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Features Extraction Using Difference Operation Method from ECG Signal to Detect Cardiac Arrhythmia

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ABSTRACT

Electrocardiogram (ECG) feature extraction plays an important part to find out most of the heart related diseases. An Electrocardiogram wave consist P, QRS and T segments. The electrical impulse generates by Sino-atrial node in the heart. Arrhythmia is one of the common heart related problems which can be detected by the analysis of electrocardiogram of a person. The working of human heart can easily understand with the help of magnitude and intervals value of P, QRS and T waves. The electrocardiogram data used in this research consists of normal and abnormal signals.ECG signals first filtered by IIR notch to remove the artifacts. After filtering, QRS complex of an ECG signal identified. For detection of QRS complex we used DOM (difference operation method). After successfully detection of QRS complex we calculated its R-peak, sharpness, slope and duration. For the classification purpose we used linear classifier in which the ECG data were divided into two partition-one for trained the data called training set in which we used 75% data to trained the classifier and another for test the data called test set in which we used 25% data to test the classifier and classify the normal and arrhythmia signals. The accuracy achieved in this method is 95.30%, sensitivity 96.09% and specificity 96.87%.

Keywords : Electrocardiogram (ECG), Difference operation method (DOM), QRS complex, Arrhythmia.

I. INTRODUCTION

Electrocardiogram, a non-incursive approach is used as a elementary symptomatic tool for heart related problem. A noiseless ECG signal affords essential data regarding the electrical activity of the human heart related problems and ischaemic variations that could take place. ECG signal gives useful information about the heart functionality and cardiovascular system. Arrhythmia being a complex problem, has varied morphological features. The WHO (world health organization) evaluated that 30% people suffers or died globally just because of cardiovascular diseases[1].

Most of the times when ECG signal records from surface electrode which is connected to the chest of patient, the surface electrode are not firmly connected with the skin as the patient breathing, the chest broaden and contract generates a relative motion between skin and electrode[2]. It effects in shifting of baseline that is known as low frequency baseline wander. The respiration frequency is similar as that of essential frequency of baseline wander. It is compulsory that baseline wander is eliminated from the ECG signal before extracting useful features [3]. In this paper we have employed the physiologic characteristics of QRS complex to detect the arrhythmia by calculating the features relay on R-peak like sharpness of R-peak, time duration of QRS complex, slope on both sides of R-peak. The classifier gives the output in the form of sensitivity, specificity and accuracy.

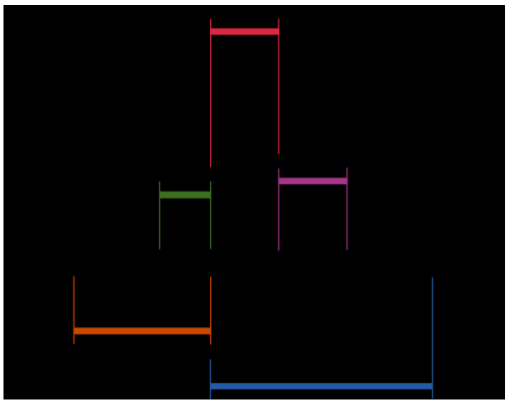

Figure 1. An Electrocardiogram waveform

TABLE I
SPECIFICATIONS OF ELECTROCARDIOGRAM SIGNAL[4],[5],[6]

Sr. no.	Characteristics	Voltage (mV)	Duration (ms)
1	P wave	0.1-0.2	60-80
2	PR-segment	-	50-120
3	PR- interval	-	120-200
4	QRS complex	1	80-120
5	ST-segment	-	100-120
6	T-wave	0.1-0.3	120-160
7	ST-interval	-	320
8	RR-interval	-	(0.4-1.2)s

Here the detailed description of each ECG wave given below:

