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R-Peak Detection by Modified Pan-Tompkins Algorithm

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ABSTRACT

Electrocardiogram (ECG) analysis and its interpretation are performed by signal processing in majority of the systems. The objective of the ECG signal is diversified and encompasses the enhancement of measurement accuracy. In some cases, the ECG is recorded in peripatetic and exhausting conditions as a result the ECG signals are contaminated by various types of noise, which originates from different physiological process of the body. Thus, noise reduction [1] also plays an important role in ECG signal processing. Sometimes, ECG signal are strongly masked with the noise, in order to remove the noise we have to perform relevant Signal processing. In this paper, R-peaks of recorded ECG signals are detected by using modified PAN- Tompkins algorithm and RR-interval is also calculated which helps in any further classifications.

Keywords : ECG, R-peaks, Pan-Tompkins, RR-interval.

1 INTRODUCTION

A Graphical representation of the cardiac movement which is generated by the cardiac muscles is termed as ECG which is used to detect various heart diseases. ECG signals are corrupted by various types of noise during recording. Different noises such as Baseline wander [2], Power-line interference, muscle noise, T-wave interference, Motion noise. The main objective is to diversify the signal from the undesired masked noise for its better measurement accuracy. An ECG contains different segments such as P, QRS and T wave which shows repolarization and depolarization of ventricles and atria. ECG acts as a primary signal- processing device which helps in monitoring heart disease [3]. Many heart diseases if early diagnosed then they are able to improve the quality of life via taking early preventive precautions. Interpretation and classification of ECG signal could be helpful in diagnosis of various diseases like atrial fibrillation, fainting, ventricular fibrillation, cardiac arrhythmia, bradycardia, tachycardia, supraventricular tachycardia, Premature ventricular contraction etc,. [4]. ECG is a non-invasive tool which is used for diagnosis and records the electrical activity of the heart and now has become a golden medium for cardiovascular disease detection [5]. Various components of the waves are P, QRS, T wave which represents arterial depolarization, ventricular depolarization and ventricular repolarization respectively [5]. Different abnormalities can be there such as damaged areas of the heart, enlargement or thickened heart chambers and abnormal heartbeats [5].

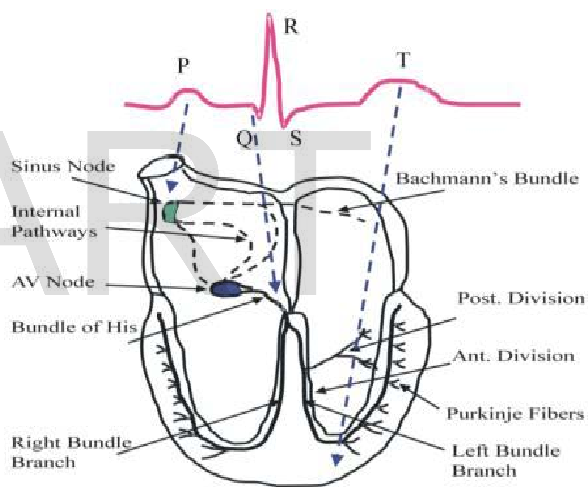

Fig1: ECG generation in heart [3].

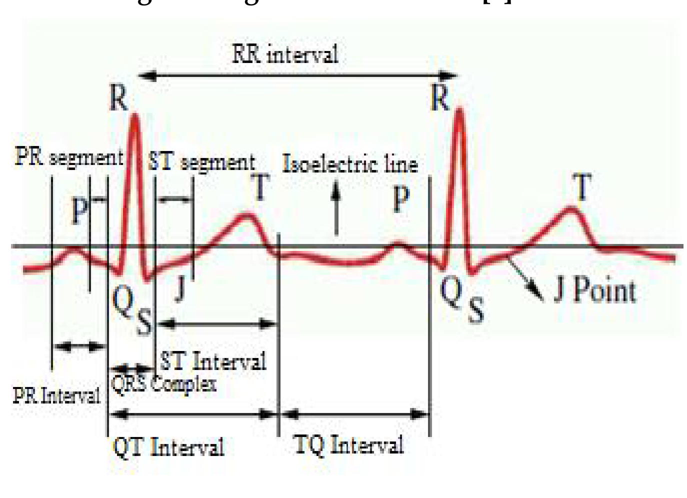

Fig2: Normal Electrocardiogram [3].

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2. Algorithm Overview

We implemented R-peak detection algorithm by using modified Pan-Tompkins Algorithm. First of all there is a band-pass filter which is composed of low pass and a high pass filter and it reduces noise .After this a derivative filter is used in order to get the slope information . After that an amplitude squaring is done and then the signal is passed to a moving- window integrator [7]. Then thresholding is done to locate R-peaks.

