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A NOVEL METHOD FOR THE DETECTION OF SLEEP APNEA BYRESPIRATORY SIGNAL IN REAL-TIME MONITOR

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Abstract—In medical field, sleep apnea become a serious disorder in recent days. Sleep apnea is a sleep disorder characterized by pauses in breathing or periods of shallow breathing during sleep. Each pause can last for a few seconds to several minutes and they transpire many times a night. In the most mundane form this follows loud snoring. There may be a choking or snorting sound as breathing resumes. As it disrupts mundane slumber, those affected are often somnolent or tired during the day. If it not checked it may lead to heart failure or even to death. It is difficult to record the respiration rate continuously from a patient. Sleep apnea and hypopnea can be detected from ECG, EMG, EEG but respiration signal give more accurate value. Sleep apnea is more dangerous than hypopnea it stops breathing at least for 10 seconds. In this paper, signals are collected from Physio-Net database. Respiration signals are recorded from 18 subjects in this 16 subjects recording are used. The signal is first filtered to remove noise by using Savitzky-Golay filter. Then the signal's peaks are determined by using Gaussian window. Finally by calculating time and amplitude breath signal is classified into apnea, hypopnea and normal breath rate. The proposed approach gives 97% accuracy. In real time monitoring breathing sensor is used and this connection is given to microcontroller from where the analog signal is converted to digital and the value is displayed and also the value is transmitted to Bluetooth to mobile phones.

Index Terms—**Sleep Apnea, Hypopnea, Physio-Net database, Savitzky-Golay, Gaussian window, breathing sensor, microcontroller, Bluetooth.**

I. INTRODUCTION

Sleep apnea and hypopnea is a serious sleep disorder that causes to stop breathing. This means the brain and the rest of the body may not get enough oxygen. In this paper, going to detect sleep apnea and hypopnea by breathe signals. A person's respiratory rate is the number of breaths you take per minute. The normal respiration rate for an adult at rest is 12 to 20 breaths per minute. A

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respiration rate under 12 or over 25 breaths per minute while resting is considered abnormal.

A. *Sleep Apnea*

Sleep apnea is a sleep disorder characterized by pauses in breathing or periods of shallow breathing during sleep [1]. Each pause can last for a few seconds to several minutes and they transpire many times a night. In the most prevalent form this follows loud snoring [14]. There are three types of apnea.

- Obstructive apneas (OA): This is the more frequent pattern, characterized by the presence of thoracic effort for continuing breathing while air flow completely stops.
- Central apneas (CA): These are characterized by a complete cessation of both respiratory movements and airflow during, at least, 10s.
- Mixed apneas (MA): This pattern is a combination of the previous two, defined by a central respiratory pause followed, in a relatively short interval of time, by an obstructive ventilatory effort [12].

The major risk factors for the disorder include obesity, male gender, and age [6]. Untreated Sleep apnea may lead to cardiovascular dysfunction, stroke, and possibly to the ischemic heart disease [14]. SAHS is a noticeable problem of social and health life, affecting 3% of children [1], 2% of female adults, and 4% of male adults worldwide [3]. In fact, still up to 80% of cases of moderate or severe SAHS have gone undiagnosed despite adequate access to health care [15], [24]. Christo Ananth et al. [4] discussed about an eye blinking sensor. Nowadays heart attack patients are increasing day by day."Though it is tough to save the heart attack patients, we can increase the statistics of saving the life of patients & the life of others whom they are responsible for. The main design of this project is to track the heart attack of patients who are suffering from any attacks during driving and send them a medical need & thereby to stop the vehicle to ensure that the persons along them are safe from accident. The effects of sleep apnea are headaches, stroke, diabetes, depression, etc... In addition, untreated sleep apnea may be responsible for poor performance in everyday activities, such as at work and school, motor vehicle crashes, and academic underachievement in children and adolescents [13].

B. *Hypopnea*

Hypopneais inordinately shallow breathing or an aberrantly low respiratory rate. Hypopnea is defined by some to be less astringent than apnea.It commonly is due to partial obstruction of the upper airway. Sleep is perturbed such that patients may get a full night's sleep but still not feel reposed because they did not get the right kind of sleep [5]. The effects of sleep apnea are affect normal life, excessive daytime sleepiness, traffic accidents, diminished productivity in the workplace, emotional, myocardial infraction, stroke, psychiatric problems, cognitive dysfunction, etc… Hypopnea occurs due to anatomical defects such as

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nasal septum deformation or congenital narrowness of nasal passage of the nasal cavity and the oesophagus,obesity or being overweight, neuromuscular disease, use of sedatives, smoking and aging problems, etc…For the purpose of this study selected 16 records which were all taken from different patients.

