Cardio logical Signal Processing for Arrhythmia Detection with Comparative Analysis of Q-Factor

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Abstract - *Electrocardiogram is a graph which measures the electrical activity of the heart. Normal heart beat for human is 70 cycles per minute. Any change in natural sequence of activities of heart e.g. beating too fast, too slow or erratically is Arrhythmia, and this can be detected by analyzing ECG of the subject. The recorded ECG potentials are usually contaminated by power-line frequencies, which lie within the frequency spectrum of ECG signal making it difficult to extract useful information from it, this interference is suppressed using 50/60Hz notch filter. . ECG signals first filtered by IIR notch, to remove the power line artifacts. It has been shown that notch filter application deforms the QRS complex of the electrocardiogram. In this paper a comparative analysis of the impact for different values of Q-factor of the notch filter, on QRS complex of Electrocardiogram has been shown. After filtering, QRS complex of an ECG signal identified. For detection of QRS complex DOM (difference operation method) is used. After successfully detection of QRS complex its R-peak, sharpness, slope and duration is calculated. For the classification purpose linear classifier is used, 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.*

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

1. INTRODUCTION

Electrocardiogram (ECG) is the record of the heart muscle electric impulse. ECG machine is a device through which we record this electrical activity. This device is connected by wires to electrodes pasted on patient's chests at particular position [1].. Around 12 million deaths occur worldwide each year due to cardiovascular diseases as stated by the World Health Organization. Due to the insufficient supply of blood in the heart the clogging occurs and thus Coronary Heart Disease (CHD) takes place [2][3][4]. The cardiac arrhythmias accounts for ninety percent of the deaths due to cardiovascular diseases [5]. Arrhythmias are seen as an abnormal function of the heart.

There have been several researches in the field of arrhythmia detection. Adams and Choi [5] proposed a method based on ANN to classify different arrhythmias using the QRS complex as features of ECG. Another neural network based classification of ECG for Premature Ventricular Contractions using Wavelet transform was done by Inan et al [6] with an accuracy of 88%. Patel et al [7] proposed arrhythmia detection method based on peak detection of QRS complex. They concluded that QR S complex is an important feature for classification of arrhythmia. Rahman and Nasor [8] used the QRS complex to define and classify different types of arrhythmia. Li, Zheng an d Tai [9] detected ECG characteristic points using wavelet transforms for the detection of QRS, T, and P waves[43].

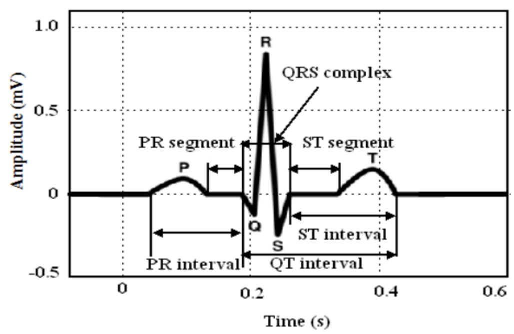

Fig.- 1: Schematic representation of normal ECG waveform

Table -1: Amplitude and duration of waves, intervals and segments of ECG signal.

Sl. no.	Features	Amplitude (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

ECG signal consists of a P wave, a QRS complex, and a T wave. Before contraction the electric currents due to atrial depolarization causes P ,while the depolarization due to ventricle contraction causes QRS complex. During recovery of the ventricles from the state of depolarization the T wave is formed.

The T wave is characterized as the wave of repolarization. The Figure 1 shows a representation of an ECG with the waves[10].

2. NOISE IN ECG SIGNAL

Unfortunately the acquired ECG does not only consist of the components derived from the electrical functionality of the heart, but it is very often contaminated by artifacts that can interfere or interrupt the signal and result in a loss of information. Sometimes, these artifacts might even present with similar morphology as the ECG[10] . The most commonly found artifacts in the ECG are:

1. Powerline interference, which is characterized by a frequency of 50 or 60 Hz depending on the country.
2. Steep voltage changes form the loss of contact between the electrodes and the skin.
3. Electrical activity from muscle contractions that varies from dc to10kHz.
4. Baseline drift which is usually caused from respiration at very low frequencies, around 0.1v 0.3Hz.

3. POWER LINE INTERFERENCES

In this paper we will deal with Power line interferences that contains 60 Hz pickup (in U.S.) or 50 Hz pickup (in India) because of improper grounding.

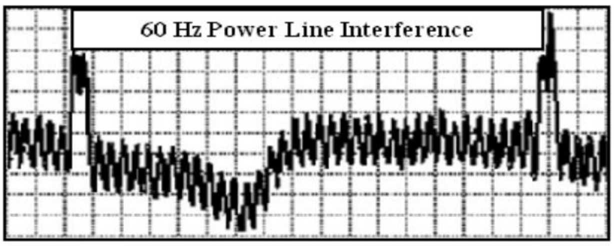

Fig-2: 60 Hz Power line interference.

