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A Patient-Adaptive Technique For ECG QRS Extraction

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Abstract- **Electrocardiogram (ECG) signal feature parameters are the basis for signal Analysis, Diagnosis, Authentication and Identification performance. These parameters can be extracted from the intervals and amplitudes of the signal. The first step in extracting ECG features starts from the exact detection of R Peak in the QRS Complex. The accuracy of the determined temporal locations of R Peak and QRS complex is essential for the performance of other ECG processing stages. Individuals can be identified once ECG signature is formulated. This is an initial work towards establishing that the ECG signal is a signature like fingerprint, retinal signature for any individual Identification. Analysis is carried out using MATLAB Software. The correct detection rate of the Peaks is up to 99% based on MIT-BIH ECG database.**

Keywords- **Filtering, Squaring Function, Moving Window Integral, Thresholding, False Positive and False Negative.**

1.INTRODUCTION

The *Electrocardiogram* is the electrical manifestation of the contractile activity of the heart. It is a graphical record of the direction and magnitude of the electrical activity that is generated by depolarization and polarization of the atria and ventricles. It provides information about the heart rate, rhythm, and morphology. The importance of the Electrocardiography is remarkable since heart diseases constitute one of the major causes of mortality in the world. ECG varies from person to person due to the difference in position, size, anatomy of the heart, age, relatively body weight, chest configuration and various other factors. There is strong evidence that heart's electrical activity embeds highly distinctive characteristics, suitable for various applications and diagnosis.

The power spectrum of the ECG signal can provide useful information about the QRS complex. This section reiterates the notion of the power spectrum presented earlier, but also gives an interpretation of the power

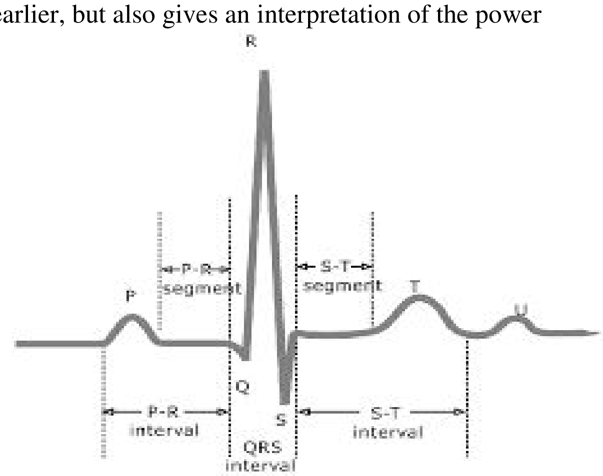

Fig i-An ECG signal with its peaks.

spectrum of the QRS complex. The power spectrum (based on the FFT) of a set of 512 sample points that contain approximately two heartbeats results in a series of coefficients with a maximal value near a frequency corresponding to the heart rate. The heart rate can be determined by multiplying together the normalized frequency and the sampling frequency. We can also get useful information about the frequency spectrum of the QRS complex. In order to obtain this information, the QRS complex of the ECG signal must be selected as a template and zero-padded prior to the power spectrum analysis. The peak of the frequency spectrum obtained corresponds to the peak energy of the QRS complex.

2.FILTERING TECHNIQUES

1. Low-pass filter.
2. High pass filter.

3.SQUARING FUNCTION

The previous processes and the moving-window integration, which is explained in the next section, are linear processing parts of the QRS detector. The squaring function that the signal now passes through is a nonlinear operation. This operation makes all data points in the processed signal positive, and it amplifies the output of the derivative process nonlinearly. It emphasizes the higher frequencies in the signal, which are mainly due to the QRS complex. A fact to note in this operation is that the output of this stage should be hard limited to a certain maximum level corresponding to the number of bits used to represent the data type of the signal.

4.MOVING WINDOW INTEGRAL

The slope of the R wave alone is not a guaranteed way to detect a QRS event. Many abnormal QRS complexes that have large amplitudes and long durations (not very steep slopes) might not be detected using information about slope of the R wave only. Thus, we need to extract more information from the signal to detect a QRS event. Moving window integration extracts features in addition to the slope of the R wave.

The width of the window should be approximately the same as the widest possible QRS complex. If the size of the window is too large, the integration waveform will merge the QRS and T complexes together. On the other hand, if the size of the window is too small, a QRS complex could produce several peaks at the output of the stage. The width of the window should be chosen experimentally. For a sample rate of 200 sps, the window chosen for this algorithm was 30 samples wide (which corresponds to 150 ms).

