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Automatic Detection of Q-T Interval in Electro-cardiograph using MATLAB

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Abstract

While measurement of QT prolongation in electrocardiogram (ECG) is important to clinical applications, but it is quite difficult to evaluate the performance of QT measurement algorithms usingclinical ECGs because the real values of the Q-point and T-end point changes are usually unknown and is difficult to detect.

This research paper deals with the Abnormality Detection and its analysis using MATLAB tool software. In this paper, abnormity which is in concern is known as QT prolongation. Due to prolongation or extention of QT interval in the ECG graph obtained from abnormal patient, known as QT syndrome is caused.

For the analysis purpose, Large number of data has been taken from QT database and MIT-BIH database. Someof the other useful data were also obtained from other useful sources such as ECG wave maven. In this paper, we have dealt only with the detection of QT interval and its detection. A MATLAB algorithm has been generated highest peak comparison method/Thresholding method which in turns detect the Q-wave and T-end point corresponding to its input samples.

This algorithm is designed and analyzed with more than 100 samples taken from the various data base sources. It detects onset of the Q-wave and T-end point which in turn is used to calculate QT interval of the analyzed ECG sample.

For Future prospects, detection of QT syndrome from a large number of ECG samples via can be done by designing artificial neural network using MATLAB programming.

Inputs weights of the ANN must be trained in such a way that output of the ANN should be 1 for QT syndrome and for rest of the condition, output will be 0(including normal and other arrythmia).

Keywords: Abnormality, Detection, Q-T points, Q-T Syndrome, Algorithm, MATLAB

Introduction

The QT interval is the time interval between the onset of the Q wave and the offset of the T wave in an Electrocardiogram (ECG). It corresponds to the interval of the beginning of ventricular depolarization and the termination of ventricular repolarization. Hence, the QT interval is a useful parameter as an index of the ventricular repolarization duration (VRD) and therefore used for the diagnosis of ventricular arrhythmias such as long QT syndromes. Besides pathological causes, the prolongation of QT interval may also owe to an adverse drug reaction. Some cardiac drugs (for example, Sotalol, Dofetilide, and Jbutilide) and non-cardiac drugs (for example, Erythromycin and Cisapride) may delay myocardial cell repolarization and result in the generally known drug-induced QT prolongation. Drugs related to the QT interval prolongation may increase the risk of deadly ventricular arrhythmias [15].

Within past years, several cases of cardiac death due to drug-caused prolongation of QT interval have been reported. As a result, drugs with similar side-effects have been withdrawn from the market or required to provide black box warnings in the drug's prescribing information. The US Food and Drug Agency (FDA) recommended pharmaceutical companies that all new drugs should be tested for their potential QT interval prolonging effects in the early research and developmentstage. As it is hard to accurately estimate the absolute value of QT interval, the drug-induced variation of QT interval before and after the pharmaceutical delivery is a practical index for the investigation of drug-induced pro-arrhythmic risk [16].

To estimate the QT interval from a single lead ECG, we need to measure the onset of QRS complex and the offset of T wave in each cardiac cycle. Compared with the T wave offset detection, the onset of QRS complex can be easily and accurately determined before the R wave. Therefore, we focused our study on the noise sensitivities of the algorithms for the detection of T wave offset point. We select six typical methods, including the threshold method, area method, slope method, differential method and wavelet transform (continuous wavelet transform and discrete wavelet transform) based method [16].

We propose a QT interval detection algorithm based on the Thresholding method of the ECG signal. Our approach has the following advantages:

a. it is insensitive to morphological variations of QRS complexes and Twaves;
b. it is insensitive to ECG baseline wandering;
c. it is computational efficient.

Prolongation of QT interval is not straightforward to estimate because the mundane QT intervals vary inversely with the beating frequency. For this reason, the absolute quantifications need to be redressed. Bazett's formula (Indik et al, 2006) is generally utilized for this rectification, albeit it has some constraints and should beused only within the mundane range of beating rates (Dogan et al, 2005) [15].

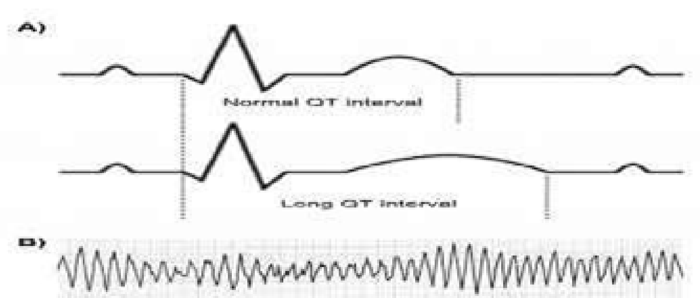

Figure 1: Shows normal and prolonged QT interval.

