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Heart Rate Variability Analysis for Early Stage Prediction of Sudden Cardiac Death

Reeta Devi, Hitender Kumar Tyagi, Dinesh Kumar

Abstract**—**In present scenario, cardiovascular problems are growing challenge for researchers and physiologists. As heart disease have no geographic, gender or socioeconomic specific reasons; detecting cardiac irregularities at early stage followed by quick and correct treatment is very important. Electrocardiogram is the finest tool for continuous monitoring of heart activity. Heart rate variability (HRV) is used to measure naturally occurring oscillations between consecutive cardiac cycles. Analysis of this variability is carried out using time domain, frequency domain and non-linear parameters. This paper presents HRV analysis of the online dataset for normal sinus rhythm (taken as healthy subject) and sudden cardiac death (SCD subject) using all three methods computing values for parameters like standard deviation of node to node intervals (SDNN), square root of mean of the sequences of difference between adjacent RR intervals (RMSSD), mean of R to R intervals (mean RR) in time domain, very low-frequency (VLF), low-frequency (LF), high frequency (HF) and ratio of low to high frequency (LF/HF ratio) in frequency domain and Poincare plot for non linear analysis. To differentiate HRV of healthy subject from subject died with SCD, k –nearest neighbor (k-NN) classifier has been used because of its high accuracy. Results show highly reduced values for all stated parameters for SCD subjects as compared to healthy ones. As the dataset used for SCD patients is recording of their ECG signal one hour prior to their death, it is therefore, verified with an accuracy of 95% that proposed algorithm can identify mortality risk of a patient one hour before its death. The identification of a patient's mortality risk at such an early stage may prevent him/her meeting sudden death if in-time and right treatment is given by the doctor.

Keywords**—**Early stage prediction, heart rate variability, linear and non linear analysis, sudden cardiac death.

I. Introduction

HEART rate variability (HRV) is defined as the variations in beat-to-beat timing of heart. This beat-to-beat variability in human heart rate is produced as a result of interaction of different branches of human central nervous system (CNS) and respiratory cardiovascular (RCV) system. It is derived from ECG and acts as the main indicator of an individual's heart condition. It is being studied with widespread interest into its diagnostic applications over the last 30 years. The study includes signal extraction techniques, pre-processing of HRV signal for noise removal, HRV processing for extraction of its useful and application oriented parameters etc. Literature reports the extensive use of HRV as a strong predictor of SCD [1]. SCD is the sudden and natural death of patient due to cardiac causes. Patient died by abrupt loss of consciousness within one hour of onset of acute symptoms. With the occurrence of these symptoms (very serious cardiac event), patient comes across sudden death within several minutes. It is estimated that more than 7 million lives per year are lost due to SCD worldwide, including over 300,000 in the United States alone [2]. As per data from the study by Rao et. al. in 2012 and on extrapolation of this data to national mortality figures places the annual incidence of SCD at about 7 lakhs in India [3].

As already stated above, SCD is the cause of some irregular/interrupted cardiac activity. Numbers of research papers published are available in literature relating many cardiac causes to sudden death [4]-[8]. A similar attempt has been carried out in this paper for prediction of SCD through analysis of HRV. But the advantage gained in this similar study is instant use of complete dataset (downloaded from physiobank [9]) in a single program. Same number of samples downloaded for SCD and normal sinus rhythm are filtered using same filter and same parameters are derived for each. The number of samples used corresponds to approximately one hour duration of ECG signal of the subject under study. This has been attempted to check and verify the early stage prediction of SCD of the patient.

II. Dataset Used

All signals downloaded from database [9] have been tried to keep in same duration for this study as the sampling frequency for the corresponding dataset is stated there. Total 20 signals have been studied taking ten each from following dataset:

A. Normal Sinus Rhythm Dataset

This database consists of 18 long-term ECG recordings of 5 men aged from 26-45 and 13 women aged 20-50 having no significant arrhythmias.

B. SCD Holter Database

This database includes 18 patients ECG data with underlying sinus rhythm. Out of these 18 patients, 4 patients have been mentioned with intermittent pacing, 1 continuously paced and 4 with atrial fibrillation. All patients have been reported with sustained ventricular tachyarrhythmia and most had an actual cardiac arrest.

Reeta Devi is with the Department of ECE, UIET, Kurukshetra University, Kurukshetra, India (e-mail: reetakuk@gmail.com).
Dr. Hitender Kumar Tyagi is with Department of Electronics, UCK, Kurukshetra University, Kurukshetra, (e-mail: hitender.tyagi@gmail.com).
Dr. Dinesh Kumar is Vice-Chancellor with the YMCAUST, Faridabad, Haryana (e-mail: dineshelectronics@gmail.com).

