International Journal of Electronics and Electrical Engineering

Volume 2 | Issue 2 Article 14

October 2013

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Recommended Citation
DESHPANDE, RASHMI A. (2013) "HRV ANALYSIS USING ECG AS DATA SOURCE," *International Journal of Electronics and Electical Engineering*: Vol. 2 : Iss. 2 , Article 14.
DOI: 10.47893/IJEEE.2013.1084
Available at: https://www.interscience.in/ijeee/vol2/iss2/14

HRV ANALYSIS USING ECG AS DATA SOURCE

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Abstract—Heart Rate Variability (HRV) is a physical phenomenon where the time interval between heart beats varies. It is measured by the variation in the beat to beat interval. Abnormalities present in the time interval between R wave peaks in the Electro-cardiogram (ECG) indicate cardiac dysfunction. Autonomic Nervous System controls the cardiac activity of the body and provides the beat to beat regulation of the cardiovascular system. Thus Heart Rate Variability is an important tool to access autonomic function also. The source for HRV is a continuous beat to beat measurement of interbeat intervals. An ECG signal can be used as the data source for HRV analysis. In this study the HRV data is obtained from ECG signal and is processed to calculate spectral HRV index, LF/HF ratio.

Keywords*-Ectopic beat; Heart rate variability, Wavelet Transform, Detrending, Myocardial infarction.*

I. INTRODUCTION

Heart rate variability (HRV) is a physiological phenomenon where the time interval between heart beats varies. It is measured by the variation in the beat-to-beat interval. These are the oscillations in the interval between the consecutive heart beats as well as the oscillations between consecutive instantaneous heart rates. "Heart rate variability" has become the conventionally accepted term to describe variations of both instantaneous heart rate and RR intervals. To describe oscillation in consecutive cardiac cycles, other terms have been used in the literature, for example, cycle length variability, heart period variability, RR variability, and RR interval tachogram, and they more appropriately emphasize the fact that it is the interval between consecutive beats that is being analyzed rather than the heart rate [1].

Unlike the common assumption, for good health heart rate intervals should vary in a random and chaotic manner. The heart's moment by moment beating rate is naturally influenced by many physiological factors and varies constantly. The most obvious of these factors is physical activity. For example, at rest, heart might beat at an approximate rate of 60 times per minute. While running or swimming, it might accelerate to an approximate rate of 90 times a minute. This range defined by the minimum to maximum heart rate capacity is a key factor defining the level of cardiac health. As a person's physical condition deteriorates, this range becomes narrow, to the point of limiting his ability to adapt to the stresses of daily life.

After this point, any unexpected stressful condition could push the individual to the limit of their adaptability and put them at risk for cardiovascular accidents and possibly death. Low heart rate variability predicts death in patients after myocardial infarction. Variability in heart rate is clinically linked to lethal arrhythmias, hypertension, coronary artery disease, congestive heart failure, organ transplant, tachycardia, neuropathy, and diabetes [1].

HRV data can be obtained from two signals; electrocardiogram (ECG) and photoplethysmograph (PPG). In this paper HRV data is extracted by processing the ECG signal. This HRV data is also analyzed using Wavelet Transform and the LF/HF ratio is obtained.

II. MATERIAL

ECG is the main source for performing HRV analysis. A database of ECG signals will suffice the requirement of this study. The database can be created by collecting ECG samples by the following methods:

a. Hospitals: Hospitals are one of the major sources for database creation. Patients suffering from any disease are required to get their ECG done for proper diagnostics. Also heart patients suffering from various diseases like arrhythmia, tachycardia, bradycardia, will add to the database of the ECG signals.
b. Laboratories: ECG data for normal subjects of different age groups can also be generated in lab using hardware setup. A standard ECG machine with connectable memory or any hardware setup like PowerLab 26T can be used. This database will help in the verification of the algorithm and the method used for HRV analysis.
c. Databases available online: Universities or research institutes performing research on cardiac diseases using physiological signals, make their database available for aspiring researchers and students. [2].

ECG data, for this study, is obtained from the hardware in laboratory as well as database available online are used for validation of the algorithm.

III. METHODS

The process of HRV signal extraction is divided into three steps. Firstly, ECG data is acquired via hardware. This data is then interfaced to a computer and acquired in MATLAB. Finally this data is processed to convert it into HRV signal. All these steps are explained in the following sections.