According Bazett's formula, a rectified QT interval (QTc) results from dividing the QT time by the square root of the beating rate (QTc = QT/√BR) [16]. In integration to beating rate dependence, the QT interval varies during the 24 hours in a day due to a number of factors, including circadian rhythms and impulses from the autonomic nervous system (Dogan et al, 2005). In integration, the threshold values of a mundane and protracted QTc interval are remotely different 59 depending on the gender [16].

Methodology

Study Design

The first step of the QT algorithm was to provide the opportune inputs and obtain the sampling frequency for the inputted data. The algorithm was validated utilizing five ECG data sets. The data sets were obtained from the NJIT, Signal Processing Laboratory resources. These data sets were 5-minute segments of paced breathing at 12 breaths per minute. The ECG segments culled for this algorithm were all clean and noise free. The data set were sampled at 250 samples/sec. The input data was in the text format and was read into LabVIEW 7.0 Software.

Interval Measurement

The QT interval is defined as the interval from the beginning of the Q wave to the end of the T wave. The QT interval has some dependence on the heart rate variability and it is presumed to follow the preceding RR interval. The QT interval was corrected for preceding R-to-R interval using Bazett's formula and the corresponding interval was called QT corrected (QTc) [16]. The Bazett's formula is given by:

$$QTc = \frac{QT}{\sqrt{RR}}$$

Where RR= R peak-to-peak interval in seconds.

Experimental Work

QT interval detection is done by detecting the Q-point and T-end point in a particular beat of the given sample which is to be analyzed.

Detection of these points is done with the help of given Algorithm which is divided into 5 parts:

1. digitized data samples from physionet databases
2. smoothing and filtering noisy ECG signal the given sample using Sgolay filter.
3. thresholding the particular sample with the calculated mean value
4. finding Q,R,T-end point in the given loaded sample
5. detection of Q-wave and T-end point values.

MATLAB Code

```
clear all; close all; clc;
D=load('sele0704m.mat'); t=1:2500;
ECG_data=D.val(1,:);
m=mean(ECG_data); qmin=m-300; qmax=m-25;
```

```
tmin= m-28;
tmax= m+10;
% plot(t,ECG_data)
% grid on,
[~,locs_Rwave] = findpeaks(ECG_data,'MinPeakHeight',1100,...
'MinPeakDistance',78);
ECG_inverted = -ECG_data;
[~,locs_Swave]= findpeaks(ECG_inverted,'MinPeakHeight',1100,...
'MinPeakDistance',78);
figure hold on
plot(t,ECG_data); = plot(locs_Rwave,ECG_data(locs_Rwave),'rv','MarkerFaceColor','r'); plot(locs_Swave,ECG_data(locs_Swave),'rs','MarkerFaceColor','b');
%axis([0 2500 -1.1 1.1]);

grid on;

legend('ECG Signal','R-waves','S-waves'); xlabel('Samples'); ylabel('Voltage(mV)')
title('R-wave and S-wave in Noisy ECG Signal') smoothECG = sgolayfilt(ECG_data,7,21); figure
plot(t,ECG_data,'b',t,smoothECG,'r'); grid on axis tight;
xlabel('Samples'); ylabel('Voltage(mV)'); legend('Noisy ECG Signal','Filtered Signal') title('Filtering Noisy ECG Signal')
[~,min_locs] = findpeaks(-smoothECG,'MinPeakDistance',100);
% Peaks between 900mV and 930mV
locs_Qwave = min_locs(smoothECG(min_locs)>qmin & smoothECG(min_locs)<qmax); figure
%false Q-wave deletion qlocs=[0,locs_Qwave]; locs_Qwave=[locs_Qwave,0]; locs_2=find(locs_Qwave-qlocs>175); locs_Qwave=locs_Qwave(locs_2);
% T-wave detection
[~,t_locs] = findpeaks(-smoothECG,'MinPeakDistance',100);
locs_Twave = t_locs(smoothECG(t_locs)>tmin & smoothECG(t_locs)<tmax);
% len_t=length(locs_Twave); slocs=[0,locs_Twave]; locs_Twave=[locs_Twave,0]; locs_1=find(locs_Twave-slocs>175); locs_Twave=locs_Twave(locs_1);
% for n= 1:len_t-1
%     dis_t(n)= locs_Twave (n+1)-locs_Twave(n)
% %   if dis_t<175
% %   locs_Twave=[locs_Twave(1:n),locs_Twave(n+2:len_t)]
% %   len_t=length(locs_Twave)
% %   end
% end
hold on plot(t,smoothECG);
plot(locs_Qwave,smoothECG(locs_Qwave),'rs','MarkerFaceColor','g'); plot(locs_Rwave,smoothECG(locs_Rwave),'rv','MarkerFaceColor','r');
%plot(locs_Swave,smoothECG(locs_Swave),'rs','MarkerFaceColor','b'); plot(locs_Twave,smoothECG(locs_Twave),'rO','MarkerFaceColor','yellow');
grid on
title('Thresholding Peaks in Signal') xlabel('Samples');
ylabel('Voltage(mV)') ax = axis;
%axis([0 2500 -1.1 1.1])
legend('Smooth ECG signal','Q-wave','R-wave','T-Wave');
% q-t_interval=locs_Twave-locs_Qwave
```

