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ECG Peaks Detection using Principal Component Analysis

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Abstract: In this research paper, a novel method is proposed for the delineation of the ElectroCardioGraphy (ECG) signals. ECG signals are utilized to measure the heart activity of the subject. So, for the proper analysis of the ECG, knowledge of these peaks should be there. Hence, for the same, principal component analysis is exploited. Using this analysis, peaks of the ECG signals are obtained for the different types of ECG signals i.e. Apnea, Ischemia, Normal and Tachycardia. Then these results are compared representing differentiability among different ECG signals on the basis of ECG peaks. And, using this method, principal component analysis comes out to be a very efficient and a quality detection technique in identifying the ECG peaks of the different types of ECG signals used.

Keywords: Apnea, ECG, Ischemia, PCA, Tachycardia.

I. INTRODUCTION

ElectroCardioGraphy (ECG) is a technique utilized for measuring the electrical activity of the heart. There are so many heart related diseases present in this world among the human beings. So many dies because of problems in their heart. And Doctors exploits ECG to diagnose and treatment for the related problems.

This diagnosis can be made automatic if these ECG signals obtained for different subjects can be differentiated on the basis of some pattern. A standard ECG waveform is shown in the Fig.1.

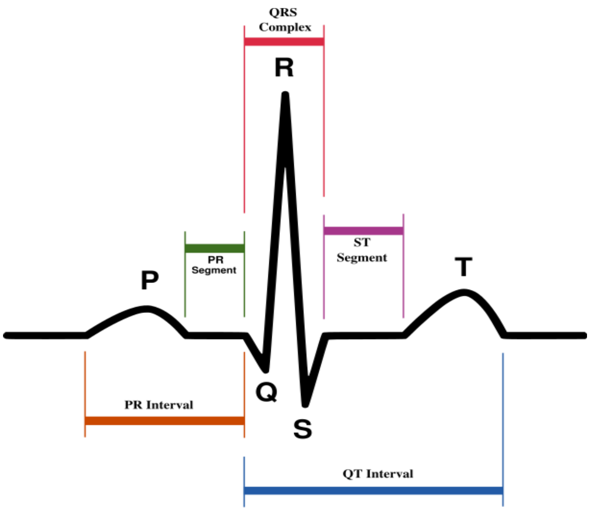

Fig.1. ECG waveform with its characteristic points

In the figure, P-QRS-T waveform is represented and these points can be used as the characteristic points for the ECG signal. For various signals in ECG, variation in the P-QRS-T waveform can be observed. There are so many algorithms already developed for the delineation of the ECG signals. Among these algorithms, real time QRS algorithm [1-3], software based algorithm [4-7], CWT [8], matched filters [9], linear predictive coding [10], ECG slope criteria [11], power spectral density [12], second order derivatives [13], DWT [14], wavelet transforms [15-16] are studied. In [17], ischemia beats were detected using a rule mining based technique. And similarly some other beats are selected in other researchers.

Now, in this research paper, a novel method is proposed for the delineation of the different types of ECG signals i.e. Apnea, Ischemia, Normal and Tachycardia. In this, PCA algorithm is utilized to identify the ECG characteristic points.

This research paper is organised in the following sections as: Section II tells about the overview of the complete work using a block diagram. Section III tells about the different types of ECG signals used and the proposed method. Section IV gives an idea about the experimental work exploited in the method proposed. Then in section V, results are discussed followed by conclusion in section VI.