It is indicated as an impulse or spike at 60 Hz/50 Hz harmonics, and will appear as additional spikes at integral multiples of the fundamental frequency. Its frequency content is 60 Hz/50 Hz and its harmonics, amplitude is up to 50 percent of peak-to-peak ECG signal amplitude. A 60 Hz notch filter can be used remove the power line interferences[10].

4. DATA USED

For this study, the data used is publicly available MIT-BIH arrhythmia database at physionet.org [12] The complete data set consist of 48 sets each containing set of 2 channels. Each set is divided into normal and arrhythmia set. The length of each recording is 27.7 seconds. The sampling rate of data is 360 Hz. In most records, the upper signal is a modified limb lead II (MLII), obtained by placing the electrodes on the chest. The lower signal is usually a modified lead V1 (occasionally V2 or V5, and in one instance V4); as for the upper signal, the electrodes are also placed on the chest [13].

5. NOTCH FILTER

The Notch Filter, (BSF) is a frequency selective circuit that functions opposite way to the Band Pass Filter. The band stop filter, also known as a band reject filter, passes all frequencies with the exception of those within a specified stop band which are greatly attenuated.

If this stop band is very narrow and highly attenuated over a few hertz, then the band stop filter is more commonly referred to as a notch filter, as its frequency response shows that of a deep notch with high selectivity (a steep-side curve) rather than a flattened wider band.

Also, just like the band pass filter, the band stop (band reject or notch) filter is a second-order (two-pole) filter having two cut-off frequencies, commonly known as the -3dB or half-power points producing a wide stop band bandwidth between these two -3dB points.

Then the function of a band stop filter is to pass all those frequencies from zero (DC) up to its first (lower) cut-off frequency point f_L, and pass all those frequencies above its second (upper) cut-off frequency f_H, but block or reject all those frequencies in-between. Then the filters bandwidth, BW is defined as: $(f_H - f_L)$[15].

6. NOTCH FILTER DESIGNING IN MATLAB

[NUM,DEN] = IIRNOTCH(ωo,BW) designs a second-order notch digital filter with the notch at frequency ωo and a bandwidth of BW at the -3 dB level.

The bandwidth BW is related to the Q-factor of a filter by

$$BW = \omega o/Q.$$

7. METHODOLOGY TO CLASSIFY ARRHYTHMIC SIGNALS

7.1 Pre-processing

ECG signal mainly contain different types of noises or artifacts which distorts the original signal that creates the

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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.

7.2 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.

7.3 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.

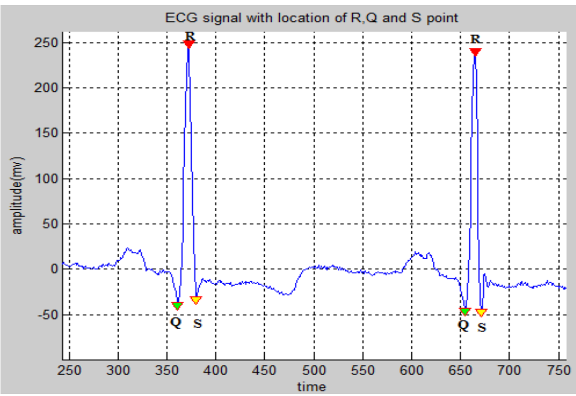

Fig.-3: QRS complex of ECG signal

7.4 Features extraction

The signal was initially filtered to remove all the noise present the signal after that ECG signal is analyzed 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. 5 shows the features of ECG signals.

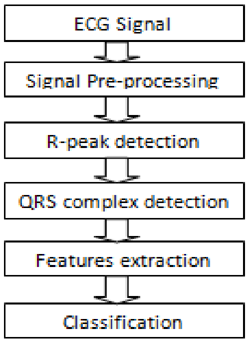

Fig.-4: Block diagram for features extraction and classification

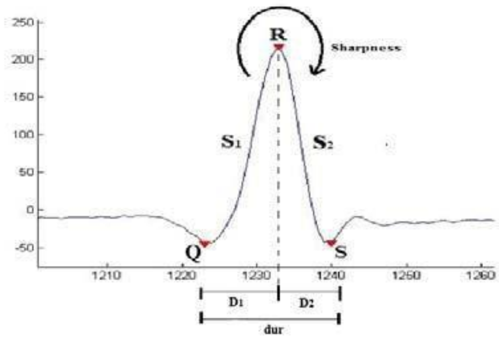

Fig.-5 : Features of ECG signal

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:

7.4.1 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:

$$\text{Slope QR} = \frac{Q-R}{D1}$$

$$\text{Slope RS} = \frac{R-S}{D2}$$

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.

