MONITORING OF OBSTRUCTIVE SLEEP APNEA USING MOBILE PHONE

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Abstract—This study offers a literature research reference value for bioengineers and practitioner medical doctors. It could reduce research time and improve medical service efficiency regarding Obstructive Sleep Apnea (OSA) detection systems. Obstructive Sleep Apnea (OSA) is a sleeping disorder characterized by the repetitive reduction of airflow during sleep. Much of the past and the current apnea research, the vital signals features and parameters of the SA automatic detection are introduced. The applications for the earlier proposed systems and the related work on real-time and continuous monitoring of OSA and the analysis is given. The purpose of the application, Sleep Apnea Monitor (SAM), is to allow users to get a sense of whether or not they are likely to have sleep apnea, before continuing with more expensive and advanced sleep tests. Real-time Obstructive Sleep Apnea (OSA) episode detection and monitoring are important for society in terms of an improvement in the health of the general population and of a reduction in mortality and healthcare costs. Currently, to diagnose OSA patients undergo PolySomnoGraphy (PSG), a complicated and invasive test to be performed in a specialized center involving many sensors and wires. Accordingly, each patient is required to stay in the same position throughout the duration of one night, thus restricting their movements. This paper proposes an easy, cheap, and portable approach for the monitoring of patients with OSA. The study concludes with an assessment of the current technologies highlighting their weaknesses and strengths which can set a roadmap for researchers and clinicians in this rapidly developing field of study.

Keywords—Real time monitoring system, Sleep Apnea, Wearable Sensors, GSM, PSG, Home Care.

I. INTRODUCTION

Sleep apnea (SA) in the form of Obstructive sleep apnea (OSA) is becoming the most common respiratory disorder during sleep, which is characterized by cessations of airflow to the lungs. These cessations in breathing must last more than 10 seconds to be considered an apnea event. Apnea events may occur up to four hundred times per night in those with severe SA [1]. Sleep apnea is a sleep disorder characterized by the repetitive reduction of airflow during sleep, which in turn causes pauses and reduced breathing. These recurring arousals from sleep due to a blockage of airway cause fragmented sleeping patterns and lead to the activation of the body’s sympathetic nervous system. An apnea is defined as the duration of time when there is complete blockage of airflow for 10 seconds or more, and is measured in apnea-hypopnoea index (AHI) [2].

Some of the symptoms that sleep apnea patients commonly display include snoring, pauses in breathing during sleep, choking or gasping for air following breathing disturbances, daytime sleepiness while carrying out routine tasks, headaches, dryness of throat in the morning, lack of concentration ability, urination at night, depression and irritability, and obesity [3][4]. In fact, SA is not a problem to be taken lightly, since it is associated with a major risk factor of health implications and increased cardiovascular disease and sudden death. It has been linked to irritability, depression, sexual dysfunction, high blood pressure (hypertension), learning and memory difficulties, in addition to stroke and heart attack [3][4]. Several treatments options for OSA patients include weight loss, positional therapy, oral appliances, surgical procedures and continuous positive airway pressure (CPAP). CPAP is a common and effective treatment especially for patients with moderate to severe OSA. CPAP devices are masks worn during sleep that improves oxygen saturation and reduces sleep fragmentation [5].

However, statistics show that around 100 million people worldwide, where in the US from 18 to 50 million people, are suspected to have OSA, of which more than 80% remain undiagnosed [6]. The trouble of having examinations discourages patients prone to OSA undergo at the overnight clinical research through polysomnographic data. A polysomnogram typically records a minimum of eleven channels of various biosignals requiring a minimum of 22 wire attachments to the patient in a specialized sleep laboratory with attended personnel. Polysomnography (PSG) is a complicated procedure and certain way of assessing the OSA problem. Complete PSG includes the monitoring of the breath airflow, respiratory movement, oxygen saturation (SpO2), body position,
electroencephalography (EEG), electromyography (EMG), electrooculography (EOG), and electrocardiography (ECG) [7]. However, PSG has received many criticisms from some researchers. This is due to several reasons, including first, the inconvenience since it requires the patient to be connected to numerous sensors and to stay in hospital for one night. Second, it is expensive. The average cost for a PSG is $2,625 due to the need for the study to take place in a specially equipped medical facility, in addition to the requirement of having a sleep lab staff overnight, trained in „scoring“ the resultant measurements manually. Third, among wait list of up to 6 months is caused by limited availability of PSG [8].