Methods for T-end Measurement

In the study of ventricular activity, it is paramount that the QT interval is quantified correctly. Consequently, an algorithm to accurately detect QRS intricate beginning points and T wave end points is of great consequentialityto compute QT intervals. Several methods for automatic electrocardiogram T wave detection and QT interval assessment have been developed [8] [6]. While beginning of the QRS involute can be quantified with good precision due to its higher frequency content, the T wave end presents more preponderant difficulties. Currently the algorithms can be divided into two categories, namely, threshold predicated algorithms and algorithms predicated on intersection of slope and an isoelectric line [4].

In the threshold method, the threshold can be derived from a certain percentage of the T peak or the derivative of the T peak, and the intersection is predicated on the threshold level with the T wave. The slope methods are predicated on the intersection of the maximum T wave slope after the T wave peak with an isoelectric line in theTP segment. Several methods for the quantification ofthe cessation and, apex of the T wave is reviewed and compared in this chapter. Quantification methods compared here include.

A. Threshold Method (TH): The point at which the Twave intersects a threshold level.
B. Derivative Threshold (DTH): The point at which thederivative of the T wave intersects a threshold.
C. Slope Intercept (SI): The intersection of the maximum slope of T the wave and the isoelectric line.
D. Least squares Intercept (LSI): The intersection of a line fitted by least squares at the maximum slope of theT wave and an isoelectric line.
E. T-Wave Area (TA): The total area of the T wave is considered and threshold is fine-tuned at 90% of thetotal area. Wherever the threshold intersects with the baseline, the point is detected as the T wave end.
F. Wavelet Detection Method (WD): This method decomposes a signal into its components predicated on different scales. The detection of QRS beginning, T peak and Incline is predicated on the maximum absolute method and zero crossings of the mother wavelet transform at characteristic scales.

Algorithm

In this study of QT interval and its relation to the abnormality caused by its prolongation resulting in arrhythmia known as QT syndrome, different methods were reviewed.

Thresholding method is used in this study to detect the QT interval

by calculating Q-point and T-end point i.e onset of QRS complex and offset of the T-wave in ECG sample. The Algorithm designed in MATLAB depicts these points in each beat of a sample. Flow chart showing the steps utilized in our study to evaluate the different ECG sample and detection of various points is given below
The algorithm was divided into three main categories:
a. Filtering and Differentiation Process
b. R-wave Detection
c. T-max and T-end Detection

First of all, smooth ECG signal is obtained through s-golay filter and then thresholding of peaks is done by optimizing the algorithm in such a way that the threshold selected in the algorithm takes these Q-point and T- end point into its consideration.
Q-T interval detection is done by detecting the Q-point and T-end point in a particular beat of the given sample which is to be analyzed.
Detection of these points is done with the help of given Algorithm which is divided into 5 parts:
a. digitized data samples from physio-netdatabases
b. smoothing and filtering noisy ECG signal thegiven sample
c. thresholding the particular sample with thecalculated mean value
d. finding Q,R,T-end point in the given loadedsample
e. detection of Q-wave and T-end point values.

