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ECG Arrhythmia Detection using PCA and Elman Neural Network

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Abstract: ***Cardiac arrhythmia refers to any abnormal electrical activity in the heart that causes irregular heartbeat. Under clinical settings, the arrhythmias can be monitored non-invasively using the electrocardiogram (ECG). Although reliable, the method is still prone to error due to its dependence on visual interpretation. Further, ECG data is enormous in dimension and increases as the data sampling rate increases. The increase in ECG sampling rate puts a limitation on processing of ECG data for analysis. However, high sampling rate gives an added advantage of ECG representation at high resolution at the same time, but analysis of ECG with this high dimensional data is time consuming. Therefore, in order to reduce the dimension of ECG data but at the maximum variance is required so that the reduced ECG data represents the full features of the ECG under scanner. In the presented work, the dimensionality of the high resolution ECG data is worked out with optimum speed of operation.***

Keywords: ECG waveform, wavelet (bior. 3.9), Elman Neural Network, PCA, ECG arrhythmia

1. Introduction

One of the crucial steps in the ECG analysis is to accurately detect the different waves forming the entire cardiac cycle. Most of the studies based around wavelet transformation identify 99.8% of ECG waveforms. Especially the wavelet transformation is worth investigating in P-wave and T-wave recognition. Some authors use wavelet technique for identification of the ECG changes resulting from acute coronary artery occlusion and are able to identify specific detailed time frequency components of ECG signal, which are sensitive to transient ischemia and eventual restoration of electrophysiological function of the myocardial tissue. The practical benefit of the wavelet based ECG approach is that T-wave abnormalities can be assessed without the need for

T-wave end point identification. The wavelet transformation is a new promising technique in non-invasive electro cardiology providing improved methods for late potential detection.

2. Related Works

Mohamad, F.N., Fac. Of Electrical Eng., Univ. MARA, Shah Alam, Malaysia (August 19, 2013) Principal component analysis and arrhythmia recognition using Elman neural network ECG samples are taken from the database and then denoise the samples using filters .Then through PCA principle components analysis reduces the morphological features, then the features are trained, tested and validated the neural network .

Ghorbanian, P. Dept. of Mech. Eng., Villanova Univ., Villanova, PA, USA Ghaffari,A. ; Jalali, A. ; Nataraj , C (29 sept.,2010) Heart arrhythmia detection using continuous wavelet transform and principal component analysis with neural network classifier Proposed an algorithm to detect six types of ECG beats.PCA is used to reduce the size of data.

Adams,E.R. ,Electr. & Comput. Eng., Mercer Univ., Macon, GA, USA Choi, A (17 Oct.2012) Using neural networks to predict cardiac arrhythmias ECG data is used to detect arrhythmia.FFT(Fast Fourier Transform) is used to analyze the cardiac arrhythmia. Then the test is validated with the help of a neural network

Segyeong Joo, Dept. of Biomed. Eng., Univ. of Ulsan Coll. of Med., Seoul, South Korea, Kee-Joon Choi, Soo-Jin Huh (26-29Sept,2010)" Prediction of ventricular tachycardia by a neural network using parameters of heart rate variability Various parameters are extracted from the ECG samples. Two-Third of these parameters is used to test the ANN (artificial neural network) and the remaining is used to verify the performance.

Silipo,R. Dept. of Syst. & Inf., Florence Univ., Italy Marchesi, C. (May, 1998) Artificial neural network for automatic ECG analysis Several (ANN) are implemented, tested and compared. ANN learning algorithm are designed according to the features extracted of particular classification from the ECG date i.e taken from a database

3. Feature Extraction

Following features are extracted from the input ECG waveform. Feature set consists of primarily:

- Mean Vector
- Mean Adjusted Data
- Covariance Matrix
- Eigen Vectors
- Eigen Values
- Energy
- Entropy
- Power
- Standard Deviation
- Variance

The features create the feature vector that is normalized between 0 and 1 so as to make input to the Elman neural network scheme. The known ECG data sets are used for training of the Elman neural network and the weights are optimized to a maximum level. For testing purposes, a training ECG is taken. For validation purposes, untrained ECG are taken and results are compared with the expected results.

4. ECG Data Pre-Processing

The ECG signal downloaded from MIT-BIH arrhythmia database may contain artifacts, noise and baseline wanders. Therefore it is necessary to denoise the ECG signal to remove all these unwanted parts of the signal. After denoising the ECG, it is subjected to QRS complex detection. The QRS complex is physiologically an *important peak in the ECG signal, also it is easy to detect by signal processing algorithms due to its sharp and prominent shape. Following features are extracted from the denoised ECG waveform. Feature consists of primarily:

Mean (μ)

Mean is given by avaerage sum of wavelet coefficients and given by the following equation:

$$\text{Mean} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Entropy (Ent)

The entropy of a signal is a measure of the randomness of the signal. In other words, it can be viewed as a measure of uncertainty. Entropy has been shown to be effective in dealing with complex biological signals. The entropy is given by:

$$\text{Entropy} = \sum_{i=1}^{n} p(x_i).\log_{10} p(x_i)$$

Where, p is a probability of random phenomenon of wavelet co-efficient.

Power (P)

Power is given by average square sum of wavelet coefficients and given by the following equation:

$$\text{Power(P)} = \frac{1}{n}\sum_{i=1}^{n} x_i^2$$

Where xi is the wavelet coefficient and n is the total no of wavelet coefficients.

