Detection Algorithm using Adaptive Thresholding for Identification of Normal and Cheyne - Stokes Breathing

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***Abstract*- Respiratory rate measurement is one of the preliminary diagnostic parameter in clinical practice. The ratio of respiratory rate to that of heart rate is indicative of the health condition of the subject. However in cases where the respiratory disorders occur due to impairment of the respiratory centre in the brain, the analysis of the pattern of breathing becomes a must. This proposed work focuses on detection of normal and Cheyne-Stokes Respiration which is periodic and provide a complete report based on the parameter.**

I. INTRODUCTION

Respiration is a regulatory mechanism. There are several factors that affect respiration. The two most common respiratory anomalies are the periodic breathing and sleep apnea. In *periodic breathing* the person breathes deeply for a short interval and then breathes in a shallow manner for an additional interval, with the cycle repeating itself over and over. One type of periodic breathing, *Cheyne-Stokes breathing*, is characterized by slowly waxing and waning respiration occurring about every 40 to 60 seconds [1]. Fig.1. shows the waxing and waning pattern of the CSR. The term *apnea* means absence of spontaneous breathing. Occasional apneas occur during normal sleep, but in persons with *sleep apnea*, the frequency and duration are greatly increased, with episodes of apnea lasting for 10 seconds or longer and occurring 300 to 500 times each night [1]. Respiratory disorders such as tachypnea, bradypnea and apnea can be classified on the basis of respiratory rate. In case of CSR there is a region of hyperventilation followed by a region of apnea. In most of the existing works to estimate respiratory rate, respiratory signals were derived from the Electrocardiogram (ECG) either through Discrete Wavelet Transform (DWT) [2] or Principle Component Analysis (PCA) [3]. The derived respiratory signals were then used in the detection of sleep apneas by performing spectral analysis on the ECG Derived Respiration (EDR) signals [4]. Also without taking into account the respiratory signal, the morphology of the ECG wave say R Wave Attenuation (RWA) and Heart Rate Variability (HRV) have been used in the detection of Obstructive Sleep Apnea (OSA) and Cheyne – Stokes breathing [5]. Apart from the EDR, respiratory signals were also derived from Ballistocardiogram (BCG) using wavelet based filtering and Independent Component Analysis (ICA) [6]. Algorithms based on the Continuous Wavelet Transform (CWT) were used to extract respiratory signals from the BCG [7]. Respiratory rate can also be estimated with the help of lung sounds obtained using acoustic sensors placed near the chest wall [8]. The accuracy of the obtained respiratory rate have been verified against that obtained using capnography techniques [9]. In this work respiratory data from the physionet [10] is first subjected to rate calculation. Also the corresponding heart rate is found from the ECG data. The resulting respiratory rate to heart rate ratio is used to comment on the health condition of the patient. The respiratory data is further subjected to adaptive thresholding based rate detection in a moving window which encompasses samples corresponding to duration of 15 seconds. Regions of hyperventilation and apnea are looked for and CSR pattern is detected. The step by step result is reported in the front panel of the LabVIEW.

II. RESPIRATORY WAVEFORM DATABASE

Polysomnography data from the University College Dublin database (UCD) at Physionet [12] is used to formulate the algorithm for data processing. Record 6 and Record 27 with a sampling frequency of 128 Hz, containing Cheyne - Stokes respiration were extracted as segments of one minute each. The ECG and corresponding respiratory signal are extracted from the entire polysomnography data.

III. ALGORITHM FORMULATION

The algorithm was formed by using waveforms of duration of one minute from two sets of data obtained from UCD. The ECG and abdominal respiratory waveforms were obtained from the polysomnographic database. 10 data each for normal and segments containing Cheyne-Stokes

Breathing pattern were extracted in order to test the algorithm. The data was processed and the respiratory rate, ECG:respiratory rate, with detection of apnea and hyperventilation and CSR are performed.

a. *Respiratory rate calculation*

Respiratory Rate is calculated using adaptive thresholding. The data considered is of 60 seconds duration. The threshold value is calculated based on the values of the signal by obtaining max values within a window of 20 samples. The signal is then differentiated and the peaks are detected in the waveform. The peaks are counted in one minute to give breaths/minute.

