International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

HRV Analysis of Arrhythmias using Wavelet based on Statistical Parameters

[1]Narottam Das, [2]Atul Wani
Department of Electronics and Telecommunication Engineering,
College of Engineering Lavale,
Pune, India

***Abstract*--- Electrocardiography is a technique of recordings of bioelectric current signal generated by heart muscles. Beat to beat time interval of ECG signal varies which results Heart Rate Variability (HRV). HRV analysis is a well-known tool for investigation of normal rhythm from abnormal rhythm. This work on HRV analysis is to distinguish normal sinus rhythm (NSR) from atrial fibrillation (AF), supra ventricular arrhythmia (SVF) and premature ventricular contraction (PVC). This HRV analysis is completely based on analysis of ECG signal upon time domain parameters using db6 wavelets. The ECG signal is pre-processed using filters. True R-peak detection is done using db4 wavelet at third level decomposition. The time domain statistical parameters like pNN50, RMSSD, Skewness and Kurtosis are used for HRV analysis. The above all parameters are considered for HRV analysis for both short and long term recordings of ECG signal**.

Index Terms—Wavelet db4, pNN50, HRV, Kurtosis, Pdf, RMSSD, Skewness.

I. INTRODUCTION

The graphical representation of recordings of bioelectric current signal generated from heart muscles is called electrocardiography (ECG). The ECG signal mainly consists of P-wave, QRS complex and T-wave. Change in environmental condition, different types of thoughts, emotions causes the heart rate fast or slow. So the instantaneous heart rate is called Heart Rate Variability. At the time of recording of ECG signal, different types of noise add with ECG recordings such as electrode contact noise, muscle noise, motion artifacts, baseline drift, power line interference and internal amplifier noise. It is very much necessary to avoid the erroneous conclusion due to the noise [1]. A Pre-processing of ECG signal is done using low-pass filter, high-pass filter and differentiator. Detection of QRS complex from the recording of ECG signal is one of the most important work for HRV analysis. The pre-processed signal is decomposed up to 5th level using db4 wavelet. For better R- peak detection and less computation 3rd level of decomposition is considered [6]. In this work HRV analysis is done using the time domain statistical parameters such as pNN50, RMSSD, Skewness, Kurtosis and pdf plot.

The total number interval differences of successive NN intervals greater than 50ms is consider as NN50. It is the variability of differences of differences in NN intervals. The pNN50 is calculated by dividing by the total number of NN intervals. All these measurements of short-term variations estimate high frequency variations in heart rate and thus highly correlated. RMSSD is one of the most commonly used parameter to distinguish normal sinus rhythm. It is also one of the variability of differences of differences in NN intervals. It is the square root of the mean squared differences of successive NN intervals [3], [7].

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the centre point. Skewness is zero for normal distribution and negative for skewed left and positive for skewed right. Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. For standard normal distribution kurtosis is of zero. In addition positive kurtosis indicates a "peaked" distribution and negative kurtosis indicates a "flat" distribution [2].

The aim of this work is to distinguish normal sinus rhythm from abnormal arrhythmias like atrial fibrillation, supraventricular arrhythmia and Premature ventricular contraction by doing analysis upon ECG signals using the time domain statistical parameters like pNN50, RMSSD, Skewness, Kurtosis and pdf plot.

II. METHOCDOLOGY

The ECG signals that has been used for this work has been obtained from MIT-BIH data base. For this work of each ECG signal data have been considered is of 30min duration. The sampling frequency for normal sinus rhythm and supraventricular arrhythmia is 128 Hz, for atrial fibrillation 250 Hz and for Premature ventricular contraction 360 Hz is considered [5].