WAVES	**DESCRIPTION**
P wave	This wave indicates the proper functioning of right and left atria and the magnitude level of this wave is low (approximately 0.1-0.2 mV) . A clean P wave ahead of the QRS complex represent sinus rhythm. It may propose atrial fibrillation, Junctional rhythm or ventricular rhythm if the P wave is absent. In the presence of very large SNR in ECG signal, P wave is hard to examine.
QRS complex	The magnitude level of this complex is very large (approximately1-2mV) but may vary from person to person and extent on age, gender. The magnitude level of this complex too help to provide knowledge about the heart related problems. It represents the time taken by the depolarization process of ventricles and also provides the instruction which indicates conductional related problems in bundle branch block of ventricles.
T wave repolarization	T wave indicates Process of ventricular. Larger T waves can cause ischemic Problem and Hyperkalaemia.[6]

II. METHODS AND MATERIAL

There are several steps involves in features extraction from ECG signal and classification

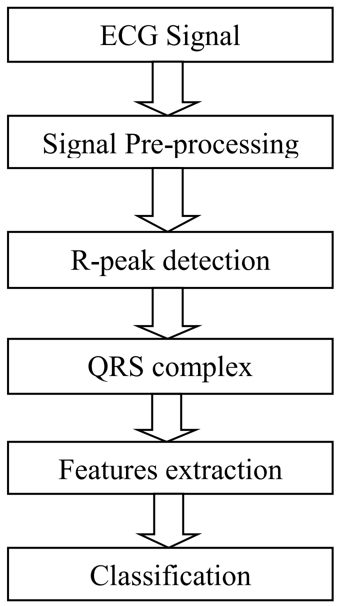

Figure 2. Block diagram for features extraction and classification

These steps are discuss below:-

A. ECG database

For this research, electrocardiogram signals are acquired from MIT-BIH arrhythmic record at physionet.org where the signals are explained by a text header file(.hea), a binary file (.dat) and a binary annotation file (.atr).Header file comprises of elaborated data about ECG signal like number of samples, sampling frequency , format of ECG signal, different types of electrocardiogram leads, detailed patients information and clinical information. The database contains the 48 sets which is divided into two set. These two sets is divided into normal and arrhythmia set.

B. Pre-processing

ECG signal mainly contain different types of noises or artifacts which distorts the original signal that creates the problems to extract the features from ECG signal so in this step we basically remove the noise from ECG signals. There are various kinds of artifacts similar to electrode contact artifacts, muscles artifacts, power line interference and so on. so basically to remove all these noises we designed a filter called IIR notch filter with sampling frequency of 360hz and cut-off frequency of 60hz.So that we can extract the features from ECG signals more precisely.

C. R-peak detection

After then pre-processing step, now we detected the R-peak of an ECG signal which is most important peak of an ECG signal. Any variation in R-peak can cause heart related problem like arrhythmia or any kind of diseases. We detected the R-peak by means of thresholding. Signal is thresholded at suitable level such that peak other than QRS complex's will suppressed at threshold level so by this we only got R-peak of an ECG signal. We set the threshold level at 150.

D. QRS detection

Now, After effectively recognition of R peak now we have to find out the QRS complex of an electrocardiogram signal. Magnitude of this complex is very large as compared to other waves. Its size vary from person to person, age and gender etc. QRS complex is detected by using DOM (difference operation method).In DOM ,it basically contains two parts thresholding and subtraction. In last step we have done thresholding now the threshold signal is subtracted by itself such that each samples value is subtracted from its predecessor sample value. This method is equivalent to differentiation of a signal which is used to check the slope and on differentiation the values at threshold level will give zero slopes. And the values before peak will give positive slope and after the peak give negative slope. Thus the point where slope changes for the first time will give the R peak. Difference operation method is used to get the Q and S peak.