3.1. Figures on MATLAB

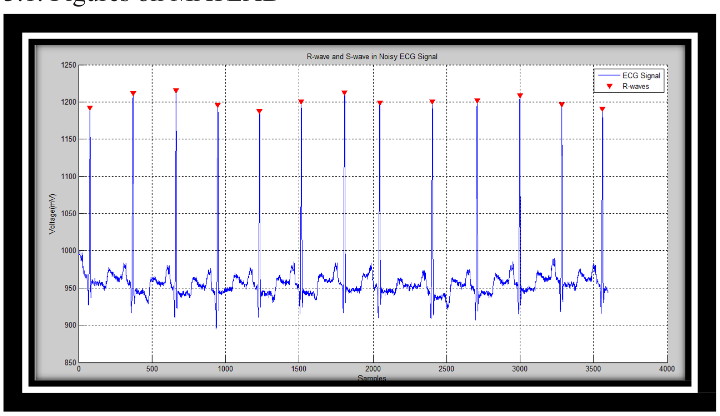

Figure 2: R - wave detection in signal

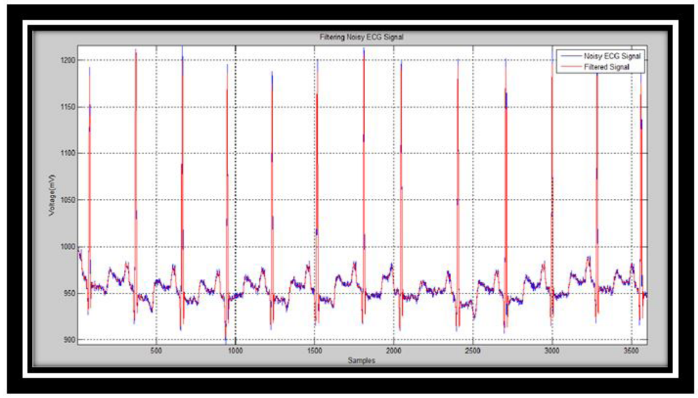

Figure 3: filtered signal of given ECG samples

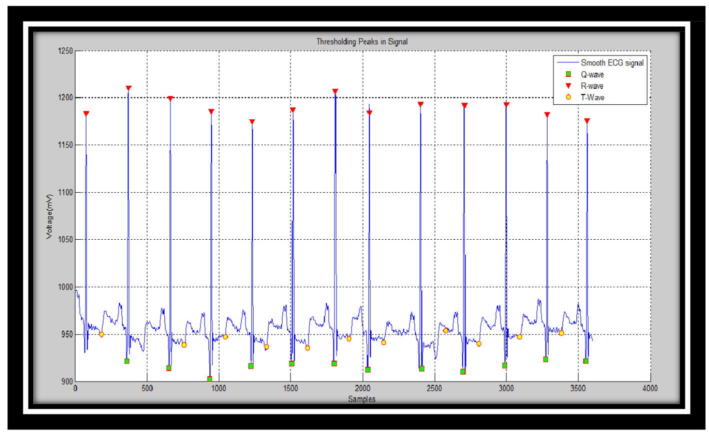

Figure 4: Q-wave and T-end point detection

Results

In this study of QT interval, we have used two sets of databases to evaluate the performance of the Algorithm.These Database soures were taken from the physio-bank data base.These database are obtained from these physio bank databases are such as MIT-BIH arrythymia database and QT database respectively. ECGs obtained drom these database sources are sampledat a given frequency of 200Hz.These sampled data obtained from physio bank database are Known as digital ECG sample.

Digitized data obtained from the above database sources are used in the proposed algorithm for the analysis of ECGs QT time interval which in turn is used to detect QT interval in each beat of an ECG sample. This will provide us idea about the Arrythmia realated to QT prolongation known as QT syndrome.

The samples which were used in the proposed algorithm provides the reliable result for various number of samples which were tested. In order to find out the QT interval, first of all Q-point and T-end point were detected through the given algorithm.

A Total of almost 100 samples were used for the analysis purpose and tested with the proposed algorithm in order to detect the given algorithm to find out Q and T-end point which is further used to calculate QT interval.

The recordings were digitized at 360 samples per secondper channel with 11-bit resolution over a 10 mV rang

For the QT –database, Over 100 fifteen-minute two- lead ECG recordings (many excerpted from other databases), with onset, peak, and end markers for P, QRS, T, and (where present) U waves of from 30 to 50 selected beats in each recording.

These above samples were analyzed and tested using the given algorithm in which almost 32samples from QT – database and 13 samples from MIT-BIH arrhythmia database were producing satisfactory results.