7.4.2 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.

Sharpness= slope QR - slope RS

7.4.3 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. 5.

7.5 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

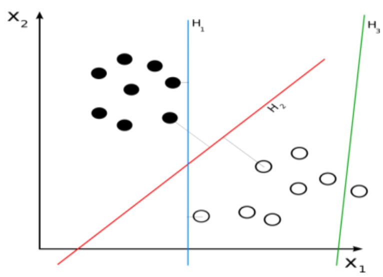

Fig-.6: Linear classifier

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.

8. RESULTS

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:

$$\text{Confusion matrix} = \begin{vmatrix} \text{True Positive} & \text{False Positive} \\ \text{False Negative} & \text{True Negative} \end{vmatrix}$$

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

Now here we have taken one subject for classification purpose.

Removing 60Hz frequency Component

For Q=2

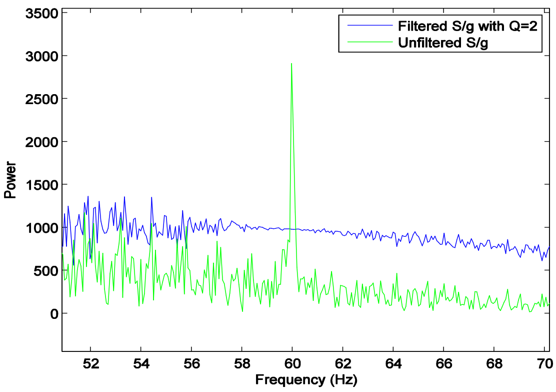

Fig-7: FFT spectrum of filtered and unfiltered ecg Signal with Q=2

R,Q,S peaks for Q=2

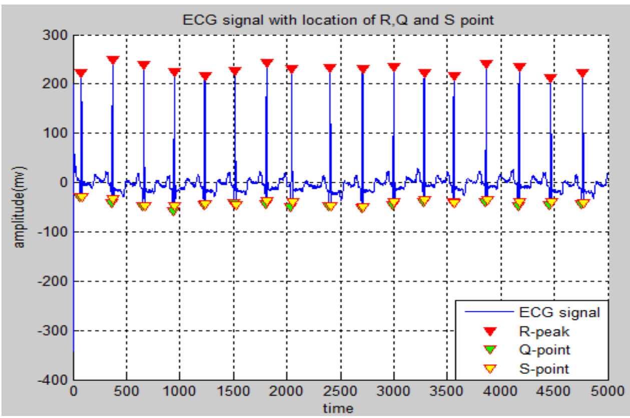

Fig-8: Normal ECG signal with location of Q points, R peaks and S points

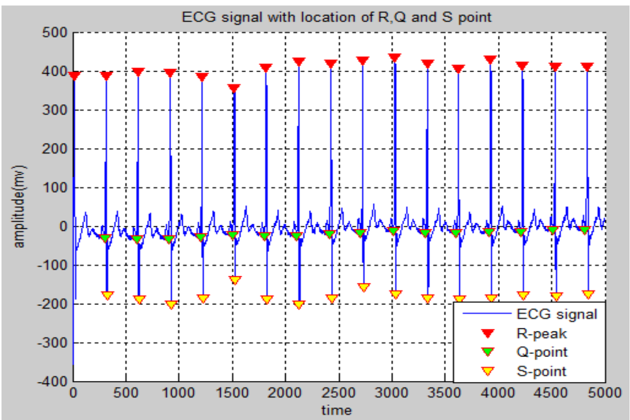

Fig-9: Arrhythmic ECG signal with location of Q points, R peaks and S points

Table -2: Accuracy, Sensitivity and Specificity of classifier in case of Q=2.

