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# Detection Of Myocardial Infarction Using Hilbert Transform

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***Abstract*— In recent years, there have been extensive studies on ST variability in ECG signals and analysis of Myocardial Infarction. The aim of this paper is to enhance the ECG through Hilbert Transform for beat ST-Segment variability measurement. Among all ECG components, QRS complex is the most significant feature. substituted and an efficient Digital filtering techniques and QRS detection algorithm have been used to remove noise and base line wander in the ECG signal. The ST-Segment Variability provides information about Myocardial Infarction and consequently about the risk of unpredicted cardiac death. We used the standard deviation of beat-to-beat ST-Segments as a marker of ST Variability (STV). In the presence of noise and wrong placement of ECG electrodes, the QRS complex may be missed or falsely detected. This may lead to poor results in calculating heart beat in turn ST segments. We have studied the effects of number of common elements of QRS detection methods using MIT/BIH arrhythmia database and devised a simple and effective method.***

***Keywords - ECG, QRS complex, ST-Segment, Heart Rate signal, RSA, Hilbert Transform, Myocardial Infarction, MIT/BIH database, MATLAB***

## I. INTRODUCTION

ECG is an acronym of Electro Cardio Gram. This is a graphical representation of the electrical activity of human heart during the cardiac cycle [1]. Many electrical and mechanical defects of the heart such as the heart rate and other cardiac parameters regarding Auricular and Ventricular hypertrophy, Myocardial Infarction (heart attack), Arrhythmias, Pericarditis, Generalized suffering affecting heart and blood pressure can be determined by the electrocardiogram. The ECG waveform consists of the P wave, PR interval, QRS complex, ST segment, T wave and QT interval [2]. These parts which correspond to polarization of atria and ventricles in a chronological manner are shown in the Fig. 1. The frequency spectrum of ECG signal ranges from 0.05 Hz to 100 Hz with QRS complexes concentrating around 10 Hz. The information pertaining to cardiac defects are determined with intervals and magnitudes of these waves and segments of the ECG signal.

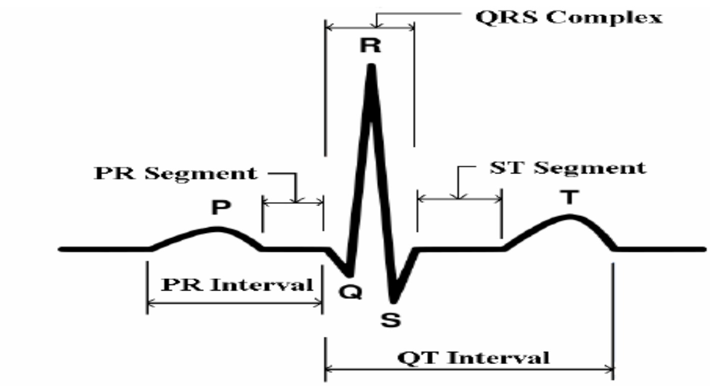


Fig 1. ECG with characteristic features

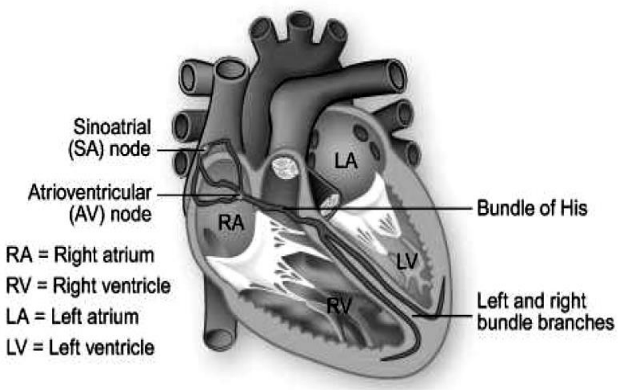


Fig 2. Physiology of the human heart

Therefore, with automatic and correct detection of Myocardial Infarction clinical diagnoses can be performed very accurately. The electrical conductivity drives the cardiac muscle tissue to contract and relaxes, and then the cardiac muscles pump the blood throughout the body [3]. The contraction and relaxation of the cardiac muscle is in a rhythm, when the cardiac muscles of the heart's ventricles contract, it is called as systole and when the cardiac muscles of heart's ventricles relax, it is called as diastole. Some of the key elements of heart are shown in Fig. 2. to know the physiology of heart. Sinoatrial node (SA node) which is generally known as the natural pacemaker of the heart triggers electrical impulses. These impulse trigger passes through the atria and causes the muscles to contract. After the contraction of the atrium muscles the impulse that travels from the SA node reaches the Atrioventricular node generally known as the AV node. The AV node triggers another pulse which now causes the ventricles to contract. The ventricles are contracted when the bundle of His collects triggering impulse from the AV node. Then the impulse branches into the left bundle branch and the right bundle branch from bundle of His, which in turn contracts the left and right ventricles. The contraction and the relaxation of the heart muscles thus brought about by the SA and the AV nodes is wavelike and in rhythm. Electrocardiography is a diagnostic tool for monitoring the rhythmic electrical activity of the heart. Sometimes the electrical impulse cannot travel throughout the heart when the part of the heart's conduction system is 'blocked' due build of plaque, cholesterol deposits in the arteries that supply blood to the heart. Because of this the rhythm of electrical activity of the heart is lost. There are a number of ways to identify the cause of failure of rhythm in the conduction of heart. Myocardial Infarction is a type of ischemic heart disease [4]. It is caused due to relative insufficiency of oxygen to the heart muscles called cardiac muscles. Myocardial Infarction is associated with acute coronary syndrome and approximately 90% of MIs result from an acute thrombus that obstructs an atherosclerotic coronary artery.

