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Wavelet Transform Based Heart Rate Variability Analysis of ECG

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***Abstract:** Electrocardiography (ECG) is recording of heart electrical activity. For analyzing and diagnosis of heart diseases ECG is very important. In graphical ECG which used for clinical diagnosis all features are not visible. Different types of signal processing methods are present which can be used for extracting ECG signal features. Wavelet transforms is one kind of signal processing tool which is used for analyzing ECG signal. For features extraction multi-resolution wavelet transform can be used. During recording of ECG different kind of noise are added with ECG. So noise should be removed from ECG, than R peaks were detected which amplitude is higher than the other peaks. Referring to R peaks the others peak as P, Q, S and T were detected. Then different feature of the ECG signal were detected. Time differences between R peaks were calculated and then heart rate calculated from mean RR interval. In ECG RR interval indicate the change between consecutive heart rate (HR). Heart rate variability (HRV) explored how RR interval varies over time. HRV is calculated from RR interval series obtained from ECG signal analysis. From the RR intervals time domain indices of HRV were determined by using MATLAB programming and MIT-BIH database signal were used as input. In the time domain method SDNN, RMSSD, and pNN50 etc were determined here.*

***Keywords:** Electrocardiography, Wavelet Transform, Discrete Wavelet Transform, Heart rate, Heart rate variability, Standard Deviation.*

I. INTRODUCTION

ECG signal is important for determined any kind of heart diseases. It plays a vital role in the diagnosis of heart related problems. The processed ECG signal gives exact, fast and feasible information which are used to evaluate the patient's cardiac conditions. Main parts of ECG signal are P wave, QRS complex and T waves [1, 2]. Most of the diagnosis and findings of ECG are made based on its features as magnitude of wave peaks and time intervals among the wave peaks. For ECG signal analysis it is very important to develop an automatic features extraction method. In fact, for determining the Heart Rate (HR) and Heart Rate Variation (HRV) R peaks detection is necessary. To detect abnormal beats further processing of the signal is needed [3]. The instantaneous RR intervals and Mean RR interval were calculated. Then HR is calculated from Mean RR interval. HRV is calculated from RR interval series obtained from ECG signal analysis.

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High quality ECG recordings give the best ground for HRV analysis [4]. In ECG, RR intervals represent time difference between consecutive R wave peaks. From the RR intervals both the frequency domain and time domain indices could be determined by using MATLAB programming. In the time domain SDNN, RMSSD, and pNN50 were determined [5, 6, 7].

II. METHODS

Different types of time frequency analysis methods are available for signal analysis, such as the Short time Fourier Transform (STFT), Wigner Ville Transform (WVT), Choi Williams Distribution (CWD) and the Wavelet Transform (WT) etc [8].

The Continuous Wavelet Transform (CWT) and the Discrete Wavelet Transform (DWT) are two distinct varieties of Wavelet Transforms which use today [9].

The Continuous Wavelet Transform of a signal x (t) is defined as:

$$T(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\psi^*\left(\frac{t-b}{a}\right) dt \ldots\ldots\ldots(1)$$

Where $\psi^*(t)$ is the complex conjugate of the wavelet function ψ (t), a is the dilation parameter of the wavelet and b is the location parameter of the wavelet.

The Discrete Wavelet Transform (DWT) can be written as:

$$T_{m,n} = \int_{-\infty}^{\infty} x(t)\psi_{m,n}(t) dt \ldots\ldots\ldots(2)$$

where $T_{m,n}$ is the detail coefficient at scale and location indices (m, n).

