A Time Domain Method for Calculation of Heart Rate Variability

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ABSTRACT
The significance of extracting the RR interval is to determine the length of heart beat interval., since HRV is physiological phenomenon at which time interval between each heart beat varies inconsistently and therefore evaluated by measuring inter-beat time interval fluctuations. Hence a reliable and accurate QRS detection algorithm is required. Modified Pan Tompkins method is used for QRS and RR time interval detection.

Calculation of VARIANCE (NN) and SDNN and of MITBIH ECG data comes to 1942and 44 indicates normal ANS regulating function.

Keywords
Heart rate variability (HRV), QRS Complex, Moving average filter, differentiator, Finite impulse response filter, RR time interval

1. INTRODUCTION
In general , a linear time-invariant system modifies the input signal spectrum *X(w)* according to its frequency response H(w) to yield an output signal with spectrum Y(w)=H(w)X(w). In a sense, H(w) acts as a weighting function or a spectral shaping function to the different frequency components in the input signal . When viewed in this context , any linear time-invariant system can be considered to be a frequency-shaping filter, even though it may not necessarily completely block any or all frequency components. Consequently , the terms " linear time-invariant term" and "filter" are synonymous and often used interchangeably. An HRV signal was obtain from ECG as sequence of RR intervals. The firing rate of SA node is controlled by ANS leading to delivery of the neurotransmitters acetylcholine (for vagal stimulation , causing a reduction in heart rate)or epinephrine (for sympathetic stimulation , causing a increase in heart rate). The heart rate is affected by normal breathing due to coupling and interaction existing between cardiac and respiratory systems[1-4]. The result obtained indicated that respiratory activation and tachycardia precedes periodic leg movement, which was taken to correlate with sympathetic pre-activation. deBoer et al.[5] applied Fourier analysis techniques to two types of data derived from heart rate data. They note standard Fourier analysis methods cannot be applied directly to a series of point events. Therefore ECG beats are decomposed into three types of signals: first is instantaneous heart rate values defined as the inverse of RR interval of each beat, second is a series of RR interval values, third is a train of delta functions at the SA node firing instants. The RR interval data of a subject breathing freely and spectra derived from the data reveals three peaks: the effect of respiration at about 0.3Hz; the peak at 0.1 Hz related to 10s waves seen in blood pressure signal; the peak at below 0.1 Hz caused by thermo-regulatory system. Studies on HRV uses Fourier analysis of heart rate.[6]

2. HEART RATE VARIABILITY
Heart rate is controlled by the autonomous and central nervous systems. It is a measure of the communication between sympathetic and parasympathetic activity in autonomous system[7,9,10]. There are two methods used for HRV analysis: the time domain and frequency domain analysis. Time domain analysis require standard deviation of normal to normal intervals (SDNN)[12]. Frequency domain method requires Fourier transform of ECG data, that is Power spectral density of series of RR interval values.[8,11]

3. TIME DOMAIN METHODS FOR MEASUREMENT OF HRV
Figure 1 shows general block diagram that describes HRV evaluation process. The significance of extracting the RR interval is to determine the length of heart beat interval., since HRV is physiological phenomenon at which time interval between each heart beat varies inconsistently and therefore evaluated by measuring inter-beat time interval fluctuations. Hence a reliable and accurate QRS detection algorithm is required. Modified Pan Tompkins method is used[13-17] for QRS and RR time interval detection.

