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A NOVEL APPROACH FOR R-PEAK DETECTION IN THE ELECTROCARDIOGRAM (ECG) SIGNAL

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ABSTRACT

The research article proposes the effective method for R-peak detection in the ECG signal. The improper beating of the heart called cardiac arrhythmia which is risk to human. The ECG samples are taken from physionet (physio bank ATM). Analysis of ECG signal and detection of R-Peaks is discussed in this paper. Initially the noise is removed from the signal using FFT technique, windowing technique and thresholding technique to detect R-peaks. In the ECG signal processing one can encounter the difficulties like unequal distance between peaks, irregular peak form, occurrence of low-frequency components due to patient breathing etc., In order to resolve and reduce the effect of these factors processing pipeline should contain particular stages which is discussed in the paper and the R-peak detection algorithm is implemented in MATLAB R 2012b.

Keywords: electrocardiogram, MATLAB R 2012b, cardiac arrhythmia, R-peaks detection.

1. INTRODUCTION

Electrocardiogram (ECG or EKG) signal plays a vital role in the clinical diagnosis of the health conditions of human heart. ECG is an investigative tool which measures and registers the electrical motion of the heart in detail. ECG is produced by a nerve impulse stimulus to a heart. The electric current is diffused around the body surface through which the current at the body surface will build on the potential drop (voltage) which is very small ranging from microvolt to mill volts with an impulse variation, this voltage is small in amplitude of impulse, which needs several hundred times of amplification. It's a periodic signal which lasts for 0.9 seconds and it consistsa waveform P,Q,R,S and T as shown in Figure-1 and the normal amplitude values of P,Q,R,S and T are shown in Table-1(a)[7].

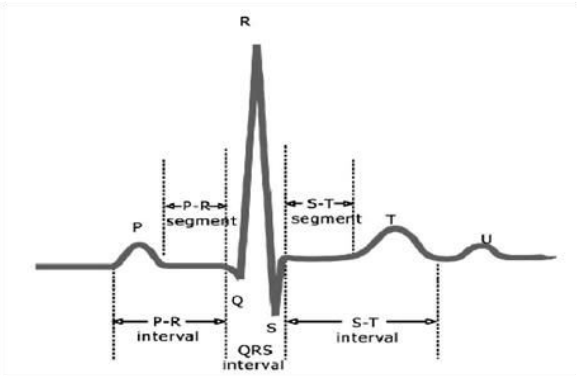

Figure-1. Normal ECG signal.

Table-1(a). Standard ECG data.

Amplitude		Duration	
P wave	0.25 mV	P-R interval	0.12 to 0.20 Sec
R wave Q wave	1.60mV 25% of R wave	Q-T interval S-T segment	0.35 to 0.44 Sec 0.05 to 0.15 Sec
T wave	0.1 to 0.5mV	P wave Interval	0.11 sec
		QRS complex	0.09 Sec
		PR segment	0.06 to 0.10 Sec
		ST segment T wave	0.10 to 0.15 sec Varies

The rapid depolarization of the ventricles is characterized by the QRS complex which takes less than 0.09 Seconds [3].QRS complex is the most important part in the ECG signal; especially the features of R-Wave in the QRS complex play a vital role in the pathological diagnosis. ECG is associated with different noises when it is recorded. It may have variety of noises such as base line wander the 50 Hz power line interference etc., These type of noises disrupts the original signal and the detection of R-peaks. For this purpose a reliable and efficient R-peak detection is essential.

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2. METHODOLOGY

The proposed methodology is depicted in the Figure-2R-peak detection structure

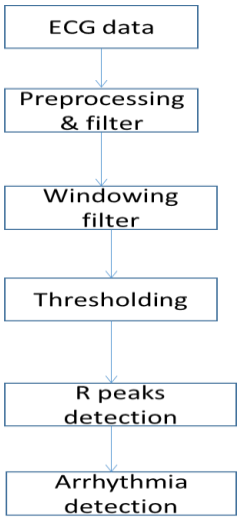

Figure-2. Block diagram of complete process of R -peak detection.