1) Pre-Processing

At the time of recording of ECG signal, different types of high and low frequency noise add with ECG recordings such as electrode contact noise, muscle noise, motion artifacts, baseline drift, power line interference and internal amplifier noise. It is very much necessary to avoid the erroneous conclusion due to the noise. In this work Pre-processing of ECG signal is done using low-pass filter, high-pass filter and differentiator. The low pass filter and high pass filter removes all types of very low frequency noise and high frequency noise. Using differentiator the DC signal is removed and QRS becomes more sharped which can be easily identified using searching algorithm [1], [8]. After pre-processing the signal is decomposed using wavelet transform for R-peak detection.

2) True R-Peak Detection

The wavelet transform function is used for R-peak detection instead of Fourier Transform as it gives both time and frequency information simultaneously. The Wavelet Transform uses a short time interval for evaluating higher frequencies and a long time interval for lower frequencies. Due to this property, high frequency components of short duration can be observed successfully by Wavelet Transform. One of the advantages of the Wavelet Transform is that it is able to decompose signals at various resolutions, which allows accurate feature extraction from non-stationary signals like ECG. A family of analysing wavelets in the time frequency domain is obtained by applying a scaling factor and a translation factor to the basic mother wavelet [6].

a) Db4 Wavelet

Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets, thus making discrete wavelet analysis practicable. The name of Daubechies family wavelets is written as 'dbN', where N is the order and 'db' is the 'surname' of the wavelet. In the following figure a few Daubechies family wavelets are shown [4].

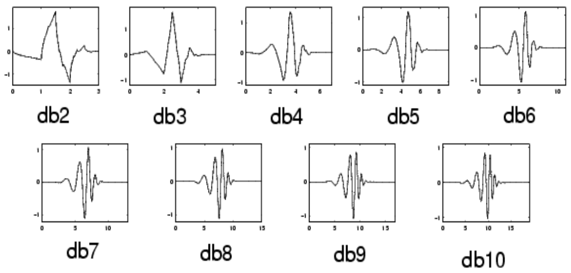


Fig 2. Daubechies family wavelets

The db4 Wavelet has been found to give details and more accurate results than others. This wavelet shows similarity with QRS complexes and also energy spectrum is concentrated around low frequencies.

b) Decomposition

The decomposition halves the time resolution and at the same time doubles the frequency resolution. Thus, at every level, the filtering and sub-sampling will result in half the time resolution and double the frequency resolution. The sequence f(n) is passed through several levels made up of low pass g(n) and h(n) analysis filters. At each level detail information d(n) is produced by the high pass filter and coarse approximations a(n) is produced by the low pass filter [6].

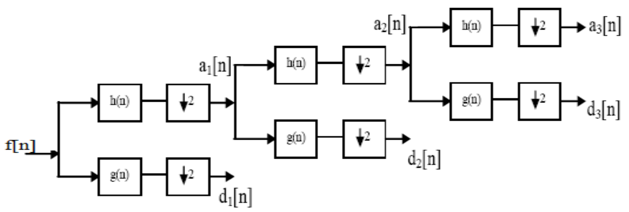


Fig 1. Decomposition

c) True R-Peak Detection

True R-peak detection is one of the major work for HRV analysis, which increases the accuracy for the arrhythmia classification. In this work wavelet db4 has been decomposed up to the 6^{th} level, but the approximate coefficient of third level is considered for R-peak detection, because of less computation without any loss of information of ECG signals. By using search algorithm, all the peaks with locations are detected. Because of some ectopic beats, all detected peaks are not true peak, so again using another search algorithm the true R-peaks and respective locations are detected [9].

3) HRV analysis using Time domain Statistical Parameters

a) pNN50

NN50 is the total number of interval differences of successive NN intervals greater than 50ms. The proportion derived by dividing NN50 by the total number of NN intervals. All these measurements of short-term variation estimate high frequency variations in heart rate and thus are highly correlated.

pNN50=(NN50/total number of NN intervals).

pNN50 of abnormal signal is more as compared to normal because the total number of RR intervals whose length is less than 50ms is more in abnormal signals, this is because of ectopic beats, but in normal sinus rhythm the total count is less because maximum RR intervals are above 500ms [2], [3].