C. Apnea Hypopnea Index (AHI)

Currently, in sleep laboratories, there are carried out overnight polysomnographic studies (PSG) aimed at early detection and assessment of the severity of SAHS in patients. PSG study is considered as the "gold standard" method for SAHS diagnosis [21]. It involves recording and studying simultaneously many signals such as electrocardiogram (ECG), nasal airflow (NAF), and blood oxygen saturation (SaO_2). To reach the final conclusion, the recorded signals are analyzed by a physician experienced in the field of sleep medicine. The final diagnosis is based on calculation of the apnea/hypopnea index (AHI) which reflects the number of sleep apnea/hypopnea (SAH) events per hour of sleep.

The AHI is calculated by dividing the number of apnea events by the number of hours of sleep. Based on the AHI, the severity of OSA is classified as follows:

- Normal/none : AHI<5 per hour
- Mild : AHI ≥ 5, but < 15 per hour
- Moderate : AHI ≥ 15, but < 30 per hour
- Severe : AHI ≥ 30 per hour

II. METHODS

In this paper an algorithm is proposed to detect the chance of apnea and hypopnea disorder from respiratory signals and also this disorder is detected by real time monitor. The data in the analysis include breath signal collected from Physio-Net database which is the public database for various research purposes. The flow chart of the simulation methodology used in this work is shown in Fig. 1 and by real monitoring is given by block diagram which is shown in Fig. 2. Apnea and hypopnea are common sleep disorder and are unable to find easily. This disorder is detected with respiratory signal in an easy way and the signals are collected from Physio-Net database. The breath signal is first smoothened and the peak is calculated and the amplitude is determined. From this respiratory signal the breath rate is calculated and classified as apnea, hypopnea and normal.

The database collected from 18 subjects from nasal, abdominal and chest. The apnea occurs for at least 10 seconds or more and there is no breath. Hypopneaoccurs for at least 10 seconds and small breath occurs and this is not danger as apnea.Physio-Net database is the collection of signal recordings and the breath signals for this work is collected from the Physio-Net database. The signal records of the MIT-BIH reference PSG database that is freely available for research purposes from Physio-Net. The database consists of 18 PSG records having lengths from 1 hour up to 7 hr. (4 hr. on average).

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The breath rate is observed directly from patients and the collected signal is given to the positive end of dual op-amp and the negative end to POT. Dual op-amp used here is LM358 to increase the power of signal. Then the amplified signal is given to PIC from where it is programmed and displayed in the LCD screen. The digitised value is passed to bluetooth by using IC from where it can be messaged to mobiles of doctors or patients or relatives.

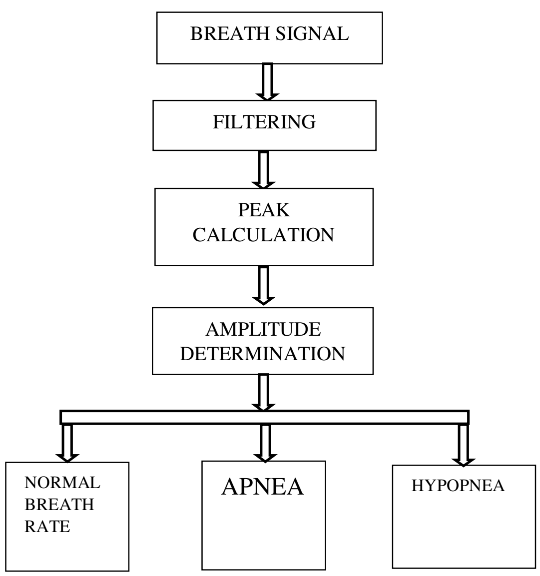

Fig. 1. Flow Chart of breath calculation by simulation.