Steps for R -peaks detection in the ECG signal:

Step 1:ECG sampled data is taken from website and FFT technique is applied

A noisy ECG samples are taken from the website physionet.org [4] The graph shown in Figure-3 is un even thusfirst step is to straighten it.In order to straighten it all the low frequency components should be removed. The X-axis values represent samples and the Y-axis represents the Voltage. Apply the Fast Fourier transform-FFT to the ECG signal Figure-3 using Equation (1)

$$X(K) = \sum_{n=0}^{N-1} x(n)\, e^{\frac{-j2\pi nk}{N}}$$

Where K= 0,1,2…….N-1; (1)[2]

Again IFFT is applied to the signal to get back the original time domain signal.]

$$x(n)=\frac{1}{N}\sum_{K=0}^{N-1} X(K) e^{\frac{j2\pi nk}{N}}$$

where n= 0,1,2…….K-1;(2)[2]

Equation (1) remove low frequencies by using FIR filter and restore ECG with the help of inverse Fast Fourier transform using equation (2) The result of FFT processing is shown in Figure-4.

Step 2: Using a windowing filter.

Second step is to find local maxima that observe only maximum in the window and ignore the others. This method has its background in the processing of signals through which the windowing operation performs the spectral analysis of non-periodic signals. In this step the window of default size is used as a result in Figure-5.

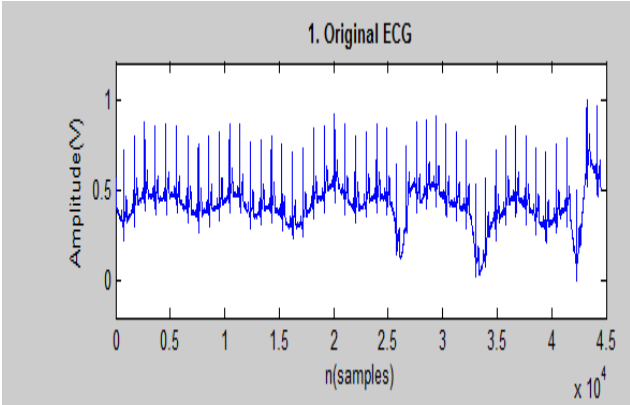

Figure-3. Original ECG signal.

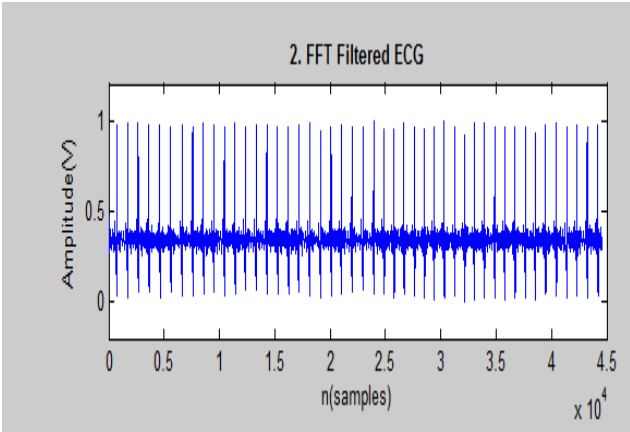

Figure-4. FFT filtered signal.

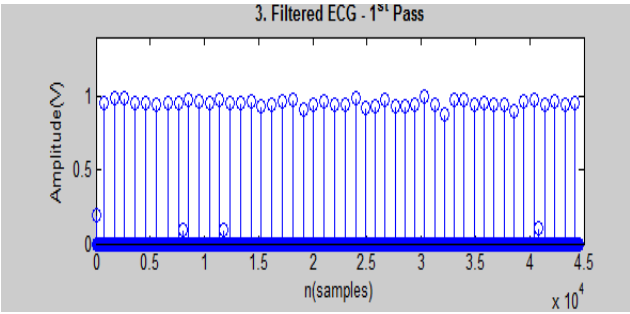

Figure-5. Filtered ECG-1st pass.