b) RMSSD

The most commonly used measures derived from interval differences include RMSSD, the square root of the mean squared differences of successive NN intervals. RMSSD depends on total number of RR intervals and length of RR intervals, so it is higher for abnormal signal as compared to normal sinus rhythm [2], [3].

c) Skewness

It is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. The skewness for a normal_distribution is zero, and any symmetric data should have a skewness near zero. Negative values for the skewness indicate data that are skewed left and positive values for the skewness indicate data that are skewed right. By skewed left, we mean that the left tail is long relative to the right tail. Similarly, skewed right means that the right tail is long relative to the left tail. Some measurements have a lower bound and are skewed right. For positive skewed more observations below the mean than above it and mean is greater is median. For negative skewed more observation above the mean below it and median is greater than mean [2].

d) Kurtosis

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case. This shows that the standard normal distribution has a kurtosis of zero. In addition positive kurtosis indicates a "peaked" distribution and negative kurtosis indicates a "flat" distribution [2].

It may happens that the two distribution have the same variance, apparently same skewness but differ in kurtosis.

III. RESULTS

For this work the ECG signals such as normal sinus rhythm, atrial fibrillation, supraventricular arrhythmia and premature ventricular contraction of MIT-BIH data base from physionet.org has been used. Each data having 30 minutes each have been considered. The well- known MATLAB software has been used for this work. The results in terms of plots and table are given below.