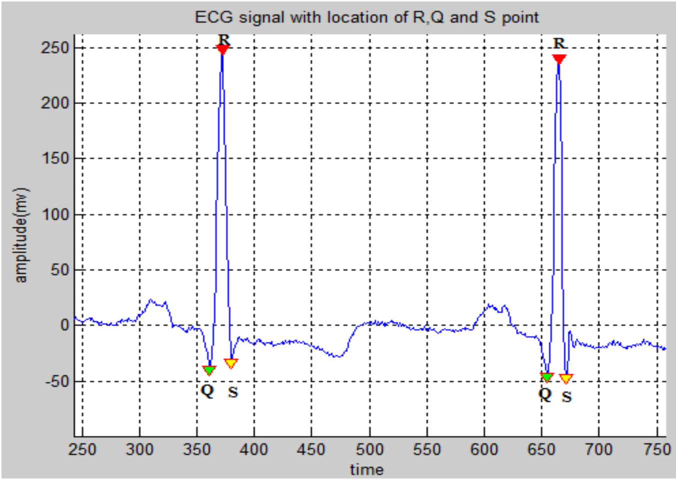

Figure 3 : QRS complex of ECG signal

E. Features extraction

The signal was initially filtered to remove all the noise present the signal after that ECG signal is analysed by detecting QRS complex, R-peak, Q and S peak. Because these are used to calculate the features like slope of curve RS and QR, sharpness of the peak, amplitude of peak and duration of the QRS complex. A matrix was construct of 1x5 which consists of amplitude of R-peak, QRS complex duration, slopes and sharpness of QRS complex. Fig. 4 shows the features of ECG signals.

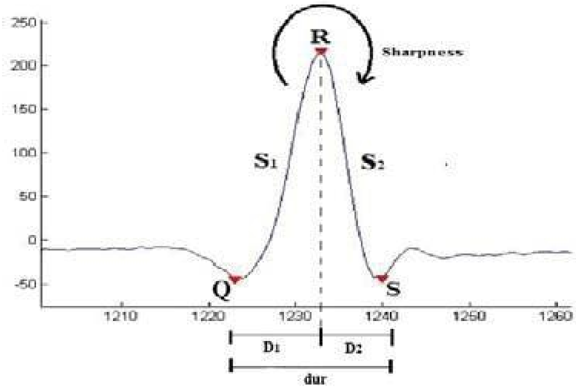

Figure 4 : Features of ECG signal

To retain consistency 12 peaks chosen indiscriminately from every subject for study. So it gave us a result in the form of 12x5matrix regarding to the 12 QRS peaks of an ECG signal.

All the calculation and programming done by using MATLAB software. All the features explained below:

(a). Slope

Analysis of QRS complex helps us to calculate the slopes (Slope QR) between Q and R and (Slope RS) R and S. It helps us to find out the arrhythmia because the slope of normal signal is different from arrhythmic signals. So the normal signal has less slope as compared to abnormal signal. The slope is calculated as follow:

$$\text{Slope}_{QR} = \frac{Q-R}{D_1}$$

$$\text{Slope}_{RS} = \frac{R-S}{D_2}$$

Here, D1 is the difference between Q and R and D2 is the difference between R and S and Q, R and S are the peaks of a QRS complex.

(b). Sharpness

It also helps to classify the normal and abnormal ECG signal it gives the sharpness of a peak. It determines the quality of a peak.

$$\text{Sharpness} = \text{slope}_{QR} - \text{slope}_{RS}$$

(c). Duration

Duration of an QRS complex leads to distinguish between normal and abnormal signal. The time interval between the Q and R in the QRS complex is known as the duration of QRS complex. It is denoted by 'dur' in fig. 4.

F. Classification

In this last step for the classification purpose we used linear classifier. A linear classifier achieves this by making a classification decision based on the value of a linear combination of the characteristics. An object's characteristics are also known as feature values and are typically presented to the machine in a vector called a feature vector.

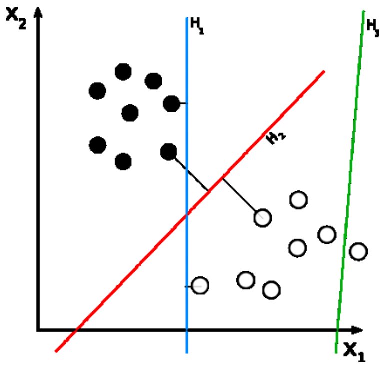

Figure 5 : Linear classifier

In this case, the solid and empty dots can be correctly classified by any number of linear classifiers. H1 (blue) classifies them correctly, as does H2 (red). H2 could be considered "better" in the sense that it is also furthest from both groups. H3 (green) fails to correctly classify the dots.

```
set=[];Fs=360;
[peak,slope1,slope2,sharpness,duration]=extract_features3(set_100m,Fs);
ind=find(sharpness<0);replace=sharpness(ind).*(-1);
sharpness(ind)=replace;clear ind;clear replace;
boxN=cat(1,peak,slope1,slope2,sharpness,duration);
[Apeak,Aslope1,Aslope2,Asharpness,Aduration]=extract_features3(set_220m,Fs);
ind=find(sharpness<0);replace=Asharpness(ind).*(-1);
Asharpness(ind)=replace;clear ind;clear replace;
boxA=cat(1,Apeak,Aslope1,Aslope2,Asharpness,Aduration);
[output]=Classifier(boxN,boxA);
```