Approximation coefficients are convolution of scaling function with signal as:

$$S_{m,n} = \int_{-\infty}^{\infty} x(t)\varphi_{m,n}(t) dt \ldots\ldots\ldots(3)$$

A signal x(t) then can be represented using a combined series expansion of both the approximation coefficients and the detail coefficients,

$$x(t) = \sum_{n=-\infty}^{\infty} S_{m_0,n}\varphi_{m_0,n}(t) + \sum_{m=-\infty}^{m_0} \sum_{n=-\infty}^{\infty} T_{m,n}\,\varphi_{m.n}(t)\ldots(4)$$

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Equation (4) can also be written as

$$x(t) = x_{m_0}(t) + \sum_{m=-\infty}^{m_0} d_m(t) \quad \ldots\ldots\ldots\ldots (5)$$

From this equation it is easy to show that

$$x_0(t) = x_M(t) + \sum_{m=1}^{M} d_m(t) \quad \ldots\ldots\ldots\ldots (6)$$

If considered M = 3, the signal approximation can be write as,

$$x_3(t) = x_0(t) - d_1(t) - d_2(t) - d_3(t) \quad \ldots\ldots\ldots (7)$$

This is called multi resolution representation of a signal [10]. The level-3 decomposition example structure is shown in Figure 1, Where the signal is X [11].

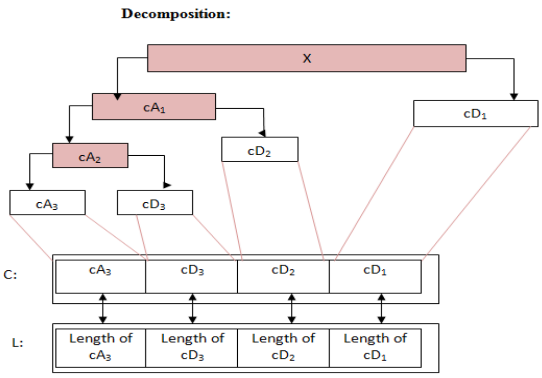

Figure 1: Three-level wavelet decomposition tree [11].

Here the wavelet decomposition vectors C and the bookkeeping vector L.

III. HRV INDICES ANALYSIS

Simple time domain HRV indices that calculated here are Mean RR interval, Mean heart rate, Standard Deviation of RR interval, The root mean square differences of successive RR interval (RMSSD) , percentage of difference between adjacent RR interval differing more than 50msec (pNN50). RR interval histogram of ECG is also analyzed. The proposed algorithm for ECG signal processing with WT and HRV indices analysis are illustrated in Figure 2.

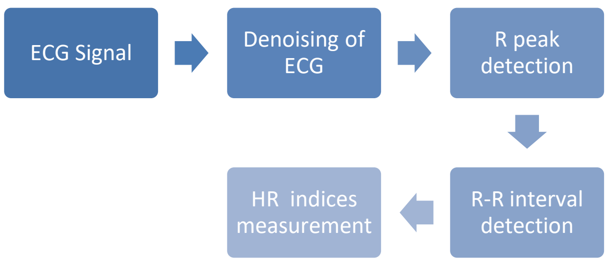

Figure 2: Flow Diagram of HRV Indices Measurement Algorithm.

Some Time domain Indices were calculated using the following formula:

Mean value of all RR interval: The mean of RR interval is, Mean, $\bar{x} = \frac{1}{N}\sum_{n=1}^{N}|x_n|$, where X_n is the matrix of RR Interval and N is the length of matrix.

Mean Heart Rate (bpm):

$$\text{Heart rate(bpm)} = \frac{60}{\text{Mean RR interval(second)}}.$$

Standard Deviation of all RR intervals (SDNN): The Standard Deviation of RR interval is, $SDNN = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}(x_n - \bar{x})^2}$

Variances of all RR intervals: Variance $= \frac{1}{N-1}\sum_{n=1}^{N} x_n{}^2$

The root mean square differences of successive RR interval (RMSSD): $RMSSD = \sqrt{\frac{1}{N}\sum_{n=1}^{N-1}(x(n) - x(n+1))^2)}$

NN50: Number of adjacent RR interval differing by more than 50 msec.