A. ECG database generation

Block diagram of the system used to obtain ECG data is shown in fig. 1. An instrumentation amplifier is used to reduce loading effects. The frequency range of a typical ECG waveform is 0.05 to 100 Hz and therefore a band pass filter is used to select these frequencies. A notch filter is used to remove the 50Hz power line frequency noise. Finally, an amplifier is used to amplify the obtained ECG data.

B. Acquiring ECG data in MATLAB

The amplified ECG signal is an analog signal. Therefore this signal is converted into digital form by using an analog to digital converter (ADC0809). This data is then given to a microcontroller (8951) which makes it suitable for serial transfer. A MAX232 IC is used to shift the TTL signal levels to those compatible with RS232 signal transfer cable. Finally ECG data is transferred through a RS 232 cable to the computer. Fig. 2 shows the interfacing circuit. This serial data is read through a MATLAB program which generates five frames at a time.

IV. DATA PROCESSING

ECG data processing is again done in two steps. Firstly R waves in the ECG signal are identified and highlighted. And then heart timing signal is derived from these detected R waves.

A. R wave detection

Wavelet transform with daubechies as the mother wavelet is used for detection of R waves in the ECG data obtained from database. The wavelet decomposition is carried out till level of 2. The algorithm for R wave detection is as follows.

1. Load ECG data in the workspace.
2. Smooth the signal.
3. Apply Wavelet Transform to the signal.
4. Take square of the resultant signal.
5. Select threshold.
6. Consider the ECG data above threshold value. Reject the remaining signal.
7. Highlight the peak values (R peaks) of the signal.
8. Extract the positions of R-peaks.

R waves are also detected using hardware. Fig. 3 shows the block diagram.

After R wave detection the heart timing signal is used for HRV signal representation and for correction for ectopic beats. An ectopic beat is an irregular beat arising in the heart due to variations in the electrical conduction system of the

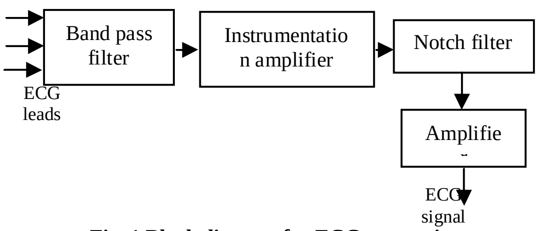

Fig. 1 Block diagram for ECG generation

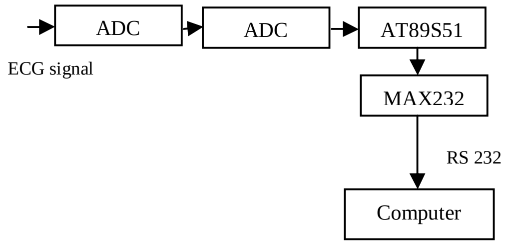

Fig. 2 Interfacing circuit

heart. Results won't be accurate if an ectopic beat is mistaken as an R peak. The results of R wave detection by MATLAB program and that by hardware are shown in section.

B. Extracting HRV data

Calculating heart rate variability means calculating time between two consecutive R waves and keeping a track of how this RR interval changes. HRV data is represented as RR interval in millisecond on Y axis and number of beats on X axis. The algorithm for extracting HRV data from ECG waveform is as follows.

1. Create a serial port.
2. Set appropriate baud rate.
3. Read data from serial port.
4. Plot the data.
5. Delete the serial port object.

The resulting HRV data is shown in section.

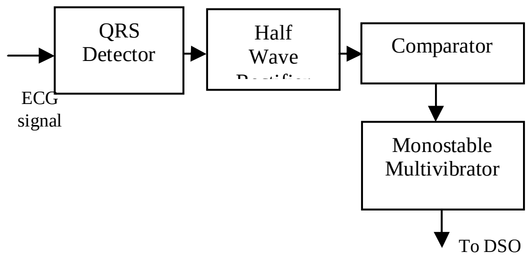

Fig. 3 R wave detection using hardware

V. HRV ANALYSIS

Time-frequency analysis is a group of techniques and methods which are used for characterizing and manipulating signals whose statistics vary in time. It gives the information about which frequencies are present in the signal and at which time intervals. Such representation is very important for HRV analysis because to obtain the standard HRV indices like LF/HF ratio, good time and frequency resolution is important. Once we have proper time – frequency representation of data, we can divide the signal into LF region, HF region and VLF regions, after which we can calculate the powers in respective regions. Wavelet transform is proved to be a very good tool for obtaining time – frequency representation of the signal.