Figure 6 : MATLAB code of linear classifier

III. RESULTS AND DISCUSSION

The extracted features gave as a input to the classifier. Efficiency of features and linear classifier combination for automatic arrhythmia detection has been tested. Classification of 8 subjects out of the 48 subjects taken indiscriminately for this research. ECG data were divided into two partition-one for trained the data called training set in which we used 75% data to trained the classifier and another for test the data called test set in which we used 25% data to test the classifier and classify the normal and arrhythmia signals. Now we obtained the data after classification in the form of 2 set i.e. Set_N and Set_A of 12x5 matrix. After that in multi fold cross validation method matrix of 9 x 5(75%) is taken for training and matrix of 3 x 5 (25%) is taken for testing. Now the entire data is divided into four iterations and results obtained were averaged. Classification's performance of classifier is measured with the help of confusion matrix define below:

$$\text{Confusion matrix} = \begin{matrix} \text{True positive} & \text{False positive} \\ \text{False negative} & \text{True negative} \end{matrix}$$

Classifications outcomes are explained in three terminologies specificity, sensitivity and accuracy defined as below:

$$\text{Specificity} = \frac{TN}{(TN + FP)}$$

$$\text{Sensitivity} = \frac{TP}{(TN + FN)}$$

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + FP + FN+TN)}$$

Here, True positive means the normal signals classified by classifier as a normal signals.

True negative means the abnormal signals classified by the classifier as an abnormal signals.

False negative means abnormal signals wrongly classified by the classifier as an normal signals.

False positive means normal signals wrongly classified by the classifier as an abnormal signals.

Now here we have taken one subject for classification purpose.

Now in first step we filtered the normal signal of a subject and done the DC offsetting as shown in fig.7.

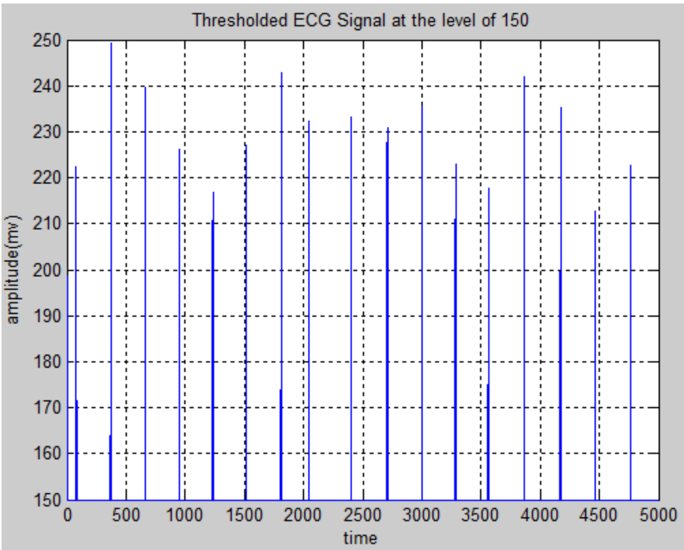

Figure 7 : Normal signal of a subject after filtering and dc offsetting

After filtering and dc offsetting now we set the threshold level so can get the R-peak. So we thresholded the normal signal at the level of 150 and got the R-peak as shown in fig.8.