In these results, proper Q-point and T-end point were obtained with a lot more precisionThrough the analysis of these samples used for the experimental purpose from the given data base sources, we have obtained some false Q-point and T-end point in a particular beat associated with the given samples which is to be analysed. These wrongly detected false Q-point and T-end point are properly explained in the given table of results. All the databases which are usedin this experimental work is abnormal.

Following are the results which are obtained from thealgorithm which is designed is given below,

It gives us the no of beats present in the particular sample, correctly detected and falsely detected Q-waveand T-end points in each beat of a sample which is analyzed.

Tabular Form

Table 1: Results for Mit-Bih Arrythmia Database

MIT-BIH ARRYTH.	**Q –wave**			**T-wave**			**Test beats**
MIT-BIH 100m.data	present	correct	false	present	correct	false	12
	12	12	00	12	10	02	
MIT-BIH 103m.data	10	08	02	10	08	02	10
MIT-BIH 108m.data	09	09	00	09	09	00	09
MIT-BIH 114m.data	08	08	00	08	08	00	08
MIT-BIH 117m.data	08	05	03	08	07	01	08
MIT-BIH 122m.data	13	09	04	13	10	03	13

Table 2: Results for Mit-Bih Arrythmia Database

MIT-BIH ARRYTH.	**Q –wave**			**T-wave**			**Test beats**
MIT-BIH 205m.data	**present**	**correct**	**false**	**present**	**correct**	**false**	**14**
	14	11	03	14	08	06	
MIT-BIH 209m.data	14	11	03	14	14	00	14
MIT-BIH 214m.data	10	07	03	10	09	00	10
MIT-BIH 219m.data	12	09	03	12	11	01	12
MIT-BIH 220m.data	11	09	02	11	06	05	11
MIT-BIH 223m.data	13	08	05	13	11	02	13
MIT-BIH 232m.data	08	07	08	08	05	03	08

Table 3: Results for Q-T Arrythmia Database

QT data base	Q –wave			T-wave			Test beats
Sel103m	present	Correctly detected	Falsely detected	present	Correctly detected	Falsely detected	11
	11	08	03	11	08	03	
Sel 33m	04	02	02	04	03	01	04
Sel 36m	09	07	02	09	05	04	09
Sel 37m	06	04	02	06	03	03	06
Sel 46m	10	09	01	10	05	05	10
Sel 49m	08	03	05	08	07	01	08
Sel 51m	08	05	03	08	07	01	08
Sel 114m	08	06	00	08	08	00	08

Abbreviation

***Q-wave or T-wave Present- Total number of samples of each Test beat present in an ECG sachet**

***Correctly Detected- Number of each beat in which Q and T point were found accurately**

***Falsely Detected- Number- Number of each beat in which Q and T-point were not located with accuracy**

***MIT-BIH- Arrythmia Data obtained from physio-net database**

Conclusion

From the above experimental work, it is concluded that in case of the uniform ECGs sample used from the different database sources, Q-point and T-end point are detected accurately for each of the beat in a particular sample which is to be analysed. But in the case of non- uniform ECGs i.e. drifting of ECGs base line or interference with the noise, the proposed algorithm is notbeen able to detect Q-point and T-end point for each of the present beat in the particular sample correctly.

The algorithm designed to obtain these Q-points and T- end points of a particular beat in a given sample which contains no. of beats is detected correctly in large no of cases. Almost 32 samples from QT databases and 13 samples from MIT-BIH arrhythmia database, these Q- point and T-end point were detected correctly with a lot more accuracy. Apart from these correctly detected samples, other sample which has been analysed by this algorithm does not provide desired result.

So for these samples which do not provide desired result, we need to further optimize our algorithm for the correctdetection of these points. A proper optimization of the given Algorithm is required for the analysis of all other wrongly detected sample points of Q and T-end.

Future Aspects

Algorithm is designed for only Q-point and T-end point in a particular beat of any given sample which is tested.

Thus by proper optimization of the proposed Algorithm, experimental work may be extended for the other wrongly detected Q and T-end point in other samples in order to find out QT interval.

For Future pospects, detection of QT syndrome from a large number of ECG samples via designing artificial neural network using MATLAB programming.

ANN must be trained in such a way that output of the ANN should be 1 for QT syndrome and for rest of the condition, output will be 0(including normal and other arrythmia).

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