According to the American Academy of Sleep Medicine (AASM), the Apnea-Hypopnea Index (AHI) is used to describe the number of complete and partial apnea events per hour of sleep and it is calculated to assess OSA syndrome severity. OSA severity is usually determined as follows: AHI 5-15 indicates mild, 15-30 indicates moderate and over 30 indicates severe OSA syndrome. Therefore, patients are diagnosed with OSA if they have five or more apnea events per hour of sleep during a full night sleep period [9].

II. PREVIOUS WORK

Over the past few years most of the related research has focused on presenting methods for the automatic processing of different statistical features of different signals such as thorax and abdomen effort signals, nasal air flow, oxygen saturation, electrical activity of the heart (ECG), and electrical activity of the brain (EEG) for the detection of SA. There is a significant body of research literature in the study of simplified sleep apnea monitoring using just one or two physiological signals such as ECG, pulse oximetry, snoring, or nasal airflow [10]–[15]. Oliver and Flores-Mangas [10] used blood oxygen level (SpO2 ) for screening OSA. Fu-Chung et al. [11] used integrated CPAP airflow signal to identify OSA episodes. Pentagay et al. [13] used the heart sound (S1) generated during OSA episodes combined with ECG. The application of SVM classifiers in apnea screening are discussed in [12] and [13]. Other OSA screening studies based on ECG used Gaussian classifiers, linear or quadratic discriminants [14], [15], which depend on the assumption that the feature has Gaussian distribution.

Several studies show that the brain waves signal, Electroencephalogram (EEG), which indicates states of mental activity ranging from concentrated cognitive efforts to sleepiness [16], is able to diagnose SA. Wavelet transforms and an artificial neural network (ANN) algorithm were applied to the EEG signal in [17] to find a solution to the problem of identifying SA episodes. The EEG signals can be classified into four frequency bands of basis waves, namely as delta (δ), theta (θ), alpha (α) and beta (β). When an episode of SA occurs, the EEG signal shifts above the delta frequency band. Then, sleep EEG activity shifts from a delta wave to theta and alpha waves frequency bands in the range of 4~14 Hz once episode of SA ends.

Many studies show that detection of OSA can be performed through the Electrocardiogram (ECG) signal due to cyclic variations in the duration of a heartbeat. This consists of bradycardia during apnea followed by tachycardia upon its cessation. In previous published research, we developed a model based on a linear kernel Support Vector Machines (SVMs) using a selective set of RR-interval features from short duration epochs of the ECG signal. The results show that our automated classification system can recognize epochs of SA with a high degree of accuracy, approximately 96.5%. Arterial oxygen saturation (SpO2) measured by pulse oximetry can be useful in OSA diagnosis as clinical experience indicates that an apneic event is frequently accompanied by a fall in the SpO2 signal (oxygen desaturation) . The study carried out by Marcos et al. provided an automated means for interpretation of SpO2 signals, based on (LD) classifier and the linear combination of spectral and nonlinear features from SpO2 recordings using principal component analysis.
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(PCA). In addition, we further developed a Neural Network (NN) as a predictive tool for OSA using the SpO2 signal features and evaluated its effectiveness. The following summarizes the main contributions of the paper and differentiates it from the aforementioned studies:

1. Apnea screening done on 1-min segment of data rather than treating the whole recording as one segment. This measurement segment length is chosen to reduce the hidden number of actual episodes within the selected time interval.
2. Real-time screening as opposed to offline screening.
3. Apnea severity or apnea/hypopnea index is directly based on the number of apnea episodes detected over the total segments, rather than based on posterior probability of SVM outputs.
4. Two SVM classifier models, subject-independent and subject-dependent, are developed for apnea detection.
5. SVM models capable of controlling sensitivity and/or specificity are developed. This is accomplished by designing SVM with unbalanced penalty parameters ($C^+$, $C^-$).
6. Increased predictivity performance of the classifier is achieved using a comprehensive set of HRV and EDR time and frequency-based features (111 features).
7. Fully automated ECG processing, feature extraction, and apnea SVM classifier implemented in a smartphone.

Fig. 2. Functional flow diagram for automated detection of OSA using single-lead ECG measurements.