There are plentiful QRS detection algorithms such as derivative based algorithms, wavelet transform, Filtering Techniques, genetic algorithms and syntactic methods in literature [5][6]. Recently few other methods based on pattern recognition, moving-averaging etc are proposed for the detection of QRS complex [7][8]. After finding the QRS complex, the location of other components of ECG like P, T waves and ST segment etc. can be detected relative to the position of QRS, in order to analyze the complete cardiac period.

## II. Methodology

The Hilbert transform plays an important role in the theory and practice of signal processing. Frequently we have to look at associations between real and imaginary parts of a complex signal in digital signal processing. These associations are normally described by Hilbert transforms. Hilbert transform not only helps us relate real and imaginary components but also used to produce a special class of causal signals called analytic which are especially important in simulation. The analytic signals help us to represent bandpass signals as complex signals which have especially attractive properties for signal processing [9].

### A. Hilbert Transform

The Hilbert transform of a real time function $x(t)$ is defined as:

$$\hat{s}(t) = H[s(t)] = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{s(t)}{t-\tau}\, d\tau \tag{1}$$

If the integral exists the independent variable will not change as a result of this transformation, so the output is also a time dependent function [10][11]. Since there a possible of singularity at τ = t it is not likely to determine the Hilbert transform as an ordinary improper integral. The integral is to be considered as a Cauchy principal value. In mathematics, the Cauchy principal value of certain is defined as

$$\lim_{\varepsilon \to 0+}\left[\int_{a}^{b-\varepsilon} s(t)dt + \int_{b+\varepsilon}^{c} s(t)dt\right] \tag{2}$$

where $b$ is a point at which the behavior of the function $s(t)$ is such that

$$\int_{a}^{b} s(t)dt = \pm\infty \quad for\,any \quad a < b \tag{3}$$

$$\int_{b}^{c} s(t)dt = \mp\infty \quad for\,any \quad c > b \tag{4}$$

If the Hilbert transform exists, it can be written as given in (1). The Hilbert transform can also be written as a convolution of 1/πt and s(t) and expressed as:

$$\hat{s}(t) = H[s(t)] = \frac{1}{\pi t} * s(t) \tag{5}$$

Equation (5) shows that is a linear function of s(t). The frequency domain representation of (5) is obtained as the product of their Fourier Transforms Fourier of two functions with help of the convolution theorem and is treated as the spectrum of H[*s*(*t*)]. Mathematically the spectrum is represented as:

$$F[\hat{s}(t)] = \frac{1}{\pi} F\left[\frac{1}{t}\right] F[s(t)] \tag{6}$$

$$= \frac{1}{\pi}\left[\int_{-\infty}^{\infty} \frac{1}{s} e^{-j2\pi f^{*} s} ds\right] F[s(t)] \tag{7}$$

Where

$$\begin{aligned} \operatorname{sgn}(f) &= +1 \ \ for\ f > 0, \\ &= \ \ 0 \ \ for\ f = 0 \\ &= -1 \ \ for\ f < 0 \end{aligned}$$

Therefore the Hilbert transform is equal to – *j* for positive frequency and + *j* for negative frequency. Hence it is equivalent to a filter, in which the every frequency component is allowed to pass without any attenuation but their phases are altered by - π/2 radians or + π/2 radians depending upon the sign of the frequencies. Finally the Fourier transform of the Hilbert transform of s(*t*) is given by

$$F[\hat{s}(t)] = -j \operatorname{sgn}(f) F[s(t)] \tag{8}$$

## *B. Proposed Method*

The procedure of our proposed method is illustrated in Fig.3. It has four stages, first the ECG signal is preprocessed using digital filters; next processed using Hilbert transform; next QRS complex is detected and finally find ST Variability (STV) analysis is performed on ST-segments [12].


Fig 3. Schematic blockdiagram of the proposed method

Especially the accurate detection of the *R* wave peak is essential in the determination of the QRS complex. As described in the previous chapter, one of the properties of the Hilbert transform is that it is an odd function. This means that it will cross zero on the *x*-axis every time that there is an inflection point in the original waveform. Similarly a zero crossing between consecutive positive and negative inflection points in the Hilbert transformed conjugate will be represented as a peak in its original waveform. Using this characteristic, a detector for determining the *R* wave peak in the input ECG waveform was developed. The peaks in the Hilbert transform sequence *h*(*n*) represent regions of high probability of finding *R* wave peaks. An adaptive threshold is used to locate the peaks in the *h*(*n*) sequence. For finding the R wave peak accurately, a moving 1000 points window is used to subdivide the Hilbert transform *h*(*n*) sequence. The RMS (Root Mean Square) value and the maximum amplitude in the present window are then calculated.

