A comparative analysis ensues:

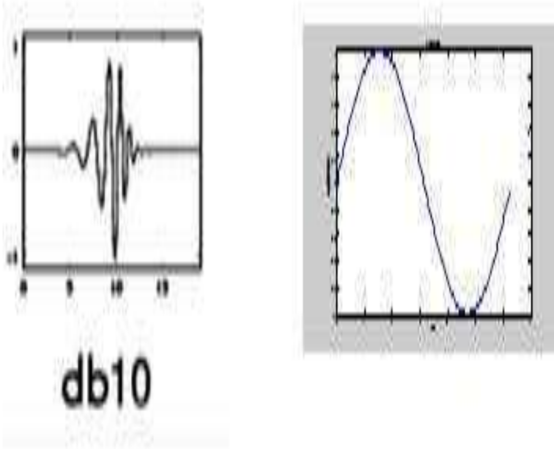

Fig.2 Base Functions of Fourier Transform and Wavelet Transform

The mathematical description of the wavelet transform can be given by:

$$C(S, P) = \int_{-\infty}^{\infty} f(t)\,((S,P,t))\,dt$$

Here S stands for scaling
P stands for position
t stands for time shifts.
C is the Continuous Wavelet Transform (CWT)

The main disadvantage of the CWT is the fact that it contains an enormous amount of data. The sampled version of the CWT is the Discrete Wavelet Transform (DWT). The DWT is a down sampled version of the CWT and its characteristic nature is to smoothen out abrupt fluctuations which are possible due to both abruptly changing base functions and down sampling.

The scaling function can be defined as:

$$W\Phi(Jo, k) = \frac{1}{\sqrt{M}} \sum_n S(n).\Phi(n)_{jo,k}$$

The Wavelet function can be defined as:

$$W\psi(j, k) = \frac{1}{\sqrt{M}} \sum_n S(n).\psi(n)_{j,k}$$

Where $\frac{1}{\sqrt{M}}$ is Normalizing term

The DWT coefficients can be plotted to see the smoothening effect of the tool. Now, wavelets have different families depending upon the base function of the wavelet. A few common families are shown.