a) Plots

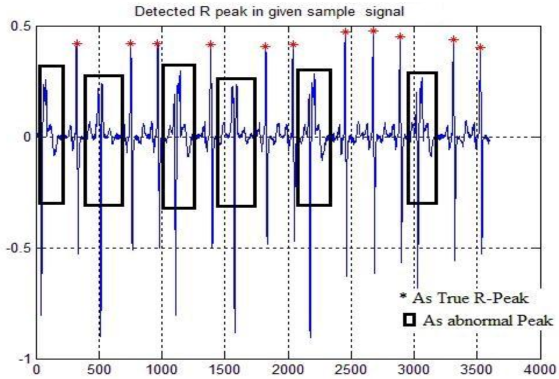


Fig 3. True R-Peak Detection

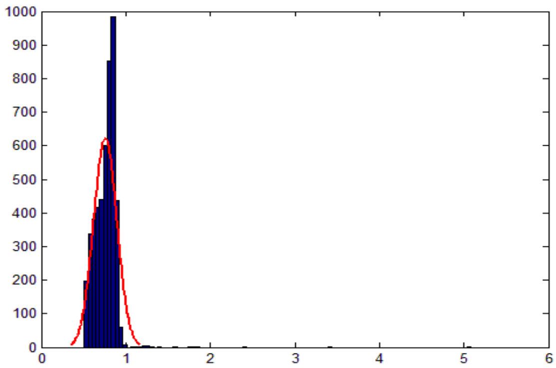


Fig 4. Pdf of Normal Sinus Rhythm

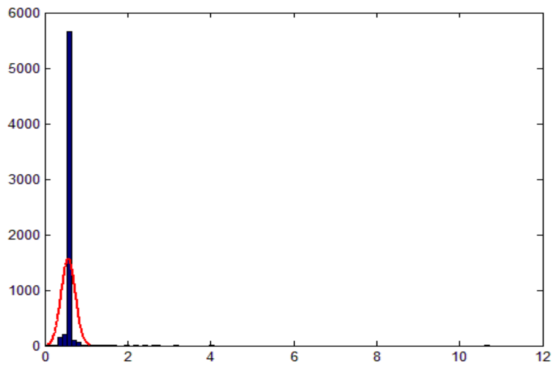


Fig 5. Pdf of Atrial Fibrillation

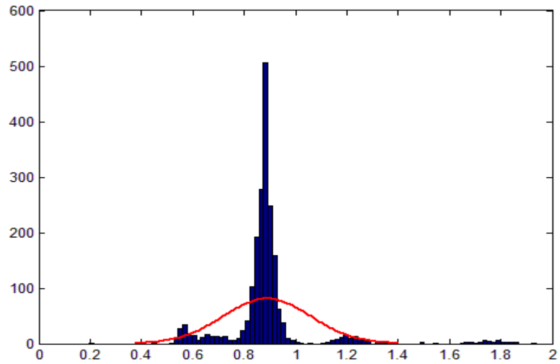


Fig 6. Pdf of Supraventricula Arrhythmia

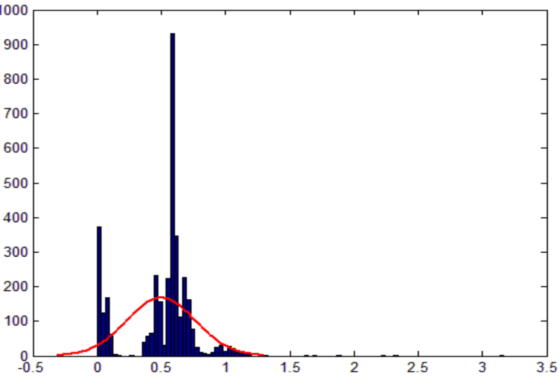


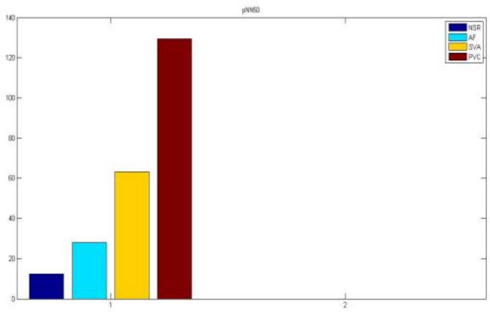
Fig 7. Pdf of Premature Ventricular Contraction

b) Table

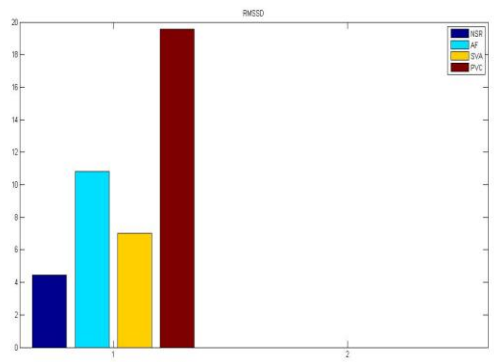
TABLE I
TIME DOMAIN STATISTICAL PARAMETERS

Signals	Parameters			
	pNN50	RMSSD	Skewness	Kurtosis
NSR	12.4059	4.4653	17.2093	274.4718
AF	28.0705	10.8201	59.2819	3156.6
SVF	63.1093	7.004	8.0549	89.1980
PVC	129.439	19.5751	3.5039	39.0836

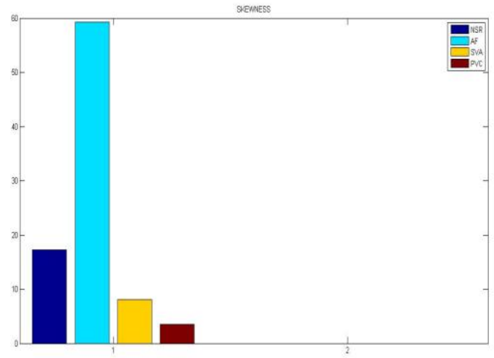
c) Bar Plots of Time domain Statistical Parameters