III. Preprocessing

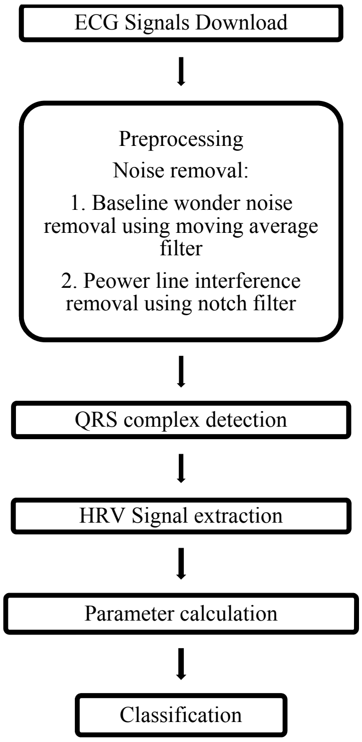

Fig. 1 Processing stages

Fig. 1 shows the processing stages of the ECG signal. Different stages includes preprocessing for noise removal using moving average filter for baseline wonder noise and notch filter for power line interference. Then QRS complex detection is performed for extraction of HRV parameters. Time domain parameters are obtained to classify the results.

IV. Results and Discusssion

A. *Results for Normal Sinus Rhythm Dataset*

Normal sinus rhythm data at physionet are supposed to represent the dataset for healthy subjects. As heart rate is defined as number of heart beats per second, normal heart rate or pulse rate for healthy subjects is measured to lie in range of 60-100 beats per minute. But accurate value of normal heart rate varies from person to person. Changes in heart rate and its regularity can change with age that indicates a specific heart condition, needs to be taken care off.

Figs. 2-7 show the results for waveform of original downloaded signal, signal after removal of baseline wonder noise, pole zero plot of the notch filter and then filtered signal after removal of power line interference.