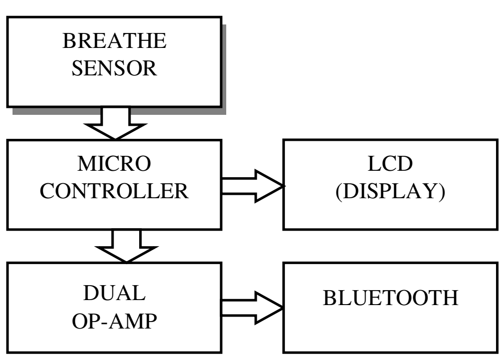

Fig. 2. Block diagram of real time breath monitor.

A. *Signal Acquisition*

The main advantage of using respiratory signal is such that it will detect the case of non-breathing stage very easily when compared with other means of analysis such as ECG, EMG. The surface of respiratory signals is acquired for duration of 1 minute. The respiratory signals alone are sufficient and perform even better than ECG, EEG and EMG. In this paper respiratory signal is taken for the detection of sleep apnea and hypopnea since it is more convenient and do not require more number of electrodes on the skin. The signal is recorded in 18 subjects and taken from PhysioNet database. In real time monitor the breath signal is directly taken from patients.

B. *Smoothening*

A Savitzky–Golay filter is used for smoothening. It is a digital filter that can be applied to a set of digital data points for the purpose of smoothing the data, that is, to increase the signal-to-noise ratio without greatly distorting the signal. When the data points are equally spaced, an analytical solution to the least-squares equations can be found, in the form of a single set of "convolution coefficients" that can be applied to all data sub-sets, to give estimates of the smoothed signal, (or derivatives of the smoothed signal) at the central point of each sub-set. Savitzky-Golay filters are optimal in the sense that they minimize the least-squares error in fitting a polynomial to frames of noisy

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data.In this Savitzky–Golay filter is used to remove noise from respiratory signal. Equation (1) shows equation of savitzxy golay filter.

Syntax

y=sgolayfilt(x,order,framelen)

y=sgolayfilt(x,order,framelen,weights)

y = sgolayfilt(x,order,framelen,weights, dim)

$$Y_j = \sum_{i=-\frac{m-1}{2}}^{\frac{m-1}{2}} C_i y_{j+1}, \qquad \frac{m+1}{2} \le j \le n - \frac{m-1}{2} \qquad (1)$$

Equation (1) Equation of Savitzky-Golay filter.

C. Peak Calculation

To determine the peak values Gausswin window is used. The frequency response of a Gaussian is also a Gaussian (it is an Eigen function of the Fourier Transform).Return the filter coefficients of a Gaussian window of length M.

Syntax:

w=gausswin(N)
w = gausswin(N,Alpha)

where, n is the positive integer. The coefficients of the gausswin window are computed from the following equation (2)

$$w\,[k+1] = e^{\frac{-1}{2}\left[\alpha\frac{k-\frac{N}{2}}{\frac{N}{2}}\right]^2} \qquad (2)$$

Equation (2) Equation of Gausswin window.

where $0 \le k \le N$ and $\alpha \le 2$.

D. Classification of signal

The signal acquired are classified into apnea, hypopnea and normal breath rate by calculating there amplitude. Finally if else condition is used to determine the results [8].

a. Amplitude determination

Amplitude is determined by calculating the maximum peak value and the minimum peak value and calculating their mean difference.

b. Time difference

The maximum value of time is differentiated with the minimum time value.

Fig. 3.Hardware kit.

E. PIC

PIC16F877A is an 8-bit microcontroller which is powerful and easy to program. It is an 10-bit analog to digital converter. In which the program can be erased and reprogrammed operates as 256 bytes EEPROM data memory. It works as an CPU in whole hardware. The whole components are connected to PIC. It consists of 40 or 44 pin packages.

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F. Breath Sensor

The breath sensor is to record the patient breath by keeping mask on patients face [18].

G. Integrated Circuit

H. Other components

a. LCD

LCD used here is LM016L which is an 16×2 display used in various devices and circuits. Easily programmable consists of two registers namely command and data. In which the digitised value is displayed.

b. Crystal

Microcontroller use crystal because all other parts are presented in it. Crystal oscillator is basically a very good filter. It is a device that can give a clock at a certain frequency given a constant voltage. Also capacitors, resistors and pots are used.

III. RESULTS

The results of apnea, hypopnea and normal breath rate is discussed.

