Time and Frequency Exploration of ECG Signal

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ABSTRACT

The time and frequency domain analysis for multicomponent non–stationary signals like Electrocardiogram (ECG) is an important issue in signal processing. Because of its non stationary, multicomponent nature, the use of time and frequency domain analysis can be very useful to identify the exact multicomponent structure of these biological signals. In this paper we have analyzed the ECG signal in time domain and calculated various statistical parameters and the study of different plots were done. Then we headed on the frequency analysis where the power spectral density is calculated using Welch method.

Keywords

FFT, ECG signal, histogram, MIT-BIH, RR interval.

1. INTRODUCTION

Electrocardiogram (ECG) interprets the electrical activity of the heart over a specified period of time[1]. It is a multi component and non-stationary signal. ECG signal is a prognostic tool used for the measurement and recording of electrical activity and it also helps in measuring the rhythm and invariability of heart beat [2]. The potential difference between two points on human body is represented by ECG. The normal ECG signal is poised of a P-wave, a QRS complex and a T-wave. The above waveform initiates with a peak which is usually referred as P-wave [3]. It exemplifies the atrial depolarization that is the requisite time for an electrical impulse generated from the sinoatrial node to proliferate throughout the atrial musculature and its duration is about 0.06-0.11 seconds. P-R interval as shown in fig 1, starts from the beginning of the P-wave and ends to the beginning of the QRS complex. It reflects the time that the impulse elapse to travel the entire distance from sinoatrial node to the ventricular muscle fibres. Its normal duration is about 0.12-0.20 seconds. The QRS complex represents ventricular depolarization and is composed of three waves - the Q-wave, the R-wave and the S-wave. Q wave is present at the beginning of QRS complex [4]. It is the first negative deflection. The first positive deflection observed is depicted by R-wave, irrespective of the fact that it is transcended by a Q-wave or not S wave is the next negative aberration which is superseded by the R-wave[5].

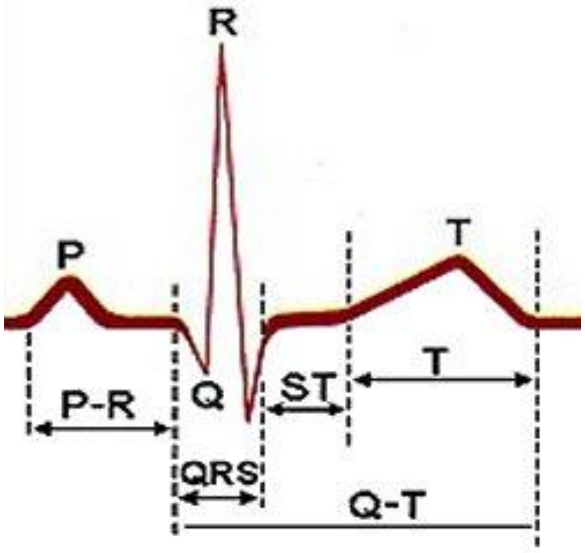

Fig 1: ECG waveform

Normal duration of the QRS complex is 0.05 to 0.10 seconds. Q-T interval reflects the requisite time for ventricular depolarization and repolarisation[5]. It extends from the initiation of QRS complex to the termination of the T-wave. In the S-T segment the T-wave exemplify the time indispensible for the ventricular repolarisation. Sometimes, a U-wave can also be observed which follows the T-wave. It represents the repolarisation of the His-purkinje fibres[6].

2. DATASET

The dataset used in this study is acquired from physio-Bank named "MIT-BIH Arrhythmia Database" which is available on-line. The source of the ECGs included in the Database is a set of over 4000 long-term Holter recordings. These recordings were obtained by the Beth Israel Hospital Arrhythmia Laboratory between 1975 and 1979. Approximately 60% of these recordings were obtained from inpatients. The database contains 10 records (numbered from 100 to 110) that were chosen from the same set. It comprises of a variety of rare but clinically important phenomena that would not be well-depicted by a small random sample of Holter recordings. The first group acts as a representative sample of the variety of waveforms and shows that an arrhythmia detector might be confronted in routine clinical use. The second groups were chosen to include complex ventricular, junctional, and supraventricular arrhythmias and conduction aberrancies. By placing the electrodes on the chest, we can obtain a modified limb lead II (MLII) that is the upper signal in most of the records. The lower signal is usually a modified lead V1. Nine Del Mar Avionics model

445 two-channel recorders were used for original analog recordings [7].