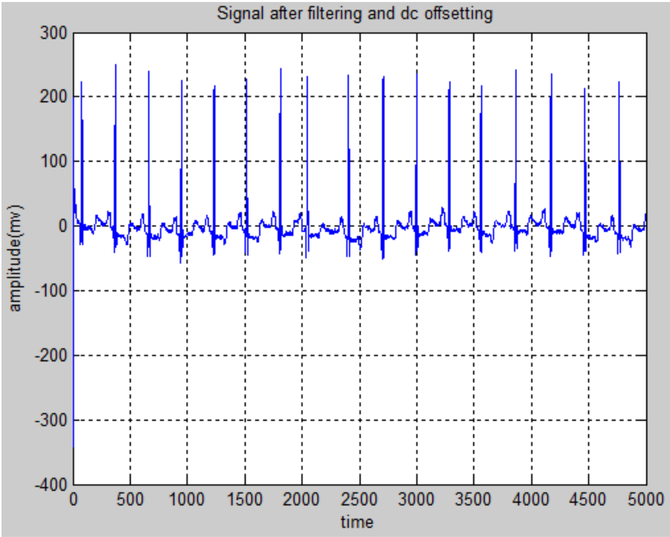

Figure 8 : ECG signal thresholded at the level of 150 for normal signal

After getting R-peak from thresholding now we applied DOM (difference operation method) to get the Q point and S point so we get the whole QRS complex as shown in fig.9.

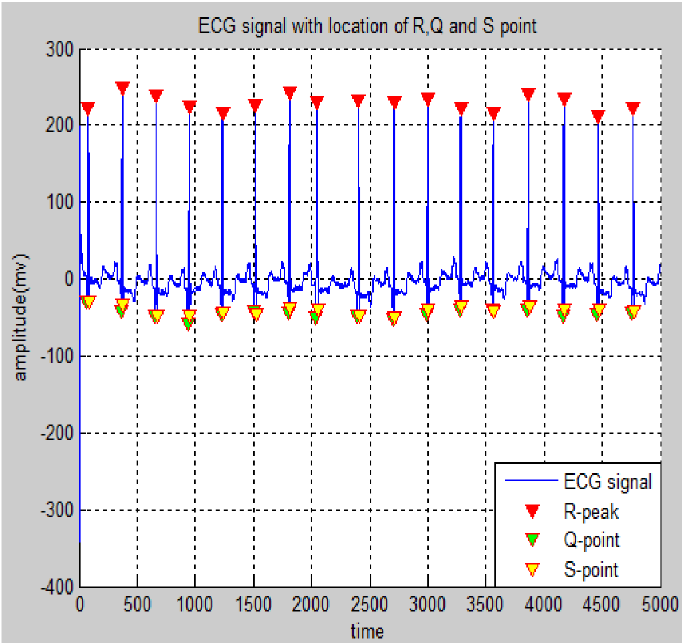

Figure 9 : Normal ECG signal with location of Q points, R peaks and S points

These all steps for the normal signal of a subject after this we extracted the features from a signal and did same for the arrhythmic signal of a subject for classification purpose.