A. Input Breath signal

The respiratory signal is taken as the input signal it is recorded from 18 subjects by PSG. The signal is taken from PhysioNet database. The input breath signal has the average amplitude value of 0.5 and the sampling frequency is 250Hz. Fig.4 shows the input breath signal.

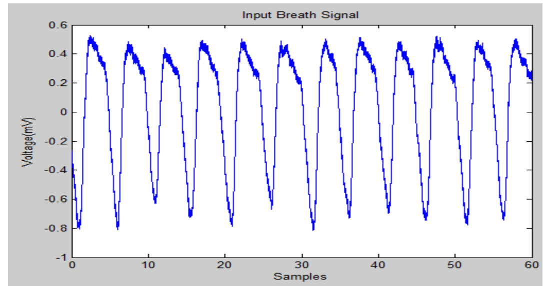

Fig. 4 Input Breath Signal

B. Filtered respiratory signal

After DC drift cancellation of the input breath signal helps to remove the DC drift noise present in the signal. The filtered breath signal remains the average amplitude value of 0.5 and the sampling frequency is 250Hz. Fig. 5 shows the DC drifted respiratory signal.

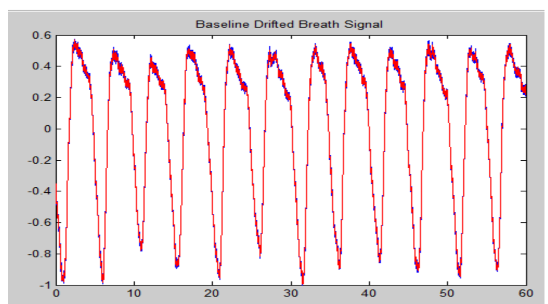

Fig. 5 Filtered Breath Signal

C. Peaks calculated signal

The peak of each breath signal is calculated and then the maximum peak of the each signal is plotted on the filtered respiratory signal. The number of peaks detected from each signal is also represented. The peaks calculated signal is shown in below fig. 6.

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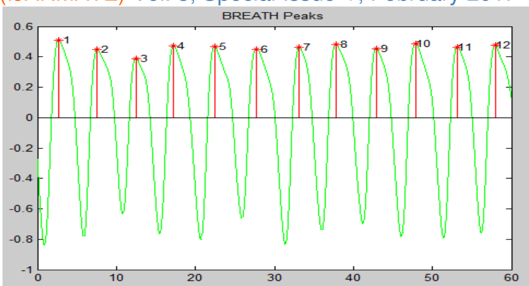

Fig. 6 Peak calculated signal

D. Apnea signal

The breath signal from apnea patient is obtained from PhysioNet database which is shown below in fig. 7. The input breath signal of one minute interval is DC drifted and peaks are calculated and then plotted on the breath signal. Here, it is observed that there is an interval of 10 seconds between two full breath signals.

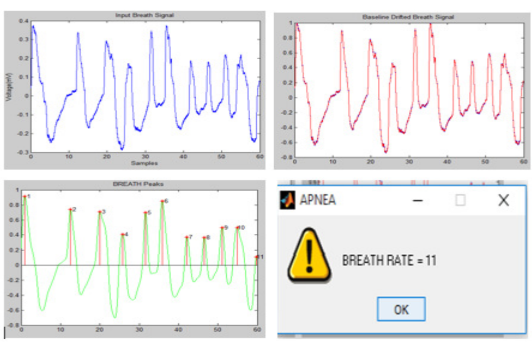

Fig. 7 Calculated Apnea Signal

E. Hypopnea Signal

The input breath signal from hypopnea patient with one minute interval is DC drifted and peaks are calculated and then plotted on the breath signal. Here, it is observed that there is an interval of 10seconds between two full breath signals but half breath occurs in-between. The hypopnea signal is shown in below fig. 8.

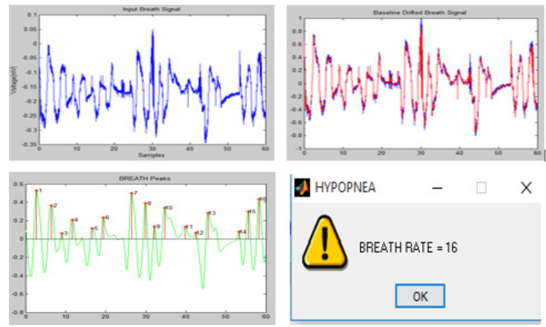

Fig. 8 Calculated Hypopnea Signal

F. Normal Breath rate VS Apnea

The peak calculated normal respiratory signal and the apnea signal is shown in below fig. 9. In normal breath signals the amplitude and time interval occurs in an normal but in apnea there is no breath occurs for the interval of 10 seconds.

