T Wave detection by correlation method in the ECG signal

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1. Introduction

Electrocardiogram is the linear presentation of the electrical potential Produced by the heart tissue. The heart is a unique muscle in body which automatically produces impulses and contracts regularly. The wave form detection of the ECG Signal (P wave, complex QRS, T wave) and the identification of their boundaries provide essential information on the heart's function.

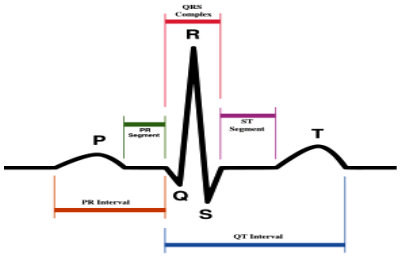

Fig 1. A Sample of ECG

Using T wave periods to determine the probability of heart attack is one of the recent methods in the literature. Measuring these periods in micro volt is considered as a factor in diagnosing. Heart conditions and its susceptibility SCD [4].so far many methods have been proposed to detect T waves. Most of which are based on spectral method. The method Proposed in this article is based on time.[3,1]

2. The Proposed Algorithm

A Complete algorithm is proposed here which automatically performs all the stages of detection including noise removal, R peaks detection, beat detection, T wave Sampling and Correlation with ECG Signal. The algorithm below is shown below. The article continues with a description of the above mentioned stages.

A .Noise removal

There are two major kinds of noises in a signal. One is Baseline noise which is an environmental noise and adds DC value to a signal. The moving average filter is used to remove this noise provided that first the deviation from the baseline signal is removed.

To do this, the signal is smoothed by moving average filter and then subtracted from the original signal to remove the deviation. This method won't completely remove the noise none the less it suffices for our purpose [7,6].

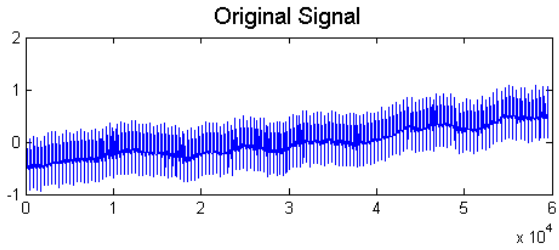

Fig 2. A Sample of ECG before noise removal

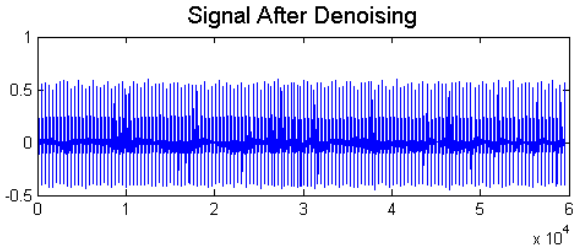

Fig 3. The same signal ECG that is sown in fig 2 after noise removal

B) R Waves Detection

In this section using the adaptive thresholds of the detected R waves with respect to the location of the peaks, we can detect the beats. The adaptive threshold in [8] is defined as follows.

$$Thr(new) = \alpha\gamma Peak + (1-\alpha)Thr(old) \quad (1)$$

Where peaks is the detected location's max, α is a coefficient between zero to is a weighing coefficient between 0.15 to 0.2 , Thr (old) is the threshold obtained from the previous beat and Thr (new) is the threshold obtained from the new beat.

Due to the probable alterations in the R wave form, applying a variable threshold leads to more acceptable results.

$$Thr(new) = 5\alpha\gamma Peak + (1-\alpha)Thr(old) \quad (2)$$

The threshold is applied on square signal so that the distance between R Peaks to T peaks will be increased and the errors one to mistaking T Peaks for R

Peaks because of the smallness of the coefficients will decrease.

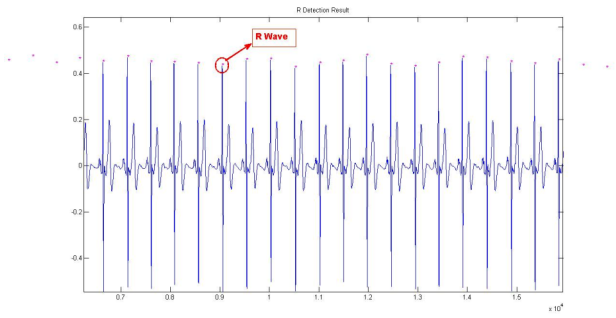

Fig 4.R wave detection

C) T Wave Sampling

According to R wave detection for the first ten seconds of the signal and given the approximate location of the T wave, the data is stored by calculating a median of the first few beat's T waves as the default T wave. This wave is approximate and an exact one will be obtained by calculating new medians to calculate a medium a number of ECG signals from the mentioned database are defined in variables and put in a matrix. Each row in the matrix shows a T wave with all the waves having the same width. The T waves of these signals were obtained by correlation with the default wave. Summing up each Counter element in all rows and calculating a median a more precise T wave will be obtained.