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5.THRESHOLDING

The set of thresholds that Pan and Tompkins (1985) used for this stage of the QRS detection algorithm were set such that signal peaks (i.e., valid QRS complexes) were detected. Signal peaks are defined as those of the QRS complex, while noise peaks are those of the T waves, muscle noise, etc. After the ECG signal has passed through the band pass filter stages, its signal-to-noise ratio increases. This permits the use of thresholds that are just above the noise peak levels. Thus, the overall sensitivity of the detector improves.

Two sets of thresholds are used, each of which has two threshold levels. The set of thresholds that is applied to the waveform from the moving window integrator is

SPKI = 0.125 *PEAKI* + 0.875 *SPKI*

if *PEAKI* is the signal peak

NPKI = 0.125 *PEAKI* + 0.875 *NPKI*

if *PEAKI* is the noise peak

THRESHOLD I1 = *NPKI* + 0.25 (*SPKI* – *NPKI*)

THRESHOLD I2 = 0.5 *THRESHOLD I1*

All the variables in these equations refer to the signal of the integration waveform and are described below:

PEAKI is the overall peak.

SPKI is the running estimate of the signal peak.

NPKI is the running estimate of the noise peak.

THRESHOLD I1 is the first threshold applied.

THRESHOLD I2 is the second threshold applied.

A peak is determined when the signal changes direction within a certain time interval. Thus, *SPKI* is the peak that the algorithm has learned to be that of the QRS complex, while *NPKI* peak is any peak that is not related to the signal of interest. As can be seen from the equations, new values of thresholds are calculated from previous ones, and thus the algorithm adapts to changes in the ECG signal from a particular person. Whenever a new peak is detected, it must be categorized as a noise peak or a signal peak. If the peak level exceeds *THRESHOLD I1* during the first analysis of the signal, then it is a QRS peak. If search back technique (explained in the next section) is used, then the signal peak should exceed *THRESHOLD I2* to be classified as a QRS peak. If the QRS complex is found using this second threshold level, then the peak value adjustment is twice as fast as usual:

SPKI = 0.25 *PEAKI* + 0.75 *SPKI*

The output of the final filtering stages, after the moving window integrator, must be detected for peaks. A peak detector algorithm finds peaks and a detection algorithm stores the maximum levels at this stage of the filtered signal since the last peak detection. A new peak is defined only when a level that is less than half the height of the peak level is reached.

6.SEARCH BACK TECHNIQUES

To implement the search back technique, the algorithm maintains two RR-interval averages. One average, *RR AVERAGE1*, is that of the eight most recent heartbeats.

The other average, *RR AVERAGE2*, is the average of the eight most recent beats which had *RR* intervals that fell within a certain range.

RR AVERAGE1 = 0.125 (*RRn* – 7 + *RRn* – 6 + … + *RRn*)

RR AVERAGE2 = 0.125(*RR'n* – 7 + *RR 'n* – 6 + …+ *RR 'n*)

The *RR'n* values are the *RR* intervals that fell within the following limits:

RR LOW LIMIT = 92% × RR AVERAGE2

RR HIGH LIMIT = 116% × RR AVERAGE2

Whenever the QRS waveform is not detected for a certain interval, *RR MISSED LIMIT*, then the QRS is the peak between the established thresholds mentioned in the previous section that are applied during search back.

RR MISSED LIMIT = 166 % × RR AVERAGE2

The heart rate is said to be normal if each of the eight most recent RR intervals are between the limits established by *RR LOW LIMIT* and *RR HIGH LIMIT*.

➢ *QRS detector algorithm processing steps.*

Observe the output of each of the stages in the QRS detector. Sketch or print one cycle of the original ECG signal and the outputs of the low-pass, band pass, derivative, squaring, and moving window integrator stages. Note the filter delay at each of these stages.

➢ *Effect of the value of the Q of a filter on QRS detection.*

Implement several two-pole recursive filters with 17-Hz center frequencies to observe the effects of different values of *Q* on the ECG. The value of *r* produces the most desirable response for detecting the QRS complex.

False positives (FP) and false negatives (FN) have been reflected in the table as erroneously detected beats and missed beats, respectively. The overall error is calculated as follows:

Error = (FP+FN)/ Total # of beats.

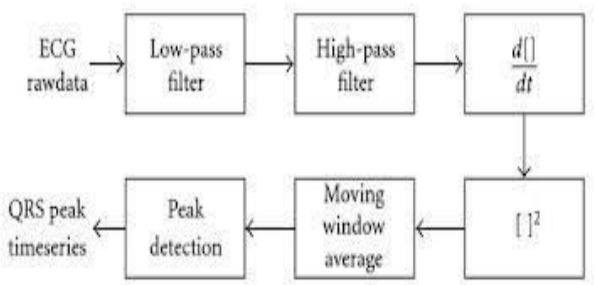

Fig ii- Block diagram of the whole process execution.