In the second stage ST episodes are identified after finding fiducial points. To find out fiducial points such as P-peak, Q-peak, R-peak and S-peak more accurately, a well known QRS enhancement Pan-Tompkins algorithm, and derivative-based methods can be used. ST segment is the separation between J point and K point [13][14]. The J-point is located at 60 ms after the R-peak in normal sinus rhythm case. In the case of RR interval less than 600 ms (tachycardia), the J-point is taken at 40 ms after the R peak. The K-point is the onset of T wave. These values are in general agreement with the recommendation of the European ST-T database. The ST segment elevation or depression is measured as the difference between the mean of ST segment in each beat and the isoelectric line. If the absolute value of ST segment deviation exceeds 0.08 mV, the beat is classified as ischemic beat. If the no of ischemic beats exceeds 75 % of total no of beats then the subject is prone to Myocardial Infarction. The variance of ischemic beats and all ST segments are calculated by using (9) and (10)

$$IST_{\text{var}} = \sum_{n=1}^{N-1} [IST(n) - \overline{IST(n)}]^2 \tag{9}$$

$$ST_{var} = \sum_{n=1}^{N-1}[ST(n) - \overline{ST(n)}]^2 \tag{10}$$

## III. RESULTS

Figure We tested our procedure on the ECG signal that is obtained from MIT/BIH database. Fig. 4 shows the original noisy ECG signal. In our proposed method first ECG records are taken from MIT-BIH Long Term ST database and preprocessed with low-pass filter and then high-pass filter to remove noise due to baseline wander, other physiological signals, the low frequencies characteristics of P and T waves and to isolate the predominant QRS energy centered at 10 Hz. The preprocessed ECG signal is processed with Hilbert Transform to distinguish and enhance the QRS complexes from other parts of ECG wave. Next R peaks, R-R intervals, QRS amplitudes, ST segment durations and amplitudes by using a simple algorithm. In this algorithm simple decision logic decides whether to use the maximum or the minimum position of the search as the temporal location of the R-wave. Fig. 5 shows the cleaned ECG with indicated PQRST points. For all ST segments it is verified that they belong to either ischemic or non ischemic beats. Later the variance of ischemic beats and all beats are calculated by using (9) and (10).

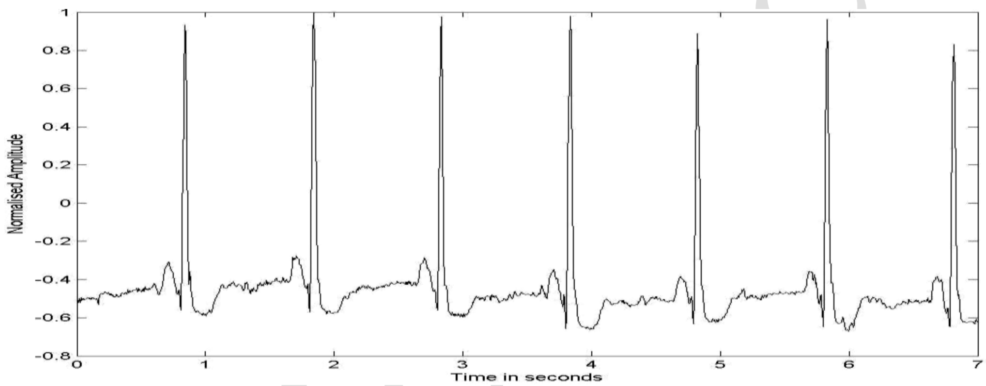


Fig 4. The orinal noisy ECG from MIT-BIH Long Term ST database

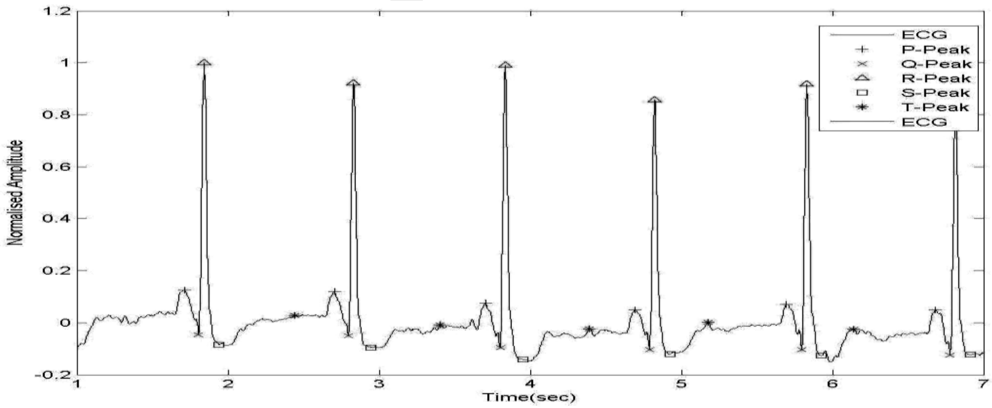


Fig 5. The cleaned ECG with indicated PQRST points

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