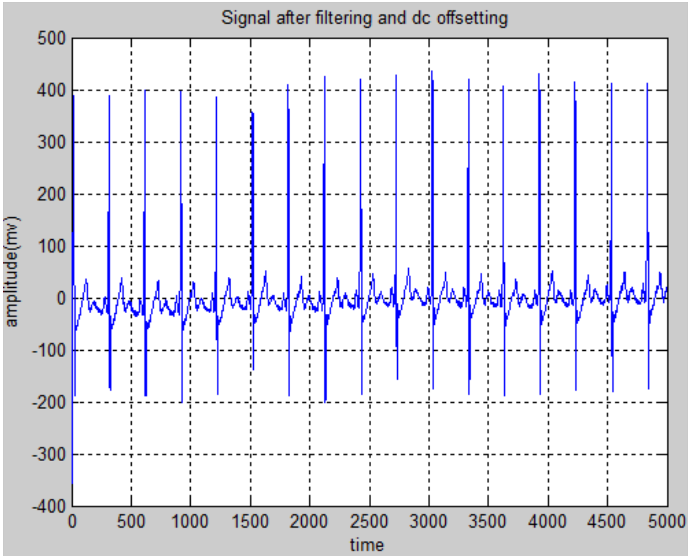

Figure 10 : Arrhythmic ECG signal of a subject after filtering and dc offsetting

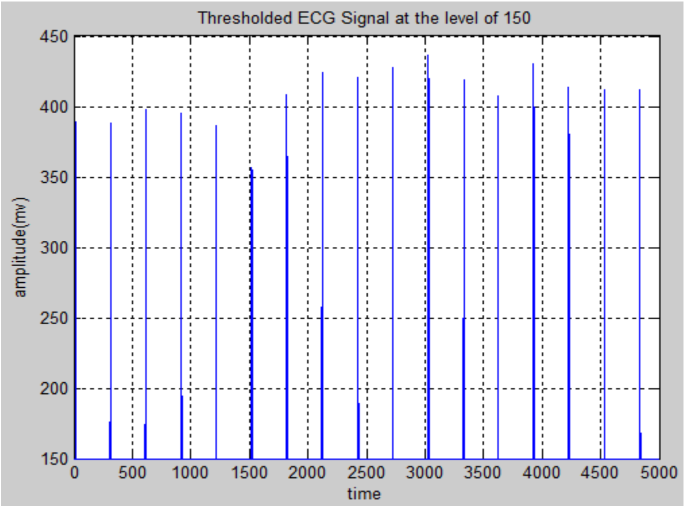

Figure 11 :: Arrhythmic ECG signal thresholded at the level of 150 for normal signal

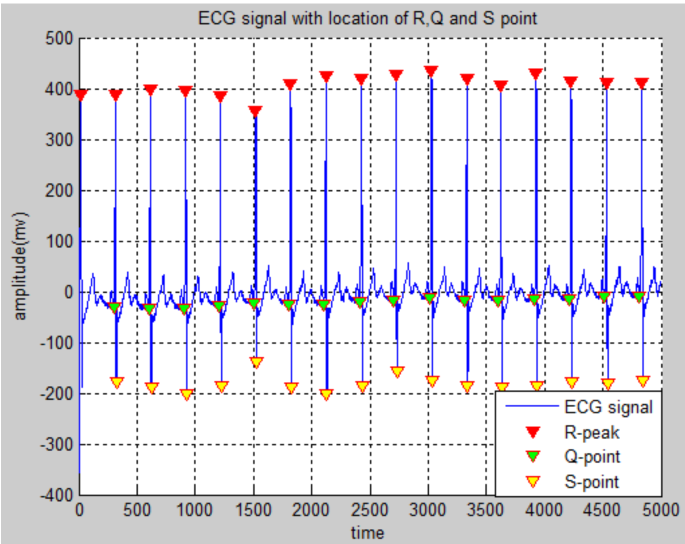

Figure 12 : Arrhythmic ECG signal with location of Q points, R peaks and S points

After features extractions now we gave the extracted features as s input to the classifier to classify the normal and abnormal signal of a subject. The classifier gave the output on the four iterations of a subject in the form of accuracy, specificity and sensitivity as shown in table-2 below:-

TABLE II
RESULTS USING THE FEATURES CALCULATED AND LINEAR CLASSIFIER FOR A SUBJECT

Partitions	Accuracy in (%)	Specificity in (%)	Sensitivity in (%)
1	100	100	100
2	100	100	100
3	100	100	100
4	100	100	100
Average	**100**	**100**	**100**

This is only for one subject after that we took 8 subjects in our research for the classification purpose and to detect the normal and arrhythmic signal and results came in the form of as same as for a subject described previous.

TABLE III
RESULTS USING THE FEATURES CALCULATED AND LINEAR CLASSIFIER FOR 8 SUBJECTS

Subjects	Accuracy in (%)	Specificity in (%)	Sensitivity in (%)
I	100	100	100
II	95.83	100	93.75
III	87.49	93.75	87.50
IV	100	100	100
V	95.83	93.75	100
VI	100	100	100
VII	87.49	87.50	93.75
VIII	95.83	100	93.75
Average	**95.30**	**96.87**	**96.09**

Finally we achieved accuracy 95.30%, specificity 96.87% and sensitivity 96.09%.

IV.CONCLUSION

In this research paper electrocardiogram (ECG) signal analysed to detect the arrhythmia using features extraction from ECG signal using difference operation method. After this all the features were applied to linear classifier to classify the normal and arrhythmic signal.

Eight subject is used in this research for classification and accuracy achieved in this method is about 95.30%.

V. ACKNOWLEDGMENT

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