Energy (E)

Power is given by square sum of wavelet coefficients and given by the following equation:

$$\text{Energy(E)} = \sum_{i=1}^{n} x_i^2$$

Where xi is coefficient and n is the the wavelet no of total wavelet coefficients

Standard Deviation (SD)

Standard deviation may be find out by the following equation:

$$SD = \frac{1}{n}\sum_{i=1}^{n} (x_i - \mu)^2$$

Where xi and μ are the wavelet coefficient and n is the total no of wavelet coefficients and Mean respectively.

5. PCA Analysis for Feature Dataset Reduction Dimensionally

The ECG data set is centred on the mean of the data set. This makes the ECG data set having mean zero. Now compute the covariance matrix by using the following matrix operation:

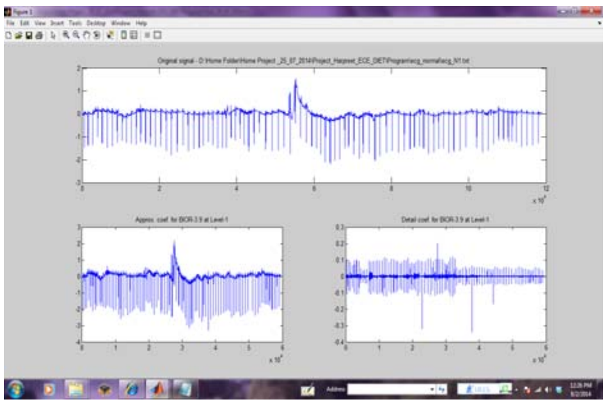
Now calculate the Eigen values and Eigen vector of the covariance matrix using the eig command in MATLAB.

The overall algorithm is implemented into following steps:

- PCA Analysis for Feature Dataset Reduction Dimensionally:
- Obtain the mean vector and mean adjusted data
- Obtain the covariance matrix
- Obtain the Eigen values and Eigen vectors
- Choosing the components and form feature vector
- Create the new data
- Training of Elman Neural Network based on Feature Set
- Weights Updating for all feature
- Arrhythmia Detection
- Validation of Results with all feature set results
- Testing with unknown ECG data base samples

6. Results

The proposed work is based on principal component analysis and elman neural network scheme. The results may be improved once the training samples are made in good numbers and with authentic results. The system needs to be validated on a large test samples so that the margins of accuracy may be decided and the system is used in ECG machines for results interpretation which is most sought domain in ECG manufacturing industry.



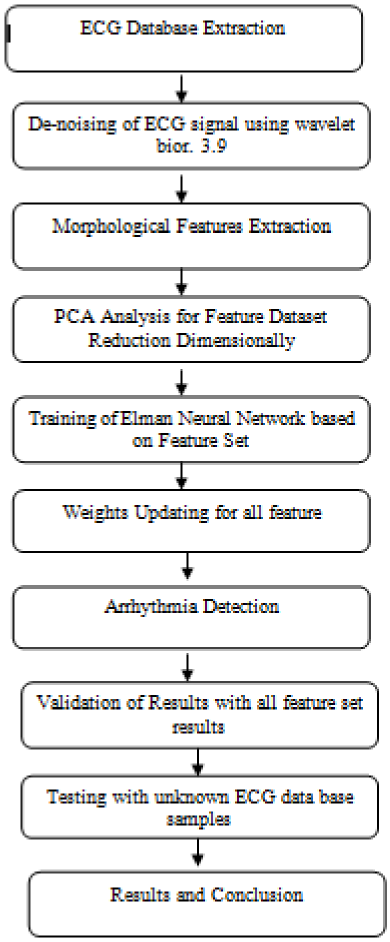
7. Conclusion

The combination of wavelet decomposition and the classification using feature vectors of the beats in ECG signals distinguishes abnormal beats and normal beats. The elimination of the normal beats which occur before and after the abnormal beats can minimize the size of normal beats cluster, which is useful for the accurate classification. The presented work finds application ECG manufacturing industries where the algorithm can be implemented in microcontroller based boards and the real time interpretation of the ECG signal could be obtained form the machine itself. The ECG interpretation is very much in demand today as the selling point feature. Further, the patient may itself get acknowledged with the ECG records as obtained form the machine itself. This gives a coarse idea about the abnormality in the ECG so that the patient can priorities his visit to the doctor. Also, once the algorithm is implemented in real time microcontroller based machines, the correlation between the abnormality and ECG could be achieved in more authentic way.

Result Table for Normal case ECGs

ECG No.	Mean	Entropy	Energy	Variance	SD	Power
ECG-1	-0.000002	0.6545	5.781776	0.000097	0.009855	0.000094
ECG-2	-0.000002	0.6536	5.782776	0.000096	0.009852	0.000097
ECG-3	-0.000002	0.6446	5.78173	0.000098	0.009848	0.000098
ECG-4	-0.000002	0.6548	5.780576	0.000095	0.009865	0.00009
ECG-5	-0.000002	0.6549	5.781705	0.000097	0.009851	0.000097

Flow Diagram



Flow Chart

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Author Profile

Harpreet Kaur is pursuing her M.Tech in ECE from DIET, Kharar, Punjab. Her field of interest is in Digital Signal Processing based system development and integration.