Step 3: Thresholding

After the step of windowing filter apply the threshold filter to remove the small peaks and preserve the significant ones. The graph afterapplying the threshold filter appears asin Figure-6.

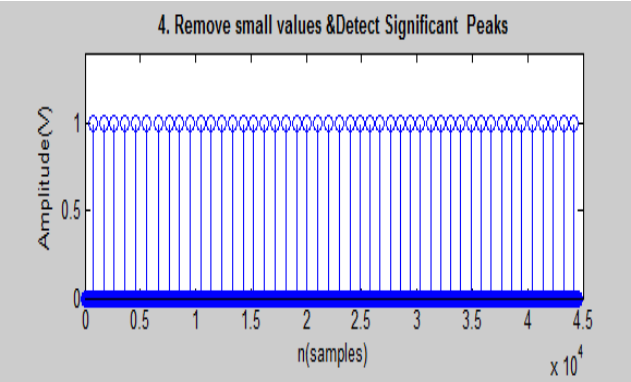

Figure-6. Detected peaks.

Step 4: Adjusted filter

From Figure-6 it is observed that the result is satisfying but it does not assure that it will have all the peaks in general case. To overcome this, the size of the filter window is altered and techniques of filtering are repeated in Figure-7.The quality of graph is more desirable than Figure-6.

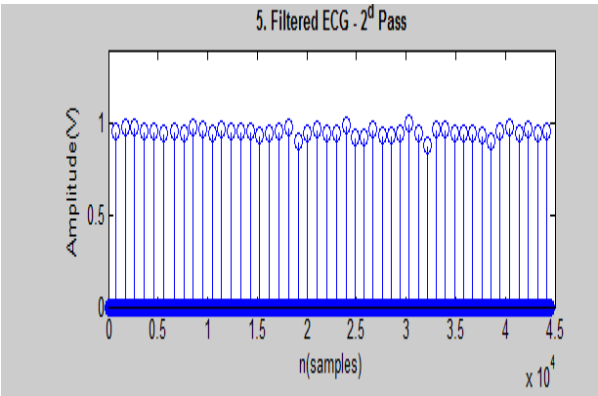

Figure-7. Filtered ECG - Second pass.

Step 5: Final result of peaks is shown in Figure-8 and Figure-9 shows the overlapped R peaks which is used for the heart rate calculation.

Heart rate calculation: The number of times a heart beats per minute is heart rate. For a normal person, heart beats 60 to 100 times per minute so the normal value is 60 to 100 beats per minute.

If the heart rate is slower, then the condition is called Bradycardia. If the heart rate is higher, then it is tachycardia and unevenly spaced cycles specify an arrhythmia [10]. If PR interval is more than 0.2 Sec, blockageof AV node is indicated. The equation to calculate heart rate is given below:

Heart Rate=(1/RR Interval in sec)*60 (3)[1]

Bradycardia: If heart beats less than 60 BPM [8] then it is slower heart rate. This condition can be observed in athletes and the patients suffering from jaundice, myxedema and in patients with increased intra carinal pressure.

Tachycardia: If heart rate is greater than 100 BPM it is tachycardia. Atrium having ectopic focus that regularly beats at a higher rate [8] causes tachycardia.

The heart rate can be calculated from the Figure-8

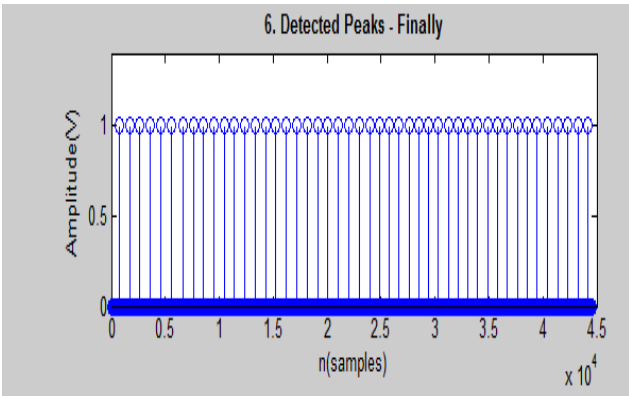

Figure-8. Final detected peaks.