b. *Ratio of heart rate and respiratory rate*

ECG corresponding to the respiratory waveform whose breath rate is found is considered. Heart rate is calculated using Pantompkin's algorithm. The signal is first smoothened for pre-processing. It is then differentiated and then squared. The squared signal frequency is obtained and from that the time period and heart rate are calculated. The ratio of the heart rate to that of its corresponding respiratory rate is thus found. Severity of health condition based on ratio of heart rate and respiratory rate:

i) Toxic if ratio >6:1
ii) Good health if ratio=5:1, 6:1
iii)Relatively good health if ratio=4:1 (elderly patients)
iv)Urgent care needed if ratio =3:1
v) Death may be near if ratio=2:1 or lower

c. *Cheyne-Stokes Respiration*

The segment analysis using a window of 15 seconds (approx 2000) samples are used. The number of peaks in these interval are calculated. The threshold for hyperventilation is kept as 6 and above breaths in each of these segments and 2 or below for decreased or cessation of breath. When alternate segments of hyperventilation and apnea are found then it can be termed as CSR.

V. LABVIEW BASED ANALYSIS

The respiratory waveform that is acquired from the database is smoothened. The threshold value is adaptively detected by obtaining half the value of mean of the maximum values within a 20 samples window. The values above this threshold are then differentiated to obtain the peaks which are counted since it is a one minute data to provide the breaths per minute. The threshold is obtained adaptively and the values above this threshold are alone differentiated. The peaks are further detected and counted. Apnea is detected as absence of peaks for more than 15 second duration. Hyperventilation is detected if the number of peaks exceeds more than 6 for any segments. The Cheyne- Stokes respiratory waveform is detected when the apnea and hyperventilation segments occur alternatively.