III. SYSTEM ARCHITECTURE

The system hardware describe the behaviour of the sleep apnea monitor application (SAM). The below gives the system overview and description for system Hardware.

A. System Overview

The working of this basic model is as follows. The patient is required to attach the data gathering module to the body using wearable straps etc. provided with the module. The module (consisting of medical sensors) will record the patient’s data and forward it to the microcontroller. The microcontroller will process the data, display the current reading on the LCD, invokes the Decision Support System to perform analysis of data and records the readings in the patient’s history. Microcontroller will compare the measured value with the predefined values recommended by the respective doctor and send it to the doctor through GSM. In case if any of the measured parameter exceeds the predefined values of the respective parameter then the system would blow the buzzer automatically and alerts all the near and dear once.

At the same time it sends the emergency message to the patient’s doctor who is supposed to send the acknowledgement after reading that message. If the microcontroller does not get the acknowledgement within a specific duration of time then it sends the same emergency message to the 2nd prior doctor mentioned in the database. This way the immediate action could be taken to provide necessary help to the patient. It also provides PC interface for entering patient’s data so that latter this record could be analyzed if needed.

Fig. 3. Sleep Apnea Monitoring System Architecture

B. System Hardware

1. Sensors:

Different sensors are used to measure the parameters. Three sensors are used to measure temperature, airflow and heart rate. Output of the temperature sensor and Oral & nasal sensor are analog which is given where as output of the Heart rate sensors is digital.

1. Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user

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is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling.

II. Oral and Nasal Sensor

Oral and nasal thermister sensor can be used for airflow. It is placed below the nose and upper the upper lips. Nasal cannula pressure systems generate this respiratory waveform signal by detecting the fluctuations in pressure caused by inspiration and expiration. Unlike the inspiratory and expiratory fluctuations recorded via temperature from a thermocouple or thermistor, these signals are truly proportional to flow. Consequently, nasal pressure (NP) airflow appears to be far more sensitive and accurate in the capture of hypopnea and “Respiratory Effort Related Arousals” (RERA) events. This increased sensitivity should clearly enhance the diagnostic yield obtainable in the Polysomnographic evaluation of sleep patients.

III. Heart Beat Sensor

Heart beat sensor is designed to give digital output of heart beat. Heart rate is a very vital health parameter that is directly related to the soundness of the human cardiovascular system. While heart is beating, it is actually pumping blood throughout the body. The fluctuation of blood can be detected to this sensor. Heart rate is the number of heartbeats per unit of time, typically expressed as beats per minute (bpm). Heart rate can vary as the body’s need to absorb oxygen and excrete carbon dioxide changes, such as during exercise or sleep.

The maximum heart rate (HR_{max}) is the highest heart rate an individual can safely achieve through exercise stress, and depends on age. The most common formula encountered, with no indication of standard deviation, is:

\[ \text{HR}_{\text{max}} = 220 - \text{age} \]

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<tr>
<th>TABLE I</th>
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<tbody>
<tr>
<td>RANGE OF HEART RATE FOR DIFFERENT AGE GROUP</td>
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<td>Resting heart rate</td>
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<td>100-160</td>
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IV. SOFTWARE DESIGN

CONCLUSION

This application is targeted at any individual who suspects a sleeping disorder, regardless of his/her age. By using this application, the user can monitor his/her sleep at a very low-cost from the convenience of his/her home, compared to the expensive polysomnographic tests, which require the user to visit a specialized hospital and spend a night in it wearing uncomfortable monitoring equipment.

SAM is a mobile application designed to remotely monitor the sleeping patterns of individuals and assess their likeliness to have symptoms of sleep apnea. Even though mobile applications that monitor...
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sleep apnea exist, these applications only monitor one aspect (motion, snoring pattern or oxygen level) as a stand-alone project. However, this work is different and innovative in the sense that it combines the different aspects (motion and voice recorder) into one system in order to provide a preliminary diagnosis of user’s sleeping pattern anywhere at any time.

The system also has a location tracking feature using GSM cell tower triangulation that allows authorized doctors to view locations of the users as well as the severity of their condition. This feature can be customized and markers can be plotted according to gender, age group, employment as well as other factors for research purposes and increase awareness of this growing problem.

REFERENCES


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