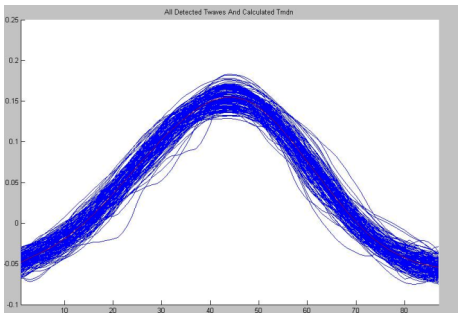

Fig 5 .The Sample T wave from and the default wave for a correlation and obtaining a more precise T wave

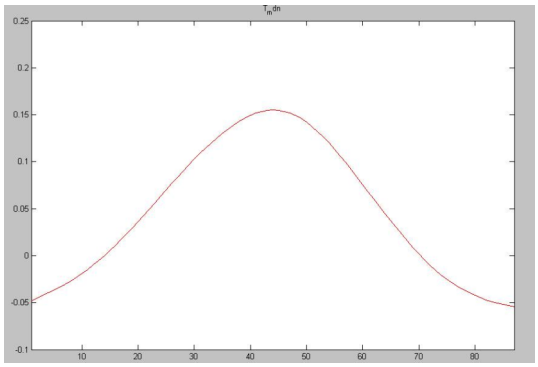

Fig 6 .The Final T wave form

It should be noted that the correlation is done with the default T wave at this stage and there is done using the resulted T wave and Calculating median to obtain even more precise T waves.

D) T Wave detection

We used correlation to detect the T wave. This time domain method is one of the quickest methods. As known the Correlation of a signal with itself is 1 which is Called autocorrelation and the more these signals are similar to another the closer the value to 0 will be to in this algorithm the entire signal is correlated with the sampled T wave from the Lost Stage. If the Value is above 0.9 it will be considered as a T wave and then by searching domain again the highest domain in the regarded scope is taken as the center of T wave. This is done through the following stages:

Stages:

D-1) Determining a window to increase the Speed:

At the first a window is defined between the two R waves where T wave probably occurs and perform the Correlation merely in this window not all the signals .the distance between two R waves is obtained from the following equation.

Based on the Heart's physiology, T wave occurs is between 0.05 ms to 0.035 ms after R wave occurance and never falls out of this interval. Thus the beginning and ending of the window will be as follow:

$$R_2R = R_{peak}(n) - R_{peak}(n-1) \qquad (3)$$

Note that there will be only on occurance T wave in each window.

Start = 0.05 R2R + R peak (n) (4)
End = 0.35 R2R + R peak (n)

D-2) Selecting an appropriate step to perform correlation:

This is also done to increase speed. After applying different step on the ECG signals the best Δ is empirically fined as follows.

$$\Delta = \frac{\text{Sampling T wave width}}{16} \qquad (5)$$

D-3) Correlation

At this stage the sampled T wave is correlated by the specified windows.

The highest Correlation Value in a window is Stored as the first T wave Peak. To increase accuracy

and Since the obtained Δ is more than 9, the Scope of $\left[-\frac{Sampling\ T\ wave\ width}{8} \quad +\frac{Sampling\ T\ wave\ width}{8}\right]$ is inspected to find the point with the highest amplitude. This point is considered the T wave peak and the same band width as the T wave is assigned to it.

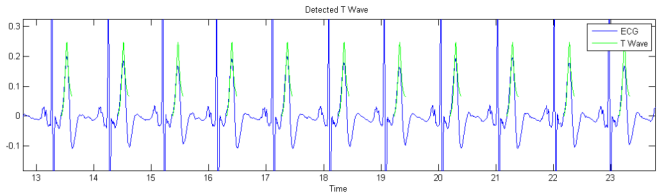

Fig 7 .T Wave detection by correlation method

3. Evaluation and conclusions

Previous methods such as slope variation method which was a spectral method were sensitive to noise and had a slow speed. Therefore could not quality as online system. Our proposed method being fast and accurate has less error, even without performing the best noise removal on the signal. In figure 8 and 9, These 2 methods are shown in the same ECG signal.

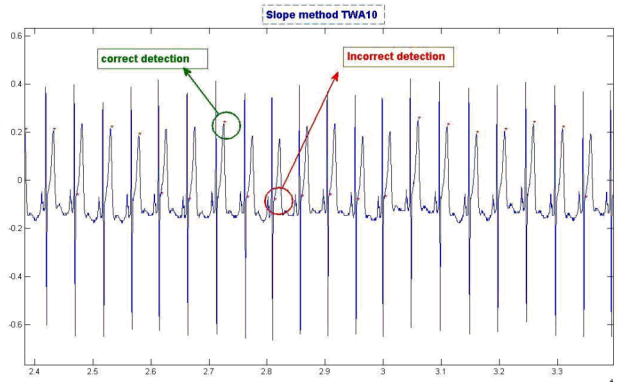

Fig 8 . T Wave detection by slope method

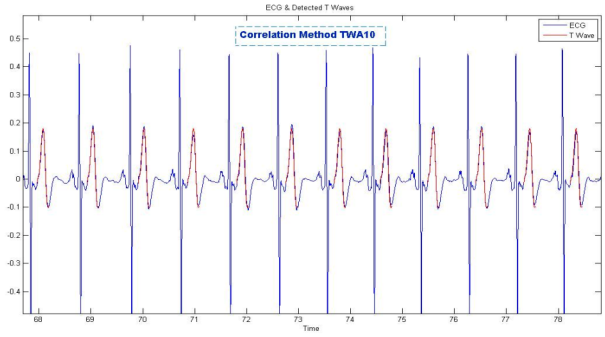

Fig 9 .The same signal that is sown in fig 5 is detected by correlation method

References:

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