Band pass Filter

The band pass filter helps in reducing the baseline wander interference, muscle noise [6] and T-wave interference. In this we have got 3db pass band from 5-12 Hz.

Low-pass Filter

In this we have used second- order low-pass filer with transfer function

$$H(z) = \frac{1-2z^{-6}+z^{-12}}{1-2z^{-1}+z^{-2}}$$

Where gain is about 36 and the cut-off frequency is about 11Hz with the processing delay of 6 samples.

High-pass filter

The designing of high-pass filter is done by subtracting the output of a First-order low pass filter from an all- pass filter .The transfer function for such a high-pass filter is

$$H(z) = \frac{-1+32z^{-16}+z^{-32}}{1+z^{-1}}$$

Where gain is about 32 and the cut-off frequency is 5Hz with the processing delay of 16 samples.

Derivative

After filtering, the filtered signal is derivative i.e. differentiated in order to get the slope information. In this we have used five-point derivative with the transfer function

$$H(z) = \frac{1}{8T}(-z^{-2} - 2z^{-1} + 2z^{1} + z^{2})$$

In this delay are 2 samples.

Squaring Function

After performing differentiation, point by point squaring is done on the signal.

$$Y(nT) = [x(nT)]^2.$$

It does non-linear amplification of the output of the derivative and makes the data points positive.

Moving Window Integration

Waveform feature information is obtained by the moving-window integration along with slope of the R wave. And it is calculated from

$$y(nT) = (1/N)[x(nt-(N-1)T)+x(nT-(N-2)T)+\ldots..+x(nT)]$$

where N is the number of samples in the width of the integration window. Important factor in the moving window is the number of samples N. In general, width of the window should be equal to the widest possible QRS complex. Several peaks are generated in the integration waveform if peaks are too narrow. QRS and T complexes will merge together if window is too wide. Sample rate is 200 samples/sec and the window is 30 samples in width [6]. In this processing delay is of 9 samples.

Thresholding

After moving window integration, thresholding is done in order to find the R-peak. A maximum Level is set which helps in detecting R-peak.

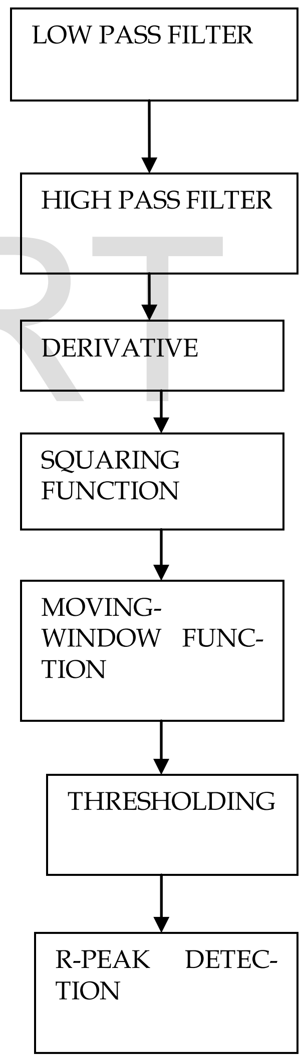

Fig3: Steps for Modified Pan-Tompkins Algorithm

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Total Detection Error rate= $\left(\frac{FP+FN}{Total\ no.of\ R-Peaks}\right)100$

Where FP=False Peak Detection
FN=Failure to detect

Efficiency can be calculated through Sensitivity
$S_e = (TP|TP+FN)100$

Where TP=True Positives (Total no. of peaks correctly detected by the detector).

3. Results

TABLE I.
Results of Evaluating the R-Peak Detection Algorithm Using the MIT/BIH Database

ECG signals	Total Error Detection Rate	Sensitivity
100	0	100%
101	9.09	100%
103	0	100%
105	0	100%
106	0	100%
108	0	100%
109	0	100%
111	0	100%
112	0	100%
113	0	100%
114	11.11	100%
115	0	100%
116	0	100%
117	0	100%
118	0	100%
119	30	83.33%
121	0	100%
122	0	100%
123	12.5	100%
124	12.5	100%
200	0	100%

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TABLE II.
MEAN of RR-Interval

ECG SIGNALS	MEAN RR-INTERVAL
100	290.4167
101	318.9091
103	308.9091
105	258.8333
106	350.9000
108	350.1000
109	230.9167
111	307.7273
112	250.3333
113	385.1250
114	395.1111
115	360.5556
116	269.9167
117	417.6250
118	299
119	407
121	357.4444
122	236.9167
123	438.8750
124	418.1250
200	465.8571

4. CONCLUSION

We used the MIT/BIH database from Physionet. R-peak is detected and RR-interval is also calculated with their mean. We have calculated Total Error Detection Rate and Sensitivity for different ECG signals.

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