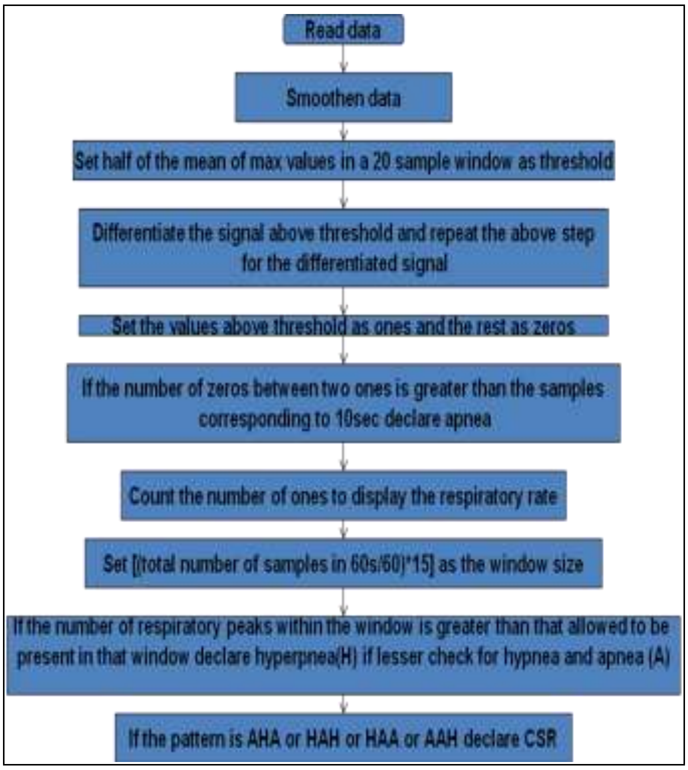

Fig.2. Detection of CSR and respiratory rate measurement

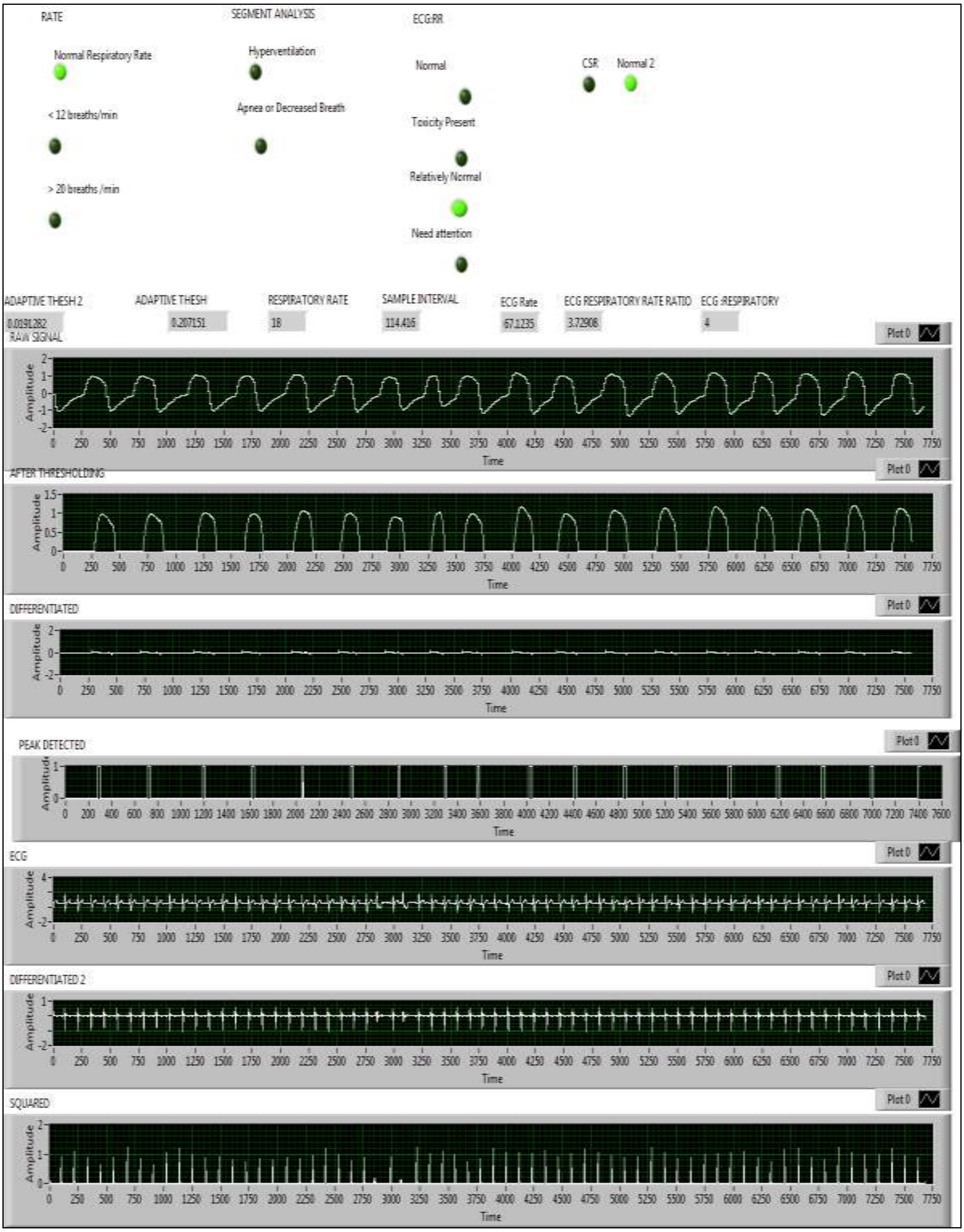

Fig.3. Front Panel showing Respiratory Rate measurement, ECG Rate: Respiratory rate Ratio and CSR detection for a normal waveform.