It has both, good frequency and time resolution to localize closely located low and high frequency components which helps in tracking physiologically informative components of HRV [3]. A Wavelet expansion consists of translations and dilation of one fixed function, the wavelet. In continuous wavelet transform the translation and dilation parameter vary continuously. The wavelet transform of a function f(t) at scale ‘α’ and position ‘τ’ is given by [7],

$$wf(\alpha,\tau) = \frac{1}{\sqrt{\alpha}}\int f(t)\varphi * (\frac{(t-\tau)}{\alpha})dt$$

Using above equation, HRV signal is resolved into different frequency bands and power in each frequency band is calculated so as to derive the HRV indices. The advantages of Wavelet Transform are rapid frequency decomposition with good time resolution. This is useful when a particular band is to be studied over time.

VI. RESULTS

Fig. 4 shows the ECG data from MIT database for a normal subject.

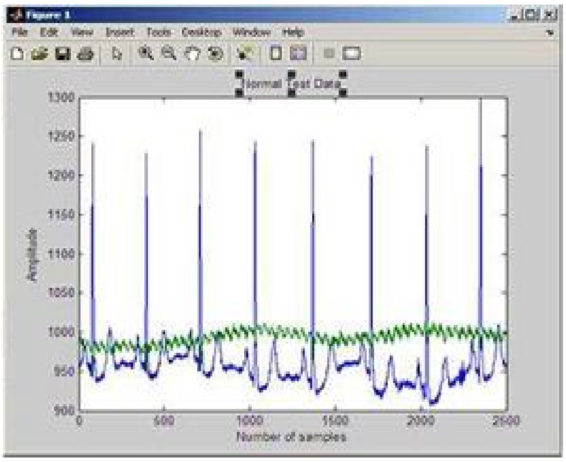

Fig. 4 ECG waveform of normal subject

The detected R peaks using the developed algorithm are as shown in the figure 5. These peaks are highlighted by orange color.

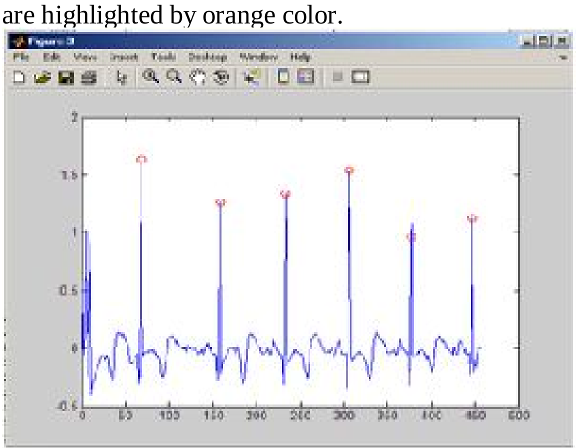

Fig. 5 Detected R peaks after using the mentioned lgorithm

Fig. 6 shows the detected R waves obtained from the hardware. The first waveform consists of pulses, wherein each pulse corresponds to an R peak. The second waveform is the ECG waveform obtained from a subject in the lab.

Fig.6 Detected R peaks by hardware

Figure 7 shows the heart timing signal obtained by applying algorithm described in section IV. This signal is also called as the tachogram.

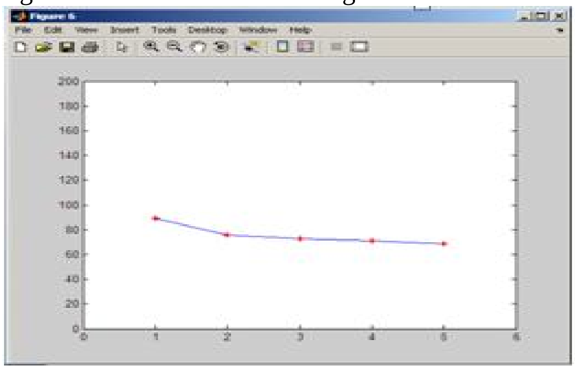

Fig. 7 Tachogram

This signal is also called as heart timing signal and it is this waveform that is processed further for analyzing HRV data.Figure 8 shows a tachogram obtained from an ECG from MIT database.

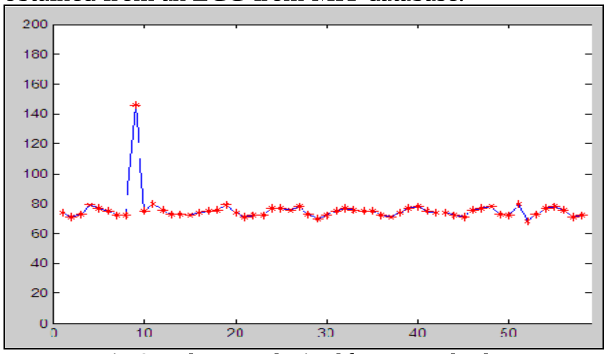

Fig. 8 Tachogram obtained from MIT database

The Power Spectral Density curve of HRV signal is shown in figure 9.