Percentage of difference between adjacent RR interval differing more than 50msec (pNN%):

IV. RESULTS AND DISCUSSION

The input ECG signals were downloaded from MIT-BIH arrhythmia and normal database. To remove noise from ECG signal Wavelet Transform is executed using MATLAB. Denoised signal with respect to original signal present on figure 1. From the denoised ECG signal R peaks were detected which have high tamed amplitude. Discovered R peak with amplitude and location shown in figure 4 for 10 second of ECG data. The RR intervals were calculated and then heart rate was calculated from the Mean RR interval. The RR interval of record 100 shown in figure 5 and variation of heart rate in figure 6 of 60 seconds duration of ECG.

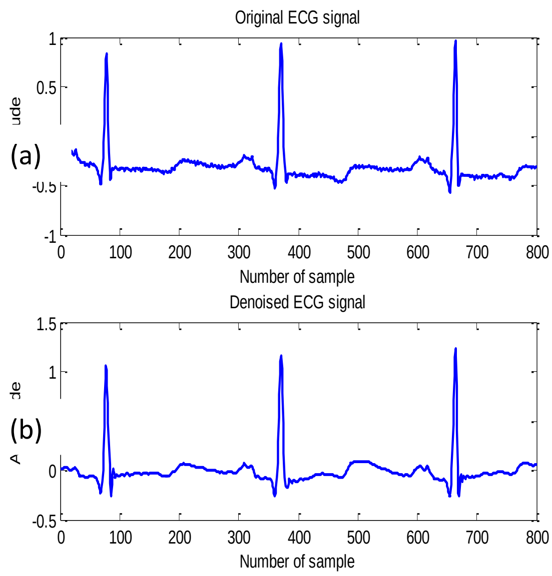

Figure 3: Representation of mit-bih record 100(a) Original and (b) De-noised ECG signal.

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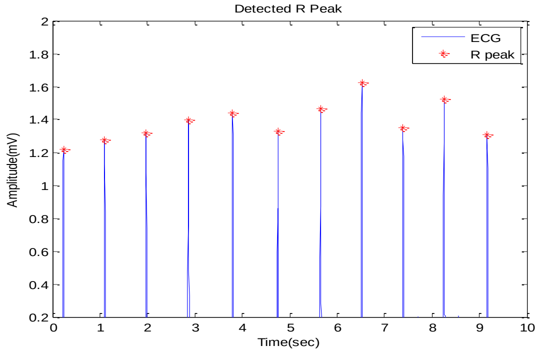

Figure 4: Detected R peaks of record 100 mit-bih database.

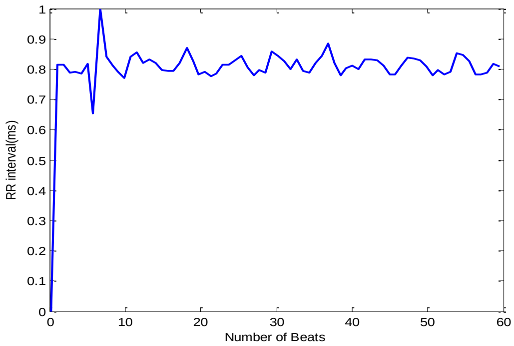

Figure 5: RR intervals of record 100 mitbih database.

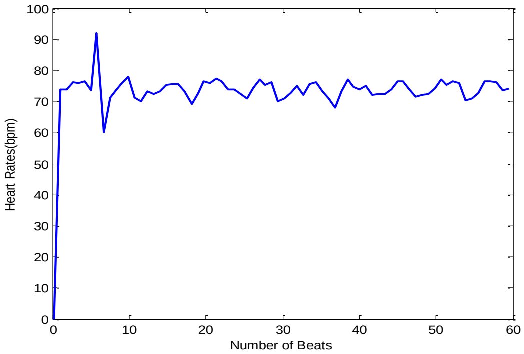

Figure 6: Heart Rate of Record 100 Mitbih Database.