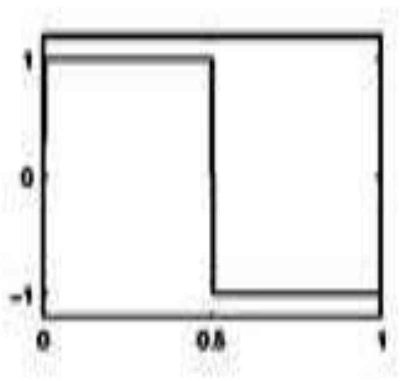

Fig.3 The Haar Wavelet

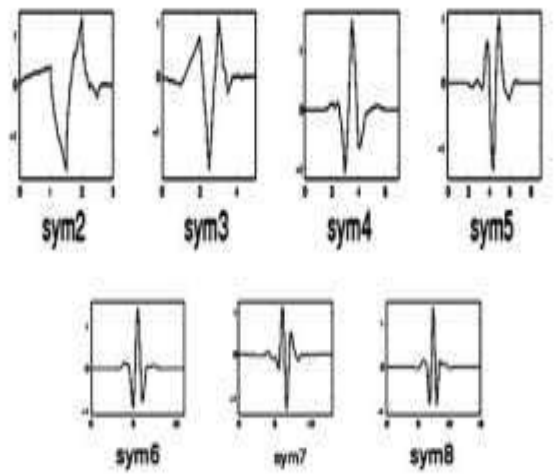

Fig.4 The Symlet

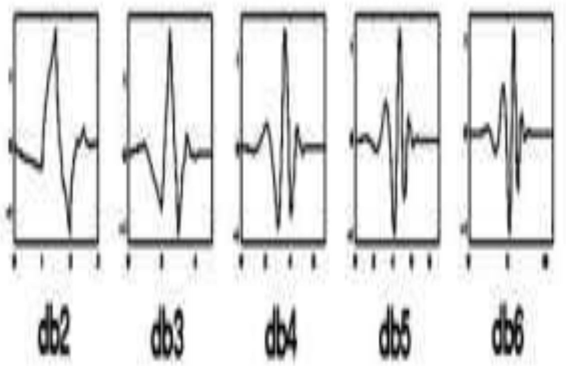

Fig.5 The DB Wavelet

One common attribute of the different wavelet families is the fact that all of them exhibit sudden or abrupt changes. This is the main reason because of which wavelets can be used for the analysis of abruptly changing signals like the Electrocardiogram (ECG) which do not follow the Dirichlet's conditions necessary for analysis using the Fourier Transform.

4. THE MINIMUM DISTANCE OR EUCLIDEAN CLASSIFIER

After the network is trained to learn a pattern in feature values like weights, the cases can be classified using the minimum distance or Euclidean Classifier. The Euclidean Classifier is based on the computation of the Euclidean Distance defined as:

$$d = \sqrt{x^2 + y^2 + z^2}$$

Here x, y and z belong to a vector space C

Let the separation of a new sample from the mean value of a particular category be D_i

We estimate Min (D_i) to categorize the data into classes. The various parameters for the classification are:

1. **True Positive (TP):** It is the case when a sample belongs to category and the test also predicts its belongingness.
2. **True Negative (TN):** It is the case when a sample does not belong to category and the test also predicts its non-belongingness.
3. **False Positive (FP):** It is the case when a sample does not belong to category and the test predicts its belongingness.
4. **False Negative (FN):** It is the case when a sample belongs to category and the test predicts its non-belongingness.

Sensitivity (S_e): It is mathematically defined as:

$$\frac{TP}{TP + FN}$$

Accuracy (Ac): It is mathematically defined as:

$$\frac{TP + TN}{TP + TN + FP + FN}$$

5. METHODOLOGY OF PROPOSED WORK

The methodology of the proposed work can be explained using the following algorithm.

Step1. Load ECG data (source MIT.BIH database)

Step2. Pre-Process Signal using Discrete Wavelet Transform

Step3. Compute features like RR interval, QQ interval, QRS Complex after proper thresholding.

Step4. Use the Euclidean Classifier.

Step8. Evaluate Accuracy and Sensitivity using most prominent feature.