Fig iii-ECG signal after the QRS peak detection.

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Table 1- Data obtained for different MIT/BIT signals with Error percentage.

Data #	# of beats	# of FP	# of FN	Error	Error%
100	2265	0	0	0	0%
101	1861	3	3	6	0.32%
102	2180	0	0	0	0%
103	2078	0	1	1	0.04%
104	2222	5	5	10	0.45%
105	2565	1	0	1	0.03%
106	2021	0	0	0	0%
107	2128	8	10	18	0.84%
108	1755	0	2	2	0.11%
109	2521	8	5	13	0.51%
111	2130	12	1	13	0.61%
112	2532	4	4	8	0.31%
113	1789	0	0	0	0%
114	1897	24	3	27	1.42%
115	1946	0	0	0	0%
116	2387	6	22	28	1.17%
117	1530	3	4	7	0.45%
118	2284	15	0	15	0.65%
119	1981	1	0	1	0.05%
121	1856	2	2	4	0.21%
122	2468	0	0	0	0%
123	1514	1	0	1	0.06%
124	1613	12	12	24	1.48%
	s=47,523	# of fp beats=105	# of fn beats=74	Total error=179	Total error%=0.37%

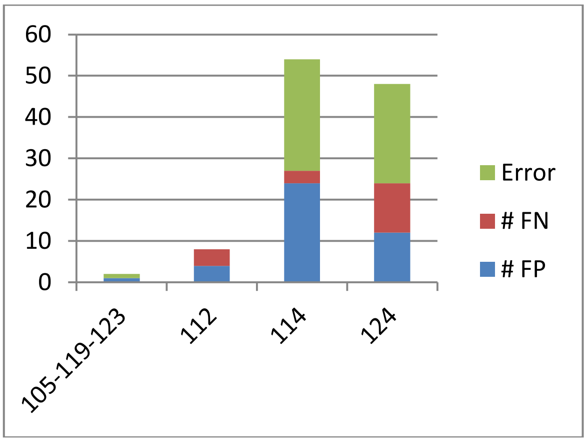

Fig 1- The value of FN, FP and Error for different MIT/BIH signals.

7.Limitations Faced

Many times when ECG signal is recorded from surface electrode that are connected to the chest of patient, the surface electrode are not tightly in contact with the skin, as the patient breath the chest expand and contract producing a relative motion between skin and electrode. This results in shift in the baseline which is also known as low frequency baseline wander. Obviously the fundamental frequency of baseline wander is same as that of respiration frequency. It is required that this baseline wander is to be removed from the ECG signal before extraction of any meaningful feature. Baseline wander makes manual and automatic analysis of ECG records difficult, especially in the detection of ST- segment deviations. This segment is very important and has the information about the heart attack. Since the spectrum of baseline wander and low frequency component of ECG signal usually overlaps, removing baseline wander may cause distortion of important clinical information.

8.Conclusion

Many existing studies on QRS extraction show high sensitivity and explicit type of transformation such as (wavelet, sine, cosine etc) also some other methods present a hardware real time system of processing entire ECG data. Our proposed method is very easy to implement and does not need any additional transformation, it is applied directly on the ECG data itself. To make the system more accurate and to implement in real time, signals are processed and work is done in MATLAB for better results. The total error in analyzing about 47,523 beats is 0.37 percent, corresponding to an average error rate of 14 beats per hour. The examination of the ECG has been comprehensively used for diagnosing many cardiac diseases. This technique can be used for ECG beat classification for raising early warnings.

Miad and Adnan's Algorithm	Our Algorithm
Lab View's wavelet detrending and denoising.	Digital Band pass Filter Denoising.
No integrator required.	Diffrentiator Required.
Only one threshold computations.	Two threshold Computations.
PEAK and NPK computed only once by Lab View's WA Peak Detector.	PEAKI and NPKI computed recursively in each window.
Only one RRavg required.	Two RRavg values required.
Search back algorithm for 166% of RRavg, THR/8.	Search back algorithm for 166% of RRavg, THR/2.

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Authors Profile

Saurabh Kumar Choudhary has done his under graduation from Shri Shankaracharya Group of Institutions in Electronics and Telecommunication department. He wishes to pursue higher studies in the United States. His work was very much appreciated at Indian Institute of technology, Delhi.

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His area of interests are Wireless communication and Microcontrollers. He has worked on many projects in the telecommunication field.

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