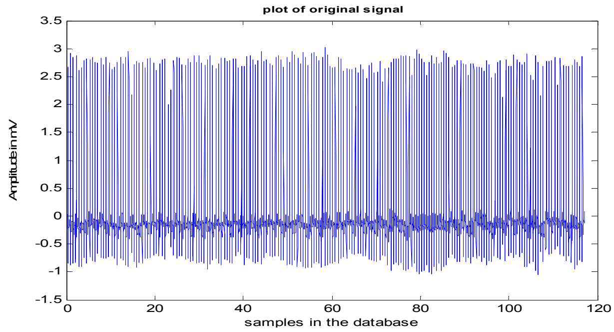

Fig. 2 Original Signal

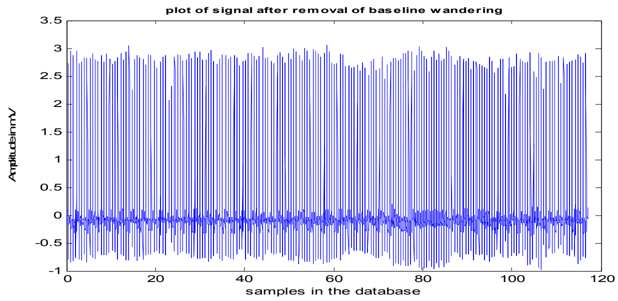

Fig. 3 Moving Average Filtered Signal

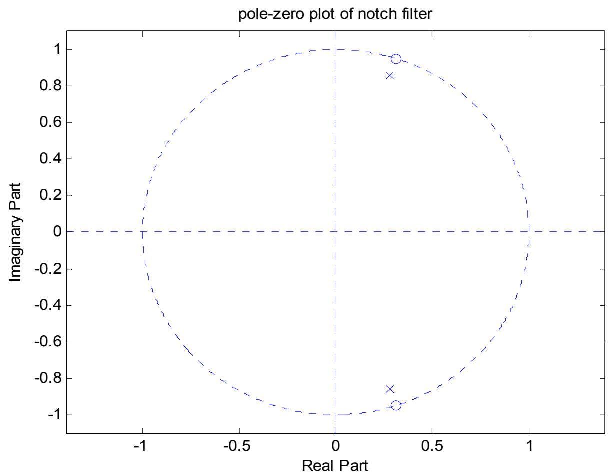

Fig. 4 Pole zero plot for Noth Filter

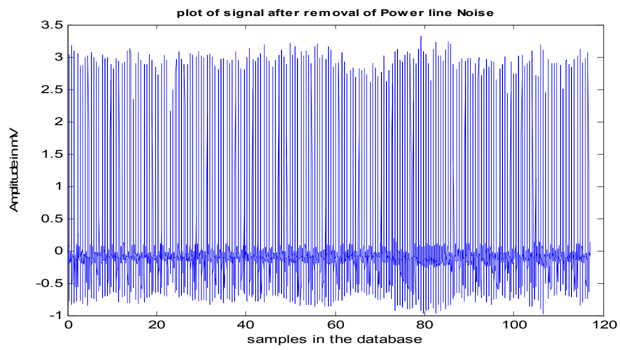

Fig. 5 Notch filtered signal

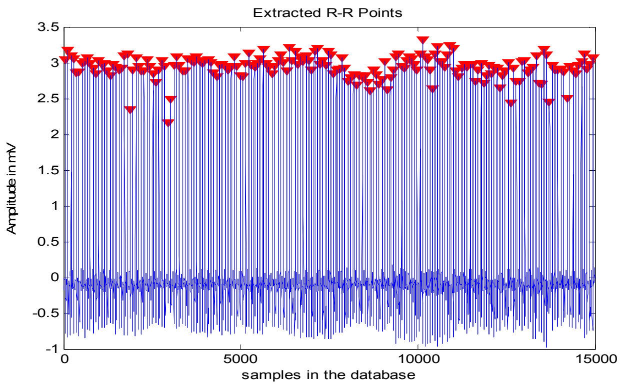

Fig. 6 RR plot

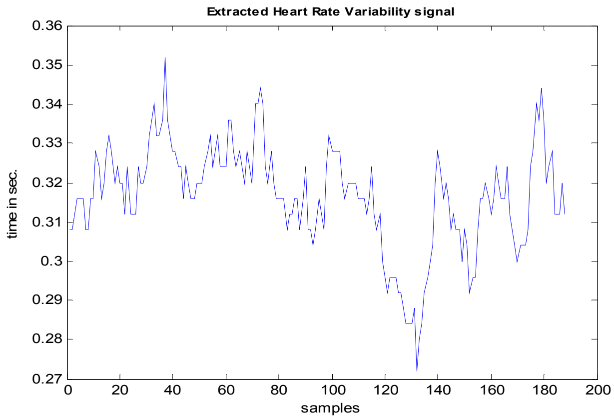

Fig. 7 HRV plot

B. Results for SCD Holter Dataset

SCD is sudden and natural death of patient due to cardiac cause. Patient died by abrupt loss of consciousness within one hour of onset of acute symptoms. Now a-days it has become leading cause of death worldwide. Dataset for SCD is available of those patients that already have met SCD.

Figs. 8-13 show the results for waveform of original downloaded signal, signal after removal of baseline wonder noise, pole zero plot of the notch filter and then filtered signal after removal of power line interference.