In order to limit analog-to-digital converter (ADC) saturation firstly the analog outputs of the playback unit were filtered and then anti-aliasing is done by using a pass band from 0.1 to 100 Hz relative to real time. The band pass-filtered signals were digitized at 360 Hz per signal relative to real time using hardware constructed at the MIT Biomedical Engineering Center [8] and at the BIH Biomedical Engineering Laboratory. The sampling frequency was chosen in such a way that it facilitates the implementations of 60 Hz (mains frequency) digital notch filters in arrhythmia detectors [9].

3. TIME AND FREQUENCY ANALYSIS

In time-domain signals are in their raw format. That means the signal is measured as a function of time[10]. Hence when we plot the signal one of the axes is time and the other is usually the amplitude. When we plot time domain signals, we obtain a time-amplitude representation of the signal[11]. In time domain analysis, the interval between adjacent normal R-waves is measured over the period of recording. A variety of statistical variable can be calculated from these intervals. Among these parameters the mean and the variance of R-R interval signal plays an important role and can be used for the classification along with the power content in low and high frequency bands[12]. While frequency domain deals with the analysis of mathematical functions or signals with respect to frequency. Frequency domain analysis which is based on power spectral estimation is carried out using fast Fourier transform[13]. The frequency spectrum of a signal is basically the frequency components (spectral components) of that signal. The frequency spectrum of a signal shows what frequencies exist in the signal. In frequency domain method either fast Fourier transformation or auto regression techniques can be used to quantify cyclic fluctuations of RR intervals[14]. Two peaks are seen in RR interval power spectra a low frequency peak[15] between 0.04 Hz – 0.15 Hz, and high frequency peak between 0.15 Hz – 0.40 Hz[16].

4. RESULT AND DISCUSSION

For the detailed analysis of ECG signal various data sets are taken from MIT-BIH and ECG 100m is taken into consideration for the detailed study of R-peak. Fig.1 illustrates a simple ECG signal with various R-peaks.

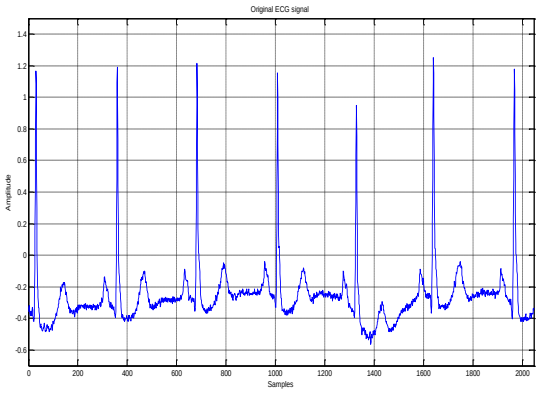

Fig.2. Time domain signal

R-peak is considered as one of the most vital part of QRS complex; it has an essential role in prognosis of heart rhythm irregularities and also determines the heart rate variability. Fig. 2 shows the time duration between consecutive QRS complex determining the heart beat which is commonly known as R-R interval and it is used to assess the ventricular rate. Hence for the detailed study of cardiac rhythm pattern, R-R interval histogram is generated.

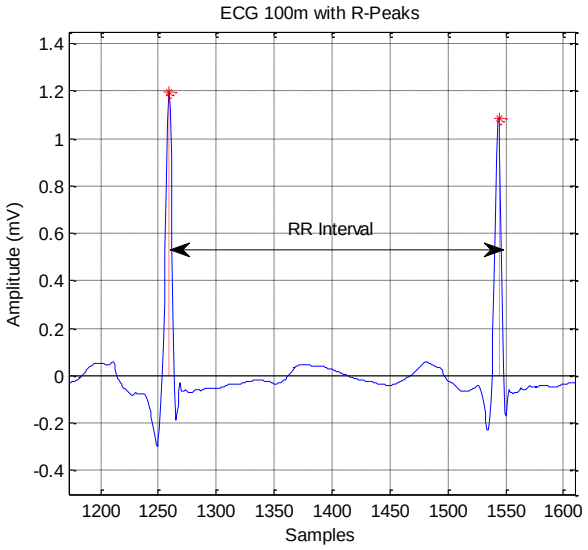

Fig 3 RR interval of ECG

Histogram graphical shows the visual impression of the distribution of data and this can be seen in fig. 3. The R-R interval histogram concisely describes the trend in heart rate over a period of time.