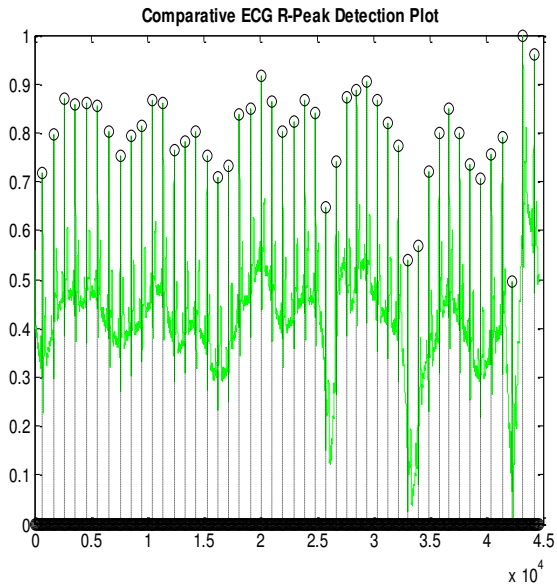

Figure-9. ECG R-peak detection plot.

3.RESULTS AND ANALYSIS

The ECG samples are taken from physionet.org website and the proposed R-peak detection algorithm is executed. The algorithm besides the accuracy of the detection, the processing time of the algorithm is optimized. As discussed in the paper to calculate heart beat and to check the cardiac arrhythmia steps from Figure-3 to Figure-7 are carried out and got the BPM as 68 (i.e. Normal Heart beat) using equation(3) the same steps are repeated for the 10 ECG samples from the database. Each record is slightly over 1 min in length and sampled at 1000 Hz shown in belowTable-1(b).From the Table-1 (b) it can be concluded that the patient details of S. No. 1,3,5,7,8 and 10 are normal heart beat whereas S. No. 4 & 9 observed bradycardia and S. No. 2 and 6 observed tachycardia.

Table-1(b). Patient details and Heart rate.

S. No.	ECG sample collected from physionet.org database	Heart rate from RR interval	Normal	Bradycardia	Tachycardia
1	Record ptbdb/patient001/s0014lre from 0:00.000 to 1:00.000	67	Normal	----------	---------
2	Record ptbdb/patient003/s0017lre from 0:00.000 to 1:00.000	112	-------	-------	Tachycardia
3	Record ptbdb/patient007/s0026lre (i) , from 0:00.000 to 1:00.000	72	Normal	----------	---------
4	Record ptbdb/patient035/s0145lre (ii) from 0:00.000 to 1:00.000	53	-------	Bradycardia	---------
5	Record ptbdb/patient067/s0230lre (iii) , from 0:00.000 to 1:00.000	75	Normal	----------	---------
6	Record ptbdb/patient180/s0545_re (avr) , from 0:00.000 to 1:00.000	115	-------	-------	Tachycardia
7	Record ptbdb/patient219/s0441_re (avr) , from 0:00.000 to 1:00.000	78	Normal	----------	---------
8	Record ptbdb/patient286/s0546_re , from 0:00.000 to 1:00.000	84	Normal	----------	---------
9	Record ptbdb/patient289/s0550_re , from 0:00.000 to 1:00.000	56	-------	Bradycardia	---------
10	Record ptbdb/patient294/s0559_re , from 0:00.000 to 1:00.000	68	Normal	----------	---------

4. CONCLUSIONS

R-peak detection algorithm is executed using pre-processing and filtering techniques, Windowing techniques and thresholding. The information obtained from the detection of R-peaks is very helpful for classification analysis and detection of arrhythmia such as tachycardia and Bradycardia. This algorithm gives the best locations of R-peaks from which R-R interval can be easily computed and heart beat rate can be calculated. From the Table-1 (c) the heart rate for the 10 ECG samples are calculated. The main advantage of this algorithm is taking less time for long time ECG signals.

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