II. BLOCK DIAGRAM

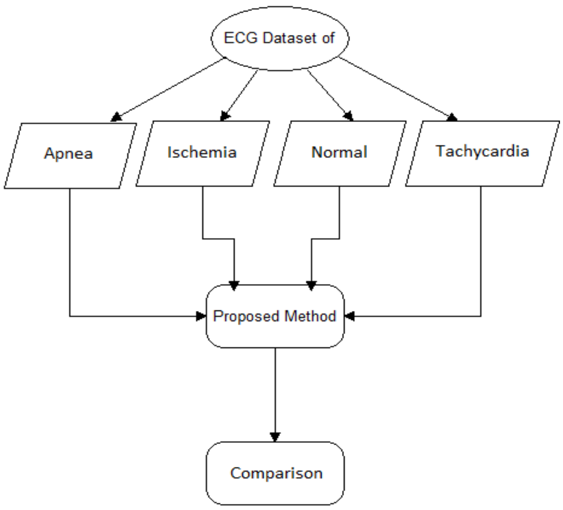

Fig.2. Block Diagram of the proposed method

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In the the Fig. 2 shown is the block diagram representing the overview of the work done during this research. In this, four different types of ECG waveforms are taken namely Apnea, Ischemia, Normal and Tachycardia. Then, as shown in the block diagram, propsed method i.e PCA is applied on these signals and their characteristic points are computed. After that, on the basis of these characteristic points, ECG signals are compared.

III.PROPOSED METHOD

A. Data-Set
Dataset is taken from the MIT-BIH database for the different types of ECG signals utilized during this research. Among these signals, Apnea, Ischemia and Tachycardia are the three types of situations in the subjects having heart related problems with normal signal as the fourth type. These signals are explained in brief in the sub-sections.

a. Normal ECG
Fig.3 represents an ECG waveform showing the heart condition of a normal human being. Comparing with the Fig.1, P-QRS-T points are observable in the Fig.3.

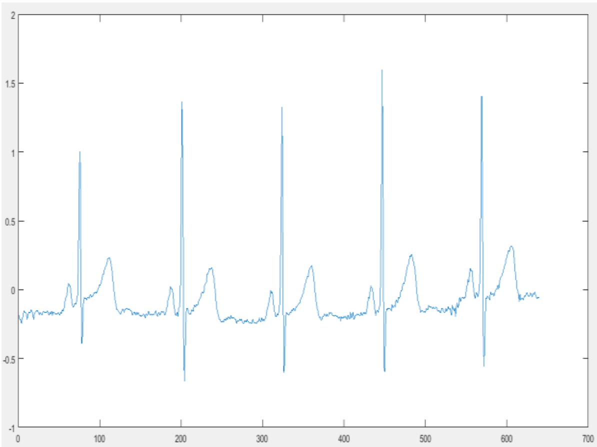

Fig.3. Normal ECG Signal Waveform

TABLE I DIFFERENT PHASES IN NORMAL ECG

Section of ECG	Source
P-Wave	Record the electrical activity through the upper heart chambers (Atria Excitation)
QRS-Complex	Record the movement of electrical impulses through the lower heart chambers. (Atria repolarization + Ventricle depolarization)
T-Wave	Corresponds to the period when the lower heart chambers are relaxing electrically and preparing for their next muscle contraction. (Ventricle repolarization)
ST Segment	Corresponds to the time when the ventricle is contracting but no electricity is flowing through it.

In the Table I, normal ECG signal is explained that how the peaks in ECG are obtained depending on the different situations in the heart.

b. Apnea
Apnea is defined as ECG waveform obtained during the intermittent halt of breathing in the subject. It is due to the irregular sleep and related to the accrued risks of high pressure level. It is shown in the Fig.4.

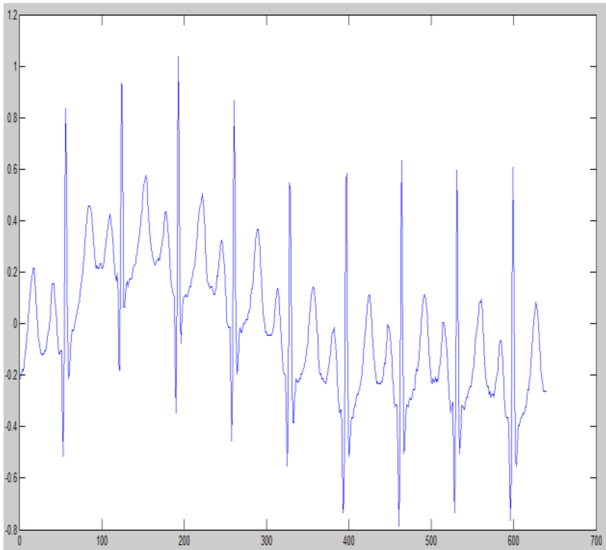

Fig.4. Apnea Signal Waveform

c. Ischemia
Ischemia is a type of ECG signal in which T wave is inverted. In this, sometimes, decrease in the amplitude and disappearance of the R wave may also occur. This type also includes a shift of the ST segment. It is shown in the Fig.5.