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**

For Q=35

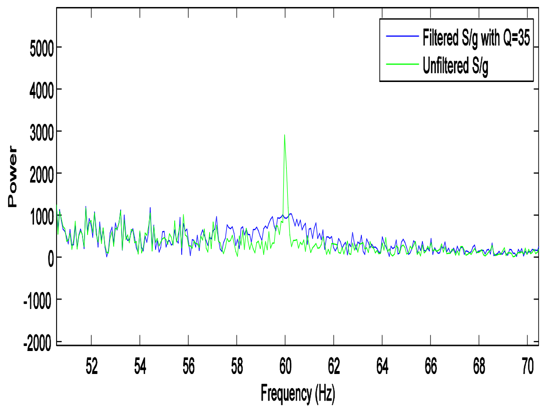

Fig-10 FFT spectrum of filtered and unfiltered ecg Signal with Q=35

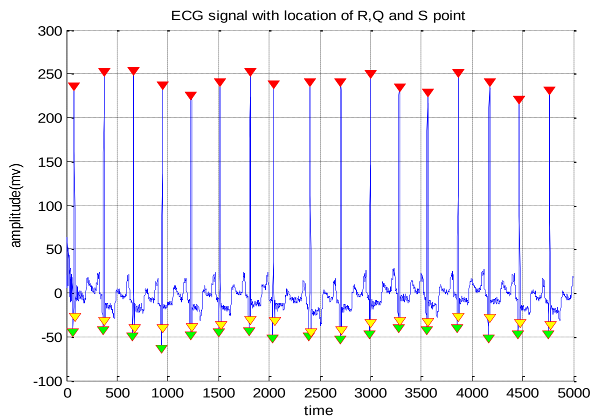

Fig-11: Normal ECG signal with location of Q points, R peaks and S points with Q =35

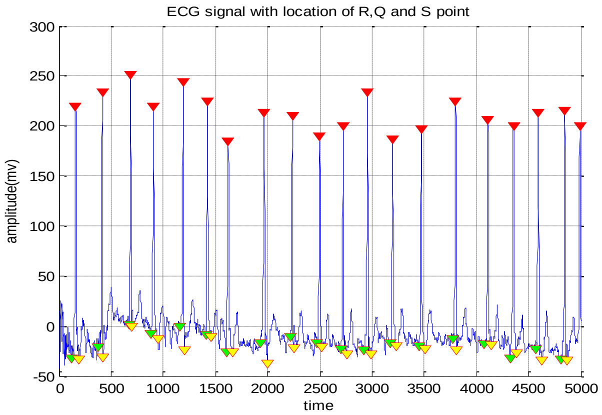

Fig-12: Arrhythmic ECG signal with location of Q points, R peaks and S points with Q=35

Comparison of notch filtered output of Q=35 and Q=15

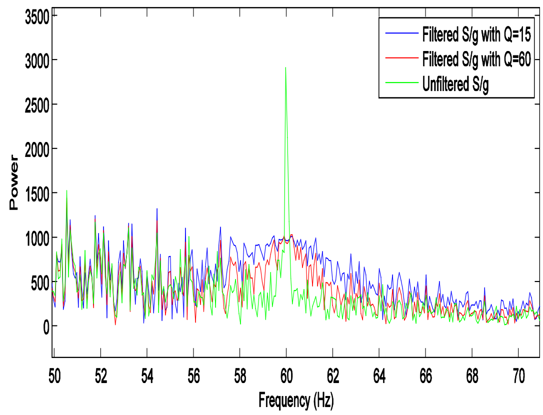

Fig.7 FFT spectrum Comparison of filtered ecg Signal with Q=15 and 60

Table -3 Results showing Index no. of R-peak for Q-factor=2 and Q-factor=35

S.No.	Q Factor	Peak No	Index of R peak	Q Factor	Peak No	Index of R peak
1	2	1	5	35	1	
2	2	2	79	35	2	78
3	2	3	372	35	3	371
4	2	4	665	35	4	664
5	2	5	949	35	5	948
6	2	6	1233	35	6	1232
7	2	7	1517	35	7	1516
8	2	8	1811	35	8	1810
9	2	9	2044	35	9	2046
10	2	10	2404	35	10	2404

Table -4 Results showing percentage change in amplitude of R-peak for Q-factor=2 and Q-factor=35

S.No.	Peak No	Percentage change in amplitude
1	1	-
2	2	6.00785
3	3	1.225169
4	4	5.646113
5	5	4.500548
6	6	3.776180
7	7	5.628712
8	8	3.751535
9	9	2.838984
10	10	3.320069

9. CONCLUSIONS

For the filtering of power line frequency (60Hz for U.S.A and 50Hz for India) designing of notch filter is important step. Only after this we can extract various features from ECG signal i.e. R-R interval, Q and S peak, R peak etc. For notch filter designing the value of Quality factor is crucial .The Fast Fourier Transform spectrum of filtered and unfiltered signal with different values of Q is shown above. As seen from the results for low value of Q deformation of frequency spectrum is more as compared to the higher Q-factor. All the plots above reflects that for all values of Q there is significant suppression of 60 Hz component. Results shown in table1 and 2 clearly indicates towards the deformation of QRS complex due to the notch filter used for suppression of power line frequency. Thus concluded that deciding Q-factor for the notch filter plays important role in its implementation. However the sensitivity accuracy and specificity remains same in both the cases.

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