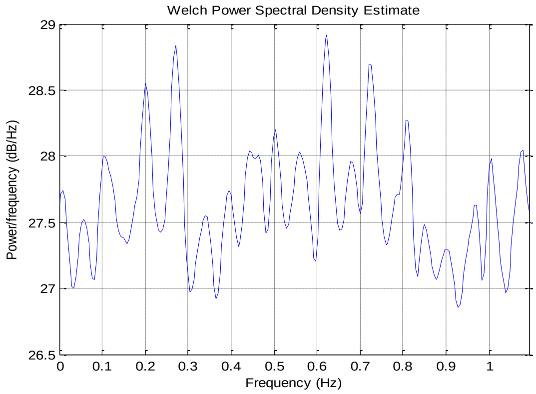

Figure 7: Power spectral density of record 100 mitbih.

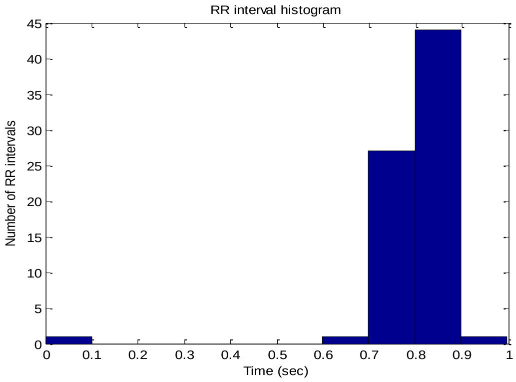

Figure 8: Histogram representation of RR intervals of record 100 mitbih.

In figure 8 histogram of RR interval was present. Table1 represent the results of HRV analysis in time domain method.

Table-I: Results of Time Domain HRV Indices

Sample No.	Total Beats detected	Mean RR interval (msec)	Mean HR (bpm)	SDNN (msec)	Variance RR (msec)	RMSSD (msec)	NN50	pNN50 (%)
100	**12**	806.25	75.02	76.28	5.818077	125.37	3	25
101	**11**	893.61	67.14	31.29	0.979167	32.18	2	20
102	**9**	1026.39	66.58	561.39	315.1609	606.91	2	25
103	**11**	856.39	70.13	29.05	0.843707	32.18	1	10
105	**14**	719.23	83.49	21.62	0.467415	20.22	0	0
113	**9**	1069.44	56.25	58.27	3.395062	81.37	4	50
115	**10**	1001.54	60.16	70.83	5.017575	105.02	6	67
123	**8**	1265.48	47.58	80.49	6.478542	112.58	3	43
16265	**16**	616.67	97.35	15.48	0.23949	20.03	0	0
16272	**9**	1089.84	58.08	342.91	117.5886	366.91	1	13
16273	**16**	622.92	96.39	17.08	0.291806	16.04	0	0
16420	**9**	968.75	78.51	693.56	481.0268	1082.98	4	50
16483	**8**	718.75	88.98	248.04	61.52344	267.91	1	14
16539	**7**	911.46	71.62	346.53	120.0846	505.25	4	67

V. CONCLUSION

Execution of Heart rate Variability (HRV) analysis lies on the ECG signal denoising process. The more accuracy of ECG signal denoising than more accurate R wave detection is possible. From the obtained features it can be said that higher value of mean RR interval than RR distances were higher and also corresponding lower heart rate. In future frequency domain features can be extracted. Extracted features can be used for classification of ECG by using any classifier as rule based classifier or any types of linear classifier.

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AUTHOR PROFILE

Iffat Ara, was born in Pabna, Bangladesh, in 1986. She received the Master and B.Sc. (Honours) degrees in Applied Physics and Electronic Engineering from the Rajshahi University, Bangladesh in 2010 and 2009, respectively. She is currently an Associate Professor in the Department of Information and Communication Engineering department at Pabna University of Science and Technology, Bangladesh. Her research interests are related to the analysis of Bio- medical signal.

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