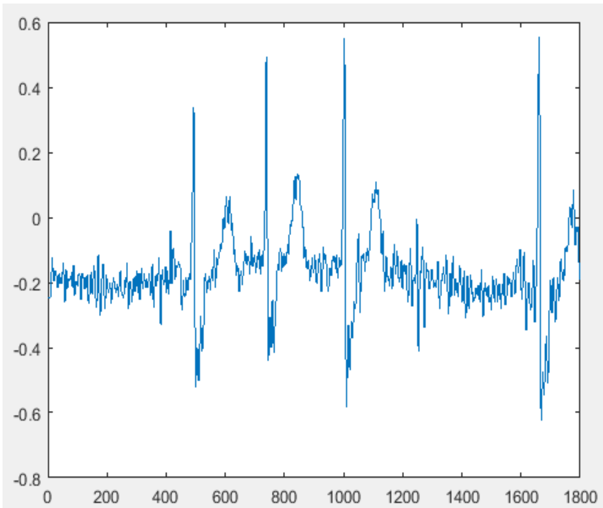

Fig.5. Ischemia Signal Waveform

d. Tachycardia
Tachycardia is a condition in the ECG in which atrial and ventricular rates are accelerated exceeding the normal ECG rate. Beats in the tachycardia are regular but comparatively faster. It is also observed by the presence or absence of the P or flutter waves in the signal.

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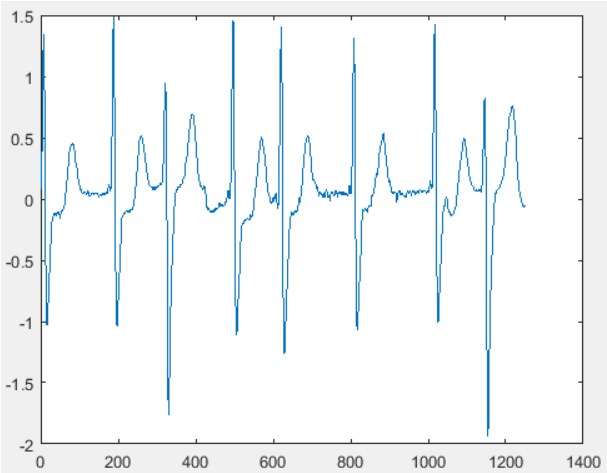

Fig.6. Tachycardia Signal Waveform

B. PCA

PCA is an orthogonal linear transformation. It transfers the data to a new frame of reference such the largest variance of any projection of the information involves lie on the first coordinate (first principal component), the second largest variance lies on the second coordinate (second principal component), and so on. Linear projection method to reduce the number of parameters. Map the data into a space of lower dimensionality.

PCA Algorithm:

Let X be an input data set.

Now, Perform the following steps:

Calculate the mean:

$$m[p] = \frac{1}{Q}\sum_{q=1}^{Q} X[p,q] \qquad (1)$$

Calculate the mean deviation and keep the data in the matrix $D_m[P \times Q]$:

$$D_m = X - m.h \qquad (2)$$

where h is a 1 × Q row vector of all 1’s:

h[q] = 1 for n = 1, …....Q

Find the covariance matrix Cv:

$$Cv = D_m . D_m^{\ T} \qquad (3)$$

Find the eigenvectors and eigenvalues of the covariance matrix $V^{-1}CvV$ where V is the eigenvectors matrix. D is the diagonal matrix of eigenvalues of Cv.

$$D[m,n] = \lambda_p \qquad (4)$$

for m = n = p is the mth eigen value of the covariance matrix Cv.

Rearrange the eigenvalues

$$\lambda_1 \geq \lambda_2 \geq \lambda_3 .... \geq \lambda_Q \qquad (5)$$

Choosing components and forming a feature vector: save the first L columns of V as the M × L matrix W,

$$W[m, n] = V[m, n], \qquad (6)$$

for m = 1, . . . ,P

n = 1, . . . , L where $1 \leq L \leq P$.

Deriving the new data set: The eigenvectors with the maximum eigenvalues are projected into space. This projection results in a vector represented by fewer dimension (L < P) containing the essential coefficients only.