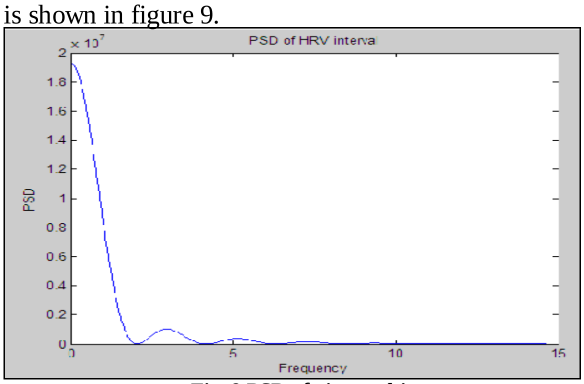

Fig. 9 PSD of given subject

The LF/HF ratio of given subject when average powers are concerned is equal to 3.54 whereas when absolute powers are concerned it is 1.33.

Table 1 shows the LF/HF ratio for MIT database when average powers are considered.

TABLE I. LF / HF RATIO OF MIT DATA

Sr. No.	Data	Average LF power	Average HF power	LF/HF
1	aami3a	22.84	4.79	4.76
2	aami3c	8.21	5.11	1.60
3	aami4a_d	7.5703	1.4842	5.10
4	100	7.3637	0.8013	5.9
5	102	7.1759	1.2387	5.79
6	103	7.1801	0.7470	9.61
7	105	5.7863	2.7104	2.13
8	106	9.1699	1.0693	8.57
9	107	10.0248	1.3325	7.52
10	e1302	3.1178	2.8856	1.0804
11	e1304	4.0452	0.5548	7.2907
12	s20111	11.8448	7.6013	1.5583
13	chf01	10.4433	5.5119	1.8947
14	chf15	3.68	8.46	0.43
15	40	8.787	2.504	3.5

The scope of this work is limited to HRV analysis using ECG data from MIT database only. When these algorithms were applied to the ECG data obtained by hardware, proper results were not obtained as data contained motion artifacts. Removal of these artifacts is in the future scope of this project.

VII. CONCLUSION

In this study, the ECG data is acquired using hardware developed in the laboratory. R waves are detected from this data using two methods; hardware and the software program using MATLAB. By comparing figures 5 & 6 we can say that R wave detection using MATLAB is more accurate as compared to that using hardware. Therefore HRV data generation based on this is also more accurate. There are many established methods of HRV analysis. Broadly they are divided as time based methods and frequency based methods. Time based methods include various statistical methods for analyzing HRV data but here length of recorded data is the major concern. As these methods are based on averaging techniques HRV data with different lengths cannot be compared. Frequency based methods are proved to be more accurate in which, HRV signal is decomposed into different frequency bands and then the power in each band is calculated. Some of the standard HRV indices are instantaneous powers in LF and HF bands, LF/HF and total power distribution in entire HRV signal. Not only the cardiac health of a patient but many other diseases can be detected from these indices like diabetic neuropathy, Sudden Infant Death Syndrome (SIDS), study of effects of anesthesia, prediction of mortality after myocardial infarction and congestive heart failure.

Data taken from MIT is the standard ECG data with minimum artifacts. With the help of Wavelet transform, the HRV signal is decomposed into different frequency bands and then the power in each band is calculated. LF/HF ratio is used as a measure of HRV. From the results obtained we can state that Wavelet transform is an efficient method to calculate the LF/HF ratio.

As stated before, if LF/HF ratio is less, the person might be in deep sleep or under the effect of anesthesia or some other similar medicine. For example in table 1, for ECG data chf15, cardiac failure has occurred and hence the HRV will continuously reduce. Due to this the obtained LF/HF ratio for selected short ECG recording is observed to be less.

This study suggests that a noticeable change in the symphathovagal balance of human body can be detected through HRV analysis.

ACKNOWLEDGMENT

The author is grateful to Prof. A. D. Gaikwad and Prof. Mrs. D. S. Ramdasi for their motivation towards completion of this paper as well as for providing precious guidance. I would also like to express sincere thanks to the staff of Instrumentation and Control Department of Cummins College of Engineering, Pune.

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