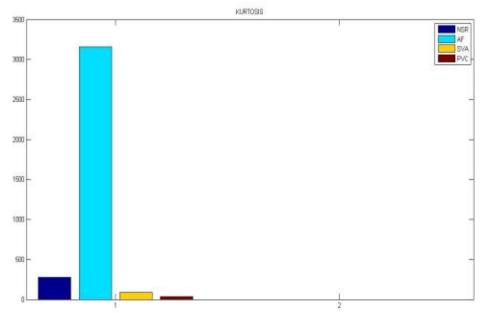
pNN50



RMSSD



SKEWNESS



KURTOSIS

IV. CONCLUSION

In this work, the normal sinus rhythm is differentiated from abnormal signals like atrial fibrillation, supraventricular arrhythmia and premature ventricular contraction. All these ECG record has been obtained from MIT-BIH data base with each of having duration 30 minutes. Because of noise in ECG signal, these signals are pre-processed in steps by low pass filtering, high pass filtering and differentiator. The pre-processed signals are then decomposed using db4 wavelet for R-peak detection. In this work the R-peak detection is found to be 98.9%. From the table and bar plot, we could see that pNN50 of PVC is 129.4390 which is more as compared to all because the total number of RR intervals whose length is less than 50ms is more as compare to all this is because of ectopic beats, but in normal sinus rhythm the total count is less because maximum RR intervals are above 500ms. . RMSSD depends on total number of RR intervals and length of RR intervals, so it is higher for PVC as compared to all and least for normal sinus rhythm. Kurtosis of all signals are higher than 3. It shows that all have a stronger peak, more rapid decay, and heavier tails as compared normal distribution. For atrial fibrillation kurtosis is 3156.6 which is highest among all because heavier tails. For normal sinus rhythm it is 274.7418, it has more peak and heavier tails as compared to supraventricular arrhythmia and PVC. Skewness of all signals is positive, that is all are positive skewed and more observation below mean than above it. This differentiation can be done even by visualizing the pdf plots. So we could distinguish the normal sinus rhythm from abnormal condition like atrial fibrillation, supraventricular arrhythmia and premature ventricular contraction.

V. REFERENCES

[1] Jiapu Pan and Willis J. Tomkins, “ A Real- Time QRS Detection Algorithm”, IEEE Transactions on Biomedical Engineering, Vol, Bme-32, No. 3, March 1985.
[2] M. Sifuzzaman, M.R. Islam, and M.Z. Ali, “Application of Wavelet Transform and its Advantage Compared to Fourier Transform,” Journal of Physical Sciences, vol. 13, pp.121-134, 2009, ISSN: 0972-8791.
[3] Task Force of the European Society of Cardiology and The North American society of Pacing and Electrophysiology, “Heart rate variability standards of measurement, physiological interpretation, and clinical use”, European Heart Journal(1996) 17, 354-381.
[4] Hui-MinWang and Sheng-Chieh Huang, “SDNN/RMSSD as a Surrogate for LF/HF: A Revised Investigation,” Hindawi Publishing Corporation, Modelling and Simulation in Engineering, Volume 2012, Article ID 931943, doi:10.1155/2012/931943.
[5] Luca T. Mainardi, “On the quantification of heart rate variability spectral parameters using time-frequency and time-varying methods”, Philosophical Transactions of the Royal Society A (2009) 367, 255-275.
[6] GB Moody, RG Mark, AL Glodberger, “ PhysioNet: A Research Resource for Studies of Complex Physiologic and Biomedical signals”, IEEE, Computers in Cardiology 2000;27: 179-182.
[7] A.H M. Zadidul Karim and Md. Meganur Rhaman, “Identification of Atrial Fibrillation (AFIB) of Heart using Robust Stastical Tools and Approximate Entropy Method”, IJCIT, ISSN 2078-5828, ISSN 2218-5224, VOLUME 01, ISSUE 02, Manuscript Code: 110135.
[8] J. Saraswathy, M. Hariharan, V. Vijean, S. Yaacob, and W. Khairunizam, "Performance comparison of Daubechies wavelet family in infant cry classification," in Signal Processing and its Applications (CSPA), 2012 IEEE 8th International Colloquium on, 2012, pp. 451-455
[9] Valtino X. Afonso, Willis J. Tompkins, Truong Q. Nguyen, and Shen Luo, “ ECG Beat Detection Using Filter Banks”, IEEE Transactions on Biomedical Engineering, VOL 46, No 2, February 1999.