IV. RESULTS DISCUSSION

Now, in the results, Eigen values computed from the PCA algorithm are utilized to detect the characteristic points in the ECG signals. These characteristic points includes Q, R,S and T peaks of the different types of ECG signals viz. Apnea, Ischemia Normal and Tachycardia signals.

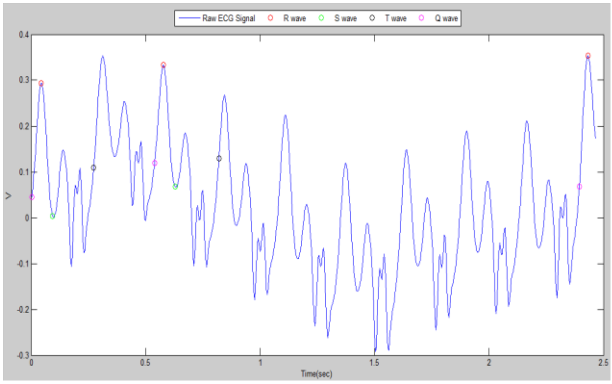

Fig.7. Apnea ECG Peaks Detection

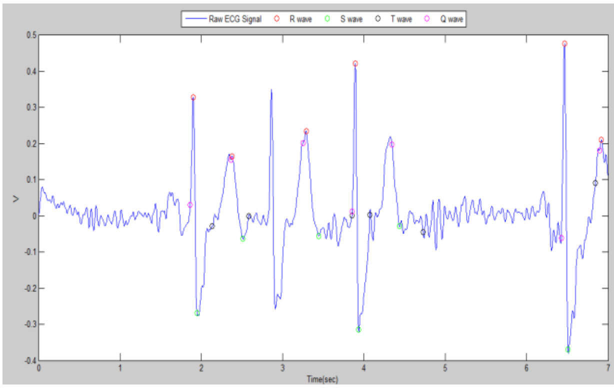

Fig.8. Ischemia ECG Peaks Detection

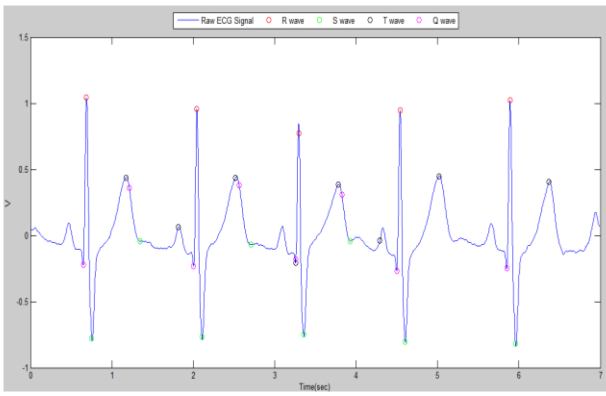

Fig.9. Normal ECG Peaks Detection

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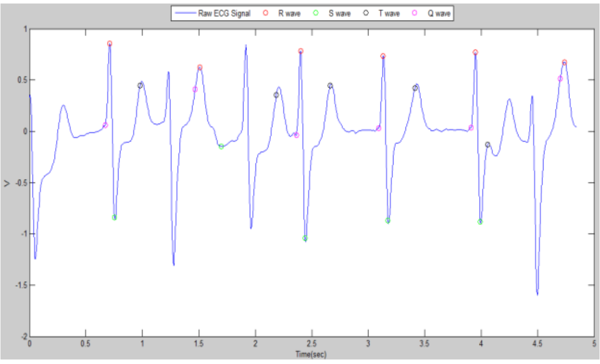

Fig.10. Tachycardia ECG Peaks Detection

In the Fig.7-10 shows the parameter detection in the ECG signals selected as sample from the datasets. It can be observed from the signals figures that variation among the signals can be observed. And this variation is also shown in the Table II.

This table shows the parameter values for the different types of ECG signals used during this work i.e. Apnea, Ischemia, Normal and Tachycardia signals. As feature values, parameters extracted are the amplitudes of Q,R,S and T peaks with their index values which contain their interval values.