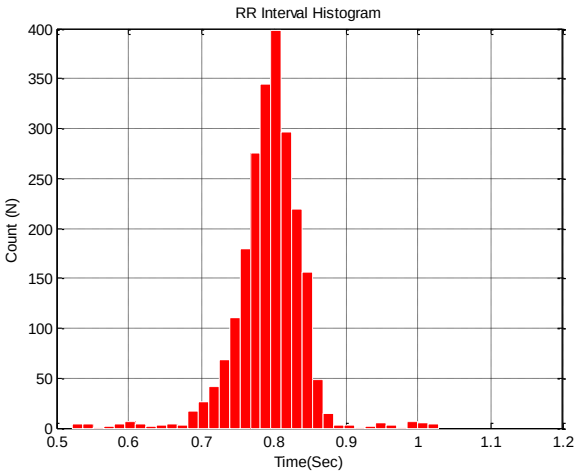

Fig 4RR histogram

The R-R interval histogram is used for mathematical analysis of parameters (mean, mode, skewness, standard deviation and kurtosis). So the R-R interval scatter plot was constructed which represents the relationship between a given interval "t" plotted on the x-axis against the "(t-1)" interval on the y-axis and it is pictured in fig. 4.

Now, the analysis of frequency domain parameters based on fast Fourier transform approach was very challenging and the fig. 5 below shows the Welch power density estimate of R-R interval.

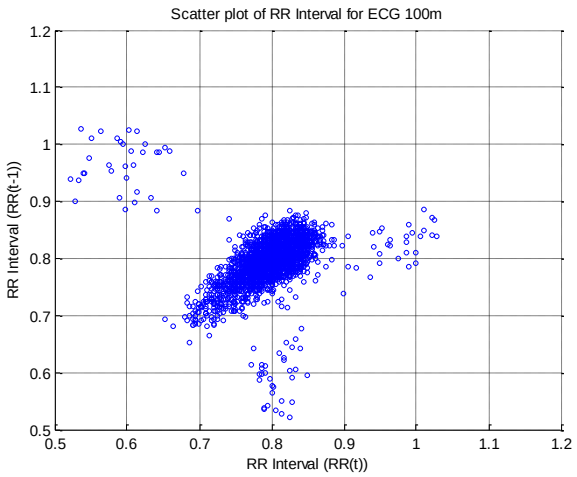

Fig5. Scatered plot of ECG signal

Welch method is used for measuring power density at various frequencies and the graph signifies that at frequency around 0.22 Hz there is a power peak observed which shows that there is an abnormality and the response after that repeats itself in the same fashion.

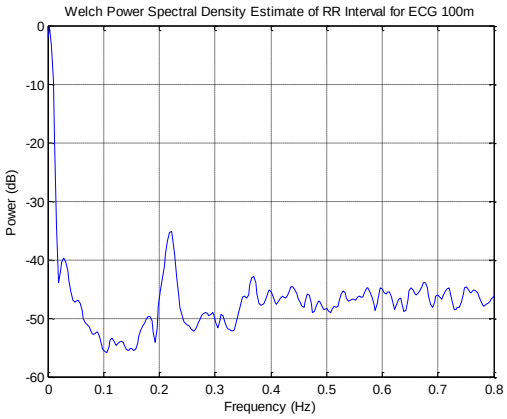

Fig.6 frequency domain analysis ECG

For the analysis of ECG signal in time domain we have taken few data from MIT-BIH numbering from 100 to 120 records. Out of which the record number 100,101 and 102 are taken into consideration for further analysis. Then the various statistical parameters namely mean, mode, standard deviation, kurtosis and skewness are measured.

The various parameters are tabulated in fig.1 for the ECG record number 100,101 and 102. From the presented table we can compare the parameters. So we can see that the mean of RR interval for ECG101 is greater than the rest two while the heart rate is highest for the first case. While the standard deviation is highest for record 101 and same for the rest two. Similarly other parameters can also be observed.

Table01 statistical parameters of ECG signal

STATISTICAL PARAMETERS	ECG100		ECG101		ECG102	
	RR (sec)	HR (BPM) (sec)	RR (sec)	HR (BPM) (sec)	RR (sec)	HR BPM (sec)
Mean	0.79	75.4	0.96	62.27	0.82	72.27
Standard deviation	0.04	1.92	0.08	3.58	0.04	0.87
Variance	0.00	3.69	0.00	12.76	0.00	0.77
Kurtosis	9.64	3.54	30.1	6.89	157	8.89
Skewness	-0.6	1.22	-3.36	2.0242	-2.2	2.48

4. CONCLUSION

This paper deals with the time and frequency domain analysis of the ECG signal. First of all ECG signal was analyzed on the basis of time domain, the overall variability of the RR intervals over the time of recording can be calculated by using time domain parameters. Time domain analysis is a commonly selected option for analyzing the biological signals, but this domain does not always present all the features of the ECG signal then the abnormalities may not always be obvious. Thus, this limitation of time domain analysis has motivated us towards the use of frequency domain technique for analysis of ECG signal.

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