6. RESULTS

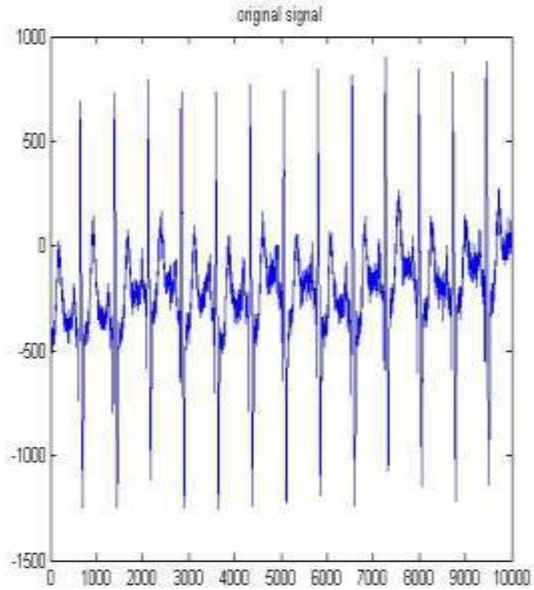

Fig.6 Original ECG Signal Summary of Results

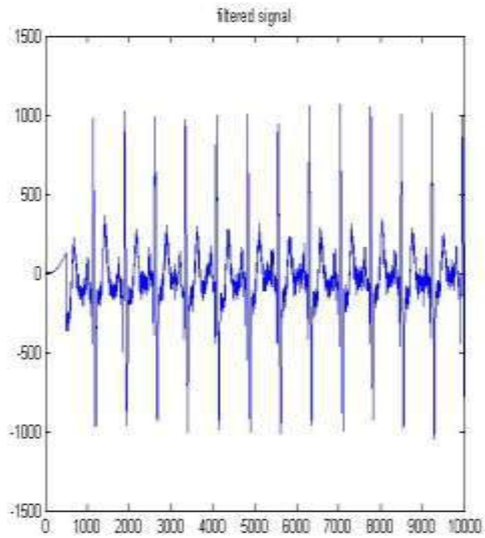

Fig.7 ECG Signal after Filtering

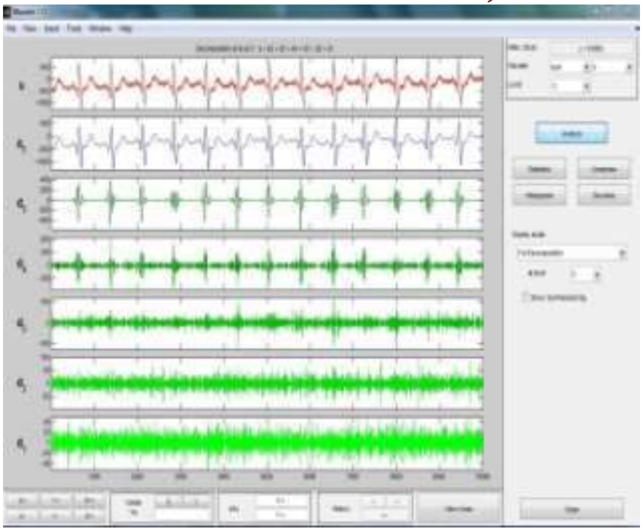

Fig.8 Wavelet Decomposition of Original ECG Signal at Sym5

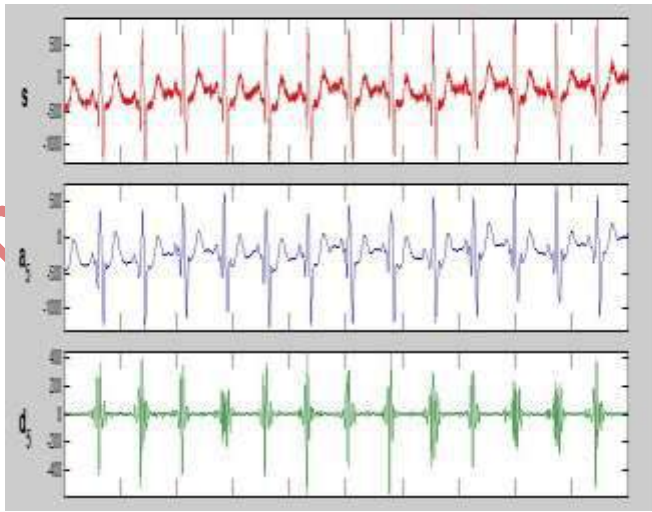

Fig.9 Smoothening Effect of DWT

Table 1:Summary of Results			
S. No	**MIT-BIH Tape No.**	**Sensitivity(Se)**	**Accuracy (Ac)**
1	**109m(LBBB)** **207m**	**99.115** **99.6350**	**99.1229** **99.6364**
2	**118m(RBBB)** **212m**	**99.1526** **99.3549**	**99.1579** **99.3590**
3	**203m(PVC)** **200m**	**99.5885** **97.1452** **-**	**99.5902** **97.2244**
4	**104m(PB)** **107m**	**97.4376** **98.7807**	**97.5016** **98.7954**
5	**106m(NORM)** **108m**	**98.3** **97.7514**	**96.4706** **95.0125**

The results have been achieved by decomposing the original signal at level 5 of Symlet5 Wavelet Family. It can be clearly seen that DWT smoothens the signal thereby removing fluctualtions. Finally the sensitivity and acuracy has been calculted. The error histograms for training, testing and validation have been shown in the end.

CONCLUSION

It can be concluded from the previous discussions and results that the proposed technique is efficient in feature extraction and classification and attains high levels of sensitivity and accuracy. It can be attributed to the fact that that data is pre-processed using DWT to smoothen out fluctuations. Better training yields accurate results as seen from the regression and error plots. The sensitivity and accuracy values validate the efficacy of the proposed technique.

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