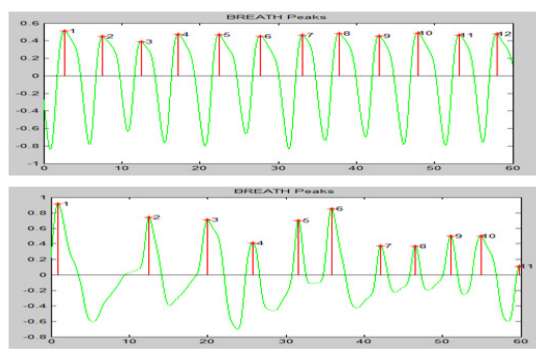

Fig. 9 Normal breath rate VS Apnea

G. Normal breath rate VS Hypopnea

The peaks calculated normal respiratory signal and the hypopnea signal is shown in fig. 10. In hypopnea half breath occurs in an interval of 10 seconds. Here, it is clearly observed the difference between

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normal breath signal and the hypopnea signal.

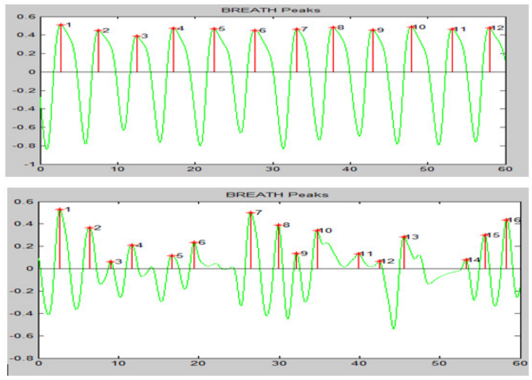

Fig. 10 Normal Breath rate VS Hypopnea

H. Apnea VS Hypopnea

The signal of apnea and hypopnea are differentiated in the below fig. 11. In apnea there is an 10 seconds interval and the patients follow up by no breath in-between the interval but in hypopnea breath occurs in half amplitude. Therefore, it clearly shows that apnea is more dangerous than hypopnea.

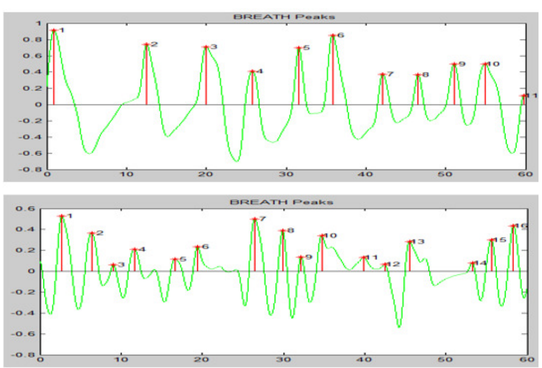

Fig. 11 Apnea VS Hypopnea

IV. DISCUSSION

The breath rate calculated and the result obtained is listed in table I. There will be no breath signal in apnea and breath signal occur less in hypopnea. Apnea is more dangerous than hypopnea. The person may also seen normal so the regular check-up is needed or else it can also lead to death.

Table I Difference of normal breath rate, Apnea and Hypopnea

BREATH RATE	TIME DIFFERENCE	AMPLITUDE DETERMINATION
NORMAL BREATH RATE	5.4120	0.2313
APNEA BREATH RATE	8.1920	0.2094
HYPOPNEA BREATH RATE	7.7160	0.1304

The time difference for the normal breath rate is very less and very high for apnea it is more dangerous than hypopnea.

V. CONCLUSION

Thus the apnea and hypopnea are detected which gives the accuracy of 97%. This is the simple method to detect and this algorithm do not need any training. Normal, Apnea and hypopnea are classified from the breath signals for one minute interval obtained from the PhysioNet database. Signals from same patient may vary little due to continuous recording this was the small disadvantage in this work.

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In real time monitoring, breathing sensor is used and this connection is given to microcontroller from where the analog signal is converted to digital and the value is displayed and also the value is transmitted to Bluetooth to mobile phones.

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