TABLE III ECG PARAMETERS CHARACTERISTIC POINTS

ECG	Parameters	Sample values
Apnea	R_i	260.667
	R_amp	0.3271
	S_i	92.5
	S_amp	0.0359
	T_i	140
	T_amp	0.1194
	Q_i	250.667
	Q_amp	0.0771
Ischemia	R_i	1067.6
	R_amp	0.2907
	S_i	971.667
	S_amp	-0.1832
	T_i	1033.2
	T_amp	0.0040
	Q_i	1060.4
	Q_amp	0.1028
Normal	R_i	770
	R_amp	0.7243
	S_i	792.1250
	S_amp	-0.5091
	T_i	903.25
	T_amp	0.2410
	Q_i	763.75
	Q_amp	-0.0117
Tachycardia	R_i	701.5
	R_amp	0.7406
	S_i	617.6
	S_amp	-0.7577
	T_i	681.2
	T_amp	0.3809
	Q_i	691.5
	Q_amp	0.1688

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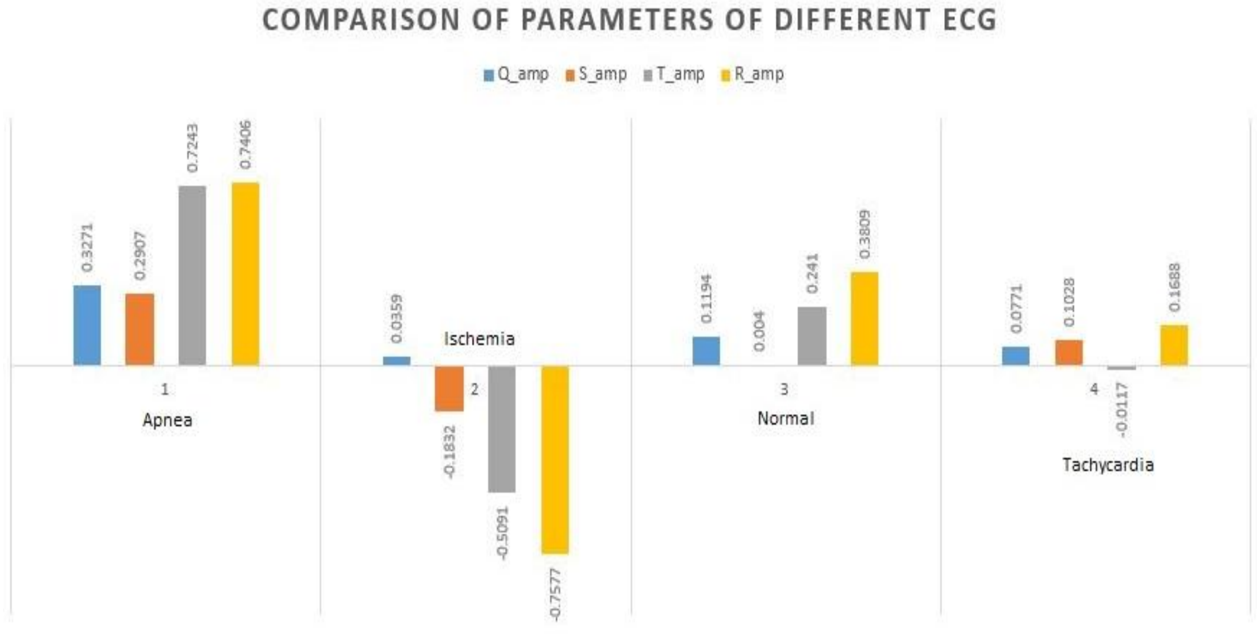

Fig.11. Comparison of characteristic points of different ECGs

Next in the Fig.11 shows is the graph representing the comparison among the feature values extracted using the Principal Component Analysis (PCA) algorithm. And it can be observed from the figure that there is difference among the characteristic points i.e. Q, R, S and T peaks.

V. CONCLUSION

The proposed method in this research paper utilizes Principal Component Analysis (PCA) algorithm to identify the characteristic points i.e. Q, R, S and T peaks. And it can be observed from the results that the different types of ECG signals viz. Apnea, Ischemia, Normal and Tachycardia signals, used during this research have different characteristic points.
As the future work, due to the difference in these characteristic points, these can be exploited to classify the ECG signals.

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