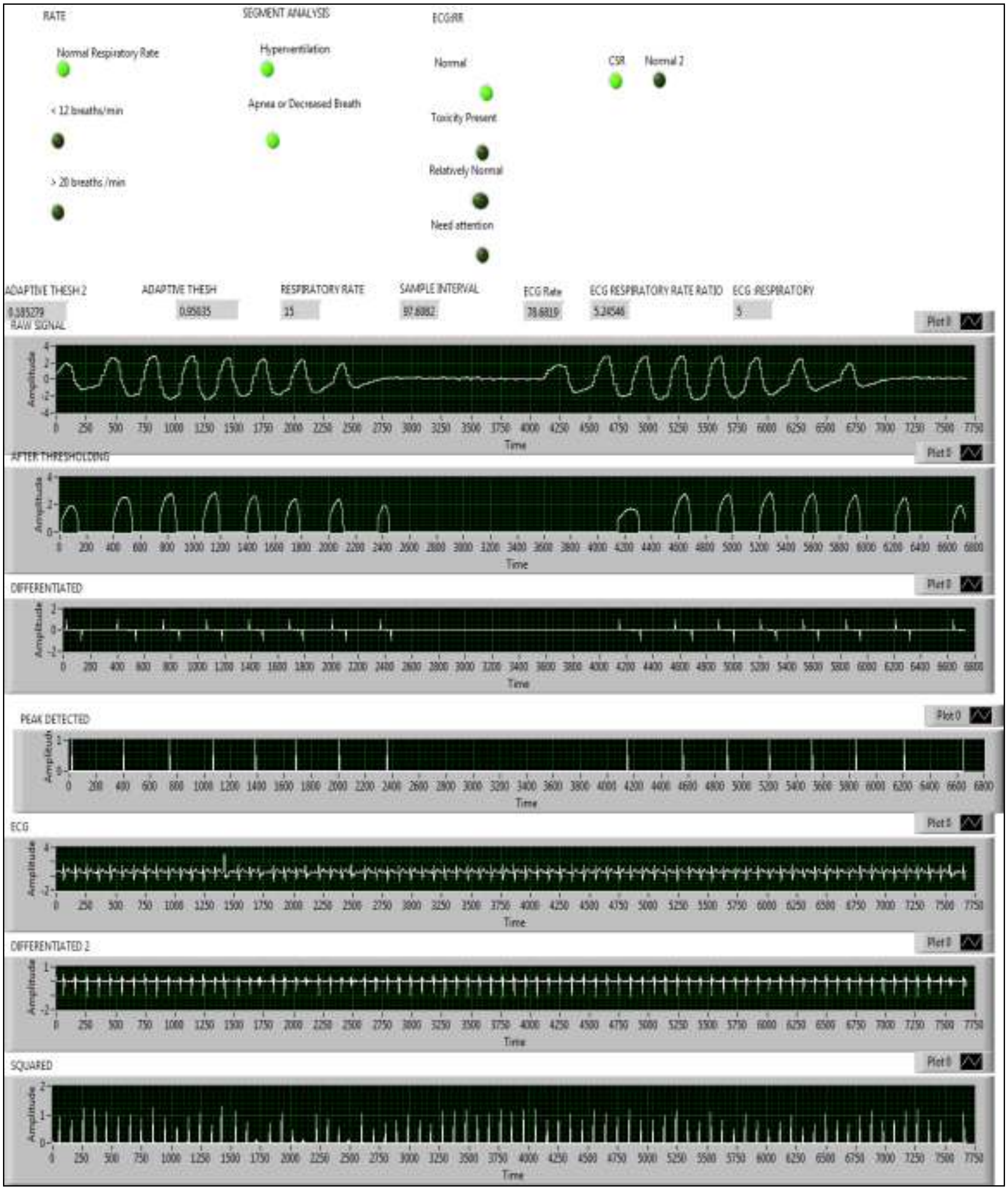

Fig.4. Front Panel showing Respiratory Rate measurement, ECG Rate: Respiratory rate Ratio and CSR detection for a normal waveform.

VI. RESULTS

The normal waveform from the same subject at UCD database was used to test the algorithm. The front panel shown in Fig. 3 indicates the respiratory rate is within the normal range of 12-20. The segment analysis shows no region of apnea or hyperventilation in any part of the waveform. ECG: Respiratory rate is 4 which is relatively normal since the subject falls at an age of above 40 yrs. Thus the overall indication shows normal. The respiratory waveform showing CSR from record 6 at UCD database is used to test the algorithm. The corresponding ECG waveform is used to find ECG: Respiratory rate. The front panel shown in Fig. 3 indicates the respiratory rate is within the normal range of 12-20. ECG: Respiratory rate is 5 which is normal. The segment analysis thus gives a clearer picture about the regions of hyperventilation and apnea. Thus the overall indication shows CSR. The total number of data for testing used was 15 for normal and 15 for CSR. Out the 15 data for normal respiratory waveform 13 data were taken from the same subject who showed CSR at a different time interval. The results for the algorithm are given in Table. I

TABLE. I. Sensitivity calculation and algorithm results.

Type of Waveform.	Number of Test Data	True Positive (TP)	False Negative (FN)	Sensitivity
Normal	15	14	1	99
Cheyne-Stokes Respiration	15	15	0	100

VII. *CONCLUSION*

In the case of normal data used all the analysis done indicates the overall condition as normal. But in case of CSR due to hyperventilation and apnea the overall rate might fall within the range of normal because certain regions with increased rate is compensated by regions with no breath. Thus the segment analysis to obtain the rate variability is done to find out regions of varying rate. The algorithm utilizes waveform taken from the database. When this extended to real time analysis will have great significance in continuous respiratory monitoring of patients.

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