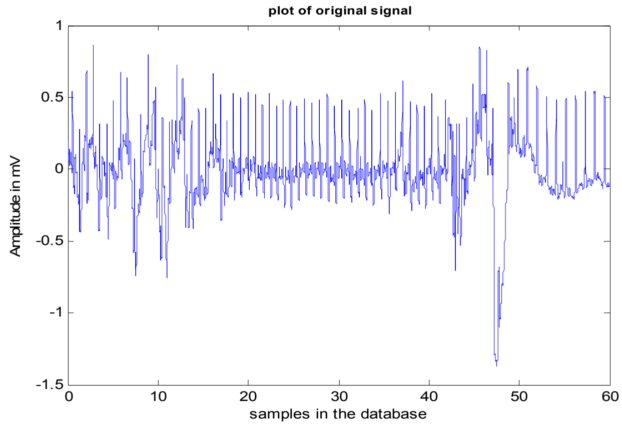

Fig. 8 Original signal

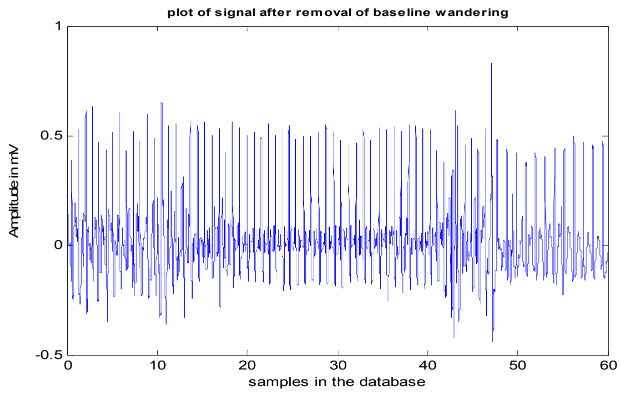

Fig. 9 Moving average filtered signal

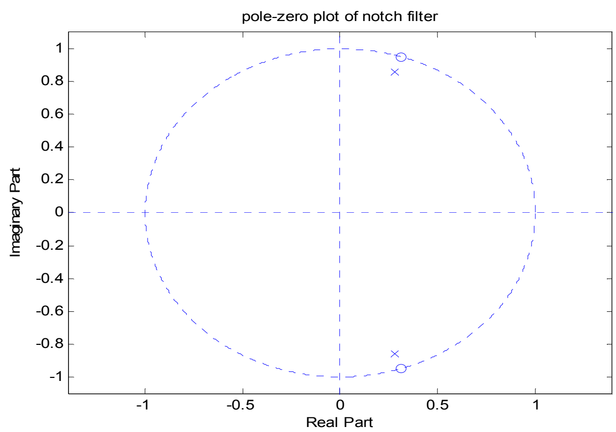

Fig. 10 Pole zero plot of Notch filter

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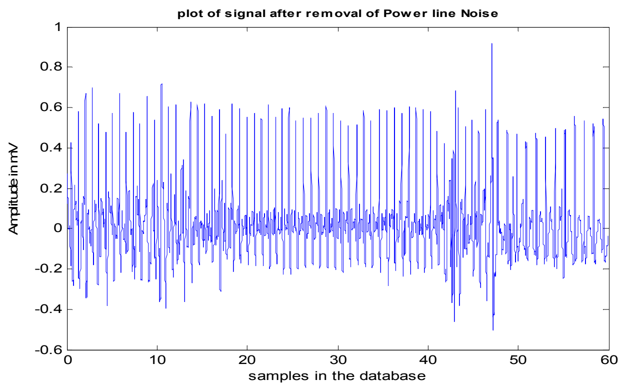

Fig. 11 Notch filtered signal

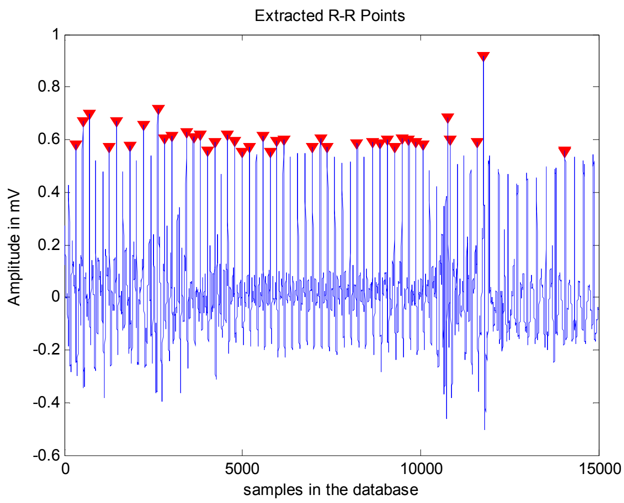

Fig. 12 RR plot

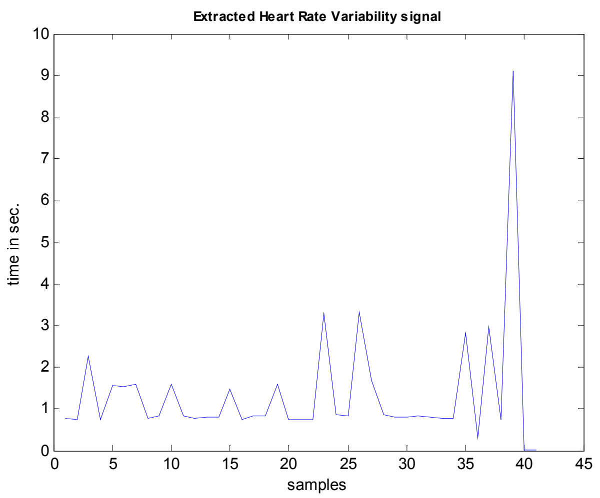

Fig. 13 HRV plot

Extracted HRV signal is used to find out different time domain and frequency domain parameters. The extracted parameters include mean RR, SDNN, RMSSD, VLF, LF, HF, LF/HF, SD1 and SD2. Table lists all the parameters with their distinguished parameters for normal subjects as well as for SCD patients.

TABLE I
AVERAGE VALUES OF EXTRACTED PARAMETERS

Parameter	Normal Subjects	SCD Patients
Mean RR	780.89	740.46
SDNN	44.75	12.87
RMSSD	28.26	12.39
VLF	580.3	39.8
LF	1047.3	52.5
HF	324	51.1
LF/HF	4.9237	1.8609
SD1	20.19	8.79
SD2	59.4	15.36

It is clear from Table I that all time and frequency domain parameters of SCD patients are significantly low than normal subjects.

V. CONCLUSION

HRV is a non invasive method for diagnose of many cardiac and other non cardiac diseases. Several time domain and frequency domain parameters are used to analyze the signal. As the cardiovascular system is a non linear system and vary with every change in sympathetic and parasympathetic activities of the body. Therefore, it is very important to extract all parameters with utmost care to conclude for a particular condition of the heart. Present work proposes extracted parameters for time and frequency domain measurements, but results can be refined with inclusion of time-frequency domain parameters.

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