TIME DOMAIN METHOD

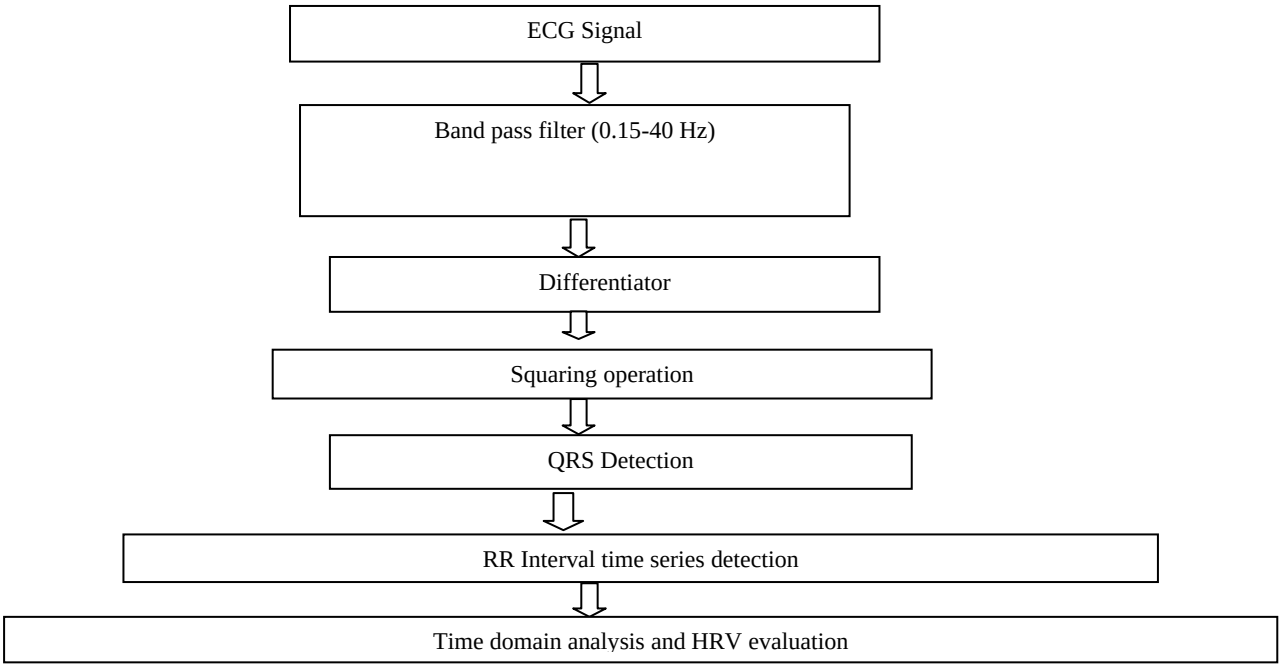

Figure 1

A MITBIH ECG sample data(213) having sampling frequency of 360 Hz is used for QRS and RR interval time series detection by modified Pan Tompkins method as shown in Figure 2.The first plot is ECG signal, used for QRS and RR time interval determination. The second plot is a FIR filter order 60 having bandwidth of 0.15-40 Hz. The third plot is a differentiator, Derivative operator enhances the QRS Complex and suppress P and T wave. The fourth plot is squaring operation, the squaring operation makes the result positive and emphasizes large differences resulting from QRS complexes, the small differences arising from P and T waves are suppressed. Emphasizes higher frequency component and attenuates lower frequency component. The high frequency components in the signal related to QRS complex are further enhanced. The fifth plot is Moving average filter for QRS width estimation order is 36.. The sixth plot is for RR interval estimation done by a moving average filter of order 90. Seventh plot shows a simple peak searching algorithm, used to detect each ECG beat. Thresholding is done by choosing a threshold value, and by computing running estimate of signal peaks, which is used to display heart rate. The choice of the window width N is to be made with the following considerations: too large a value will result in the outputs due to QRS and T waves being merged, where too small a value could yields several peaks for a single QRS. The derivative based QRS detection methods are simple to implement but are sensitive to high frequency noise. This drawback can be overcome by Modified Pan and Tompkins method used here. Figure 3 shows QRS pulses that is obtained by Modified Pan and Tompkins method.

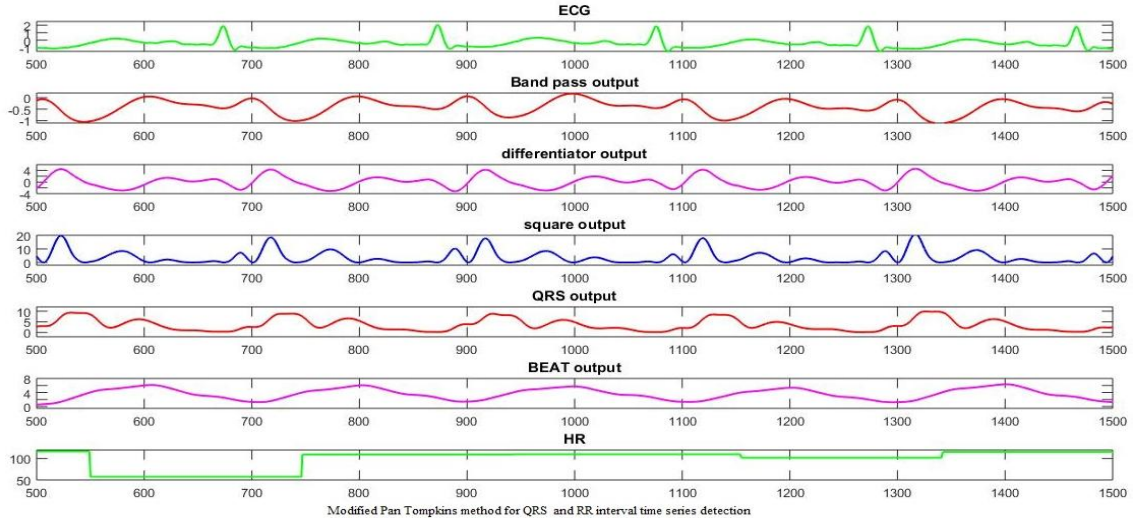

Figure 2

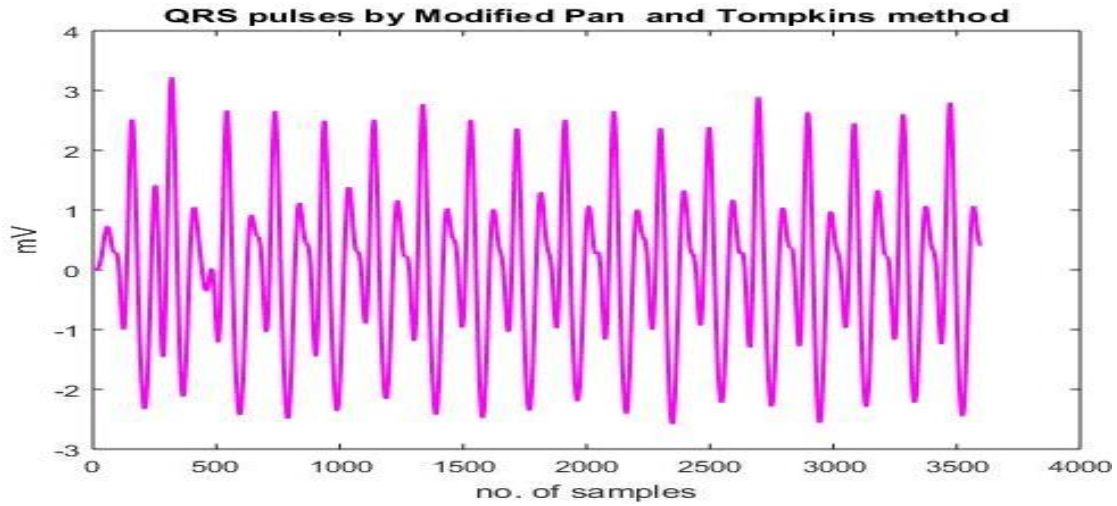

Figure 3

SDNN (standard deviation of normal to normal intervals)

Standard deviation of normal to normal intervals SDNN signifies heart rate variability. SDNN is most important parameter in HRV analysis. SDNN is directly proportional to HRV. Therefore low SDNN is low HRV. Healthy individuals are having more irregular and complex HRV signal. Low HRV is an indicator of risk related to number of chronic diseases and behavioral disorder.

Table I VARIANCE(NN) and SDNN Calculation

Beat count	Sample difference between two beats AVg.=195	Instantaneous heart rate Avg. Heart rate=110.78	NN interval in ms(x)	Mean NN interval in ms(x')	x-x'	$(x-x')^2$	$V=\sum (x-x')^2/18$	$S.D=\sqrt{\sum} (x-x')^2/18$
1. 8	224	96.43	622		77	5929		
2.	150	144.02	416		-129	16641		
3.	233	92.70	647		102	10404		
4.	196	116.64	544	545	-1	1		
5.	197	109.64	547		2	4		
6.	202	106.93	561		16	256	1942	44
7.	199	108.55	552		7	49		
8.	194	111.35	538		-7	49		
9.	188	114.89	522		-23	529		
10.	194	111.35	538		-7	49		
11.	197	109.64	547		2	4		
12.	191	113.10	530		-15	225		
13.	196	116.64	544		-1	1		
14.	197	109.64	547		2	4		
15.	202	106.93	561		16	256		
16.	189	114.28	525		-20	400		
17.	195	110.78	541		-4	16		
18.	192	112.50	533		-12	144		

4. CONCLUSION

The significance of extracting the RR interval is to determine the length of heart beat interval., since HRV is physiological phenomenon at which time interval between each heart beat varies inconsistently and therefore evaluated by measuring inter-beat time interval fluctuations. Hence a reliable and accurate QRS detection algorithm is required. Modified Pan Tompkins method is used for QRS and RR time interval detection VARIANCE(NN) and SDNN and from table I above is found to be 1942 and 44 indicates normal ANS regulating function.

5. REFERENCES

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