Development of OSA Event Detection Using Threshold Based Automatic Classification

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***Abstract*—Obstructive Sleep Apnea (OSA) is a very serious sleeping disorder resulting in the temporary blockage of the airflow airway that can be deadly if left untreated. OSA is not a rare condition; in the US, from 18 to 50 million people, most of them remain undiagnosed due to cost, cumbersome and resource limitations of overnight polysomnography (PSG) at sleep labs. Instead, automated, at-home devices that patients can simply use while asleep seem to be very attractive and highly on-demand. This paper presents a method for OSA screening and user notification based on the respiratory recording and video monitoring as a secondary system during sleep in order to alert of the apnea event and help patient to recover.**

Keywords: sleep apnea; PSG; respiratory signal; video monitoring .

I. INTRODUCTION

A. *Background and Motivation*

Sleep is the circadian rhythm which is essential for human life. Humans spend approximately one-third of their life asleep. Sleep is necessary for optimal health; as we sleep, our body repairs itself. During sleep, blood pressure fluctuates, heart rate slows down, hormone fluctuations occur, muscles and other tissues relax and repair, and the replacement of aging or dead cells occur. Without sleeping, we simply do not function as well as we can [1].

The 25 year old field of sleep medicine, has now covered 84 kinds of sleep disorders, including the most common ones such as narcolepsy, insomnia, sleep apnea, and restless leg syndrome [2].

Sleep apnea (SA) is becoming a 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 5 to 30 times an hour and may occur up to four hundred times per night in those with severe SA [3].

There are two major types of SA. One type of SA is known as obstructive, which is generally caused by a blockage of the airflow airway. Central sleep apnea (CSA) is the other type of apnea, which occurs when the brain's drive to breathe is reduced. Most cases of CSA are mixed, meaning that it is often along with OSA. However, OSA is more common in the general population than CSA [3].

In fact, SA is associated with a major risk factor of health implications and increased cardiovascular diseases and sudden death. It has been linked to irritability, depression, sexual dysfunction, high blood pressure (hypertension), learning and memory difficulties, stroke and also heart attack [4].

The most frequent night symptoms of SA can include snoring, nocturnal arousals, sweating and restless sleep. Moreover, like all sleeping disorders, symptoms of sleep apnea do not occur just during the night. Daytime symptoms can range from morning headaches, depression, impaired concentration and excessive sleepiness which cause mortality from traffic and industrial accidents. However, these symptoms are not definitive to detect SA syndrome. Nowadays, PSG is a standard testing procedure to diagnose OSA. Complete PSG includes the monitoring of the breath airflow, respiratory movement, and oxygen saturation (SpO_2), body position, electroencephalography (EEG), electromyography (EMG), electrooculography (EOG), and electrocardiography (ECG). Therefore, a final diagnosis decision is obtained by means of medical examination of these recordings. Nevertheless, the PSG process is a complex, expensive and time consuming procedure due to the need of many physiologic variables using multiple sensors attached to the patients [5].

To summarize, new simplified diagnostic methods and continuous screening of OSA is needed in order to have a major benefit of the treatment on OSA outcomes. In this regard, we present a work based on breathing detection and video monitoring that will be used in a larger real time system for OSA diagnosis. The objective of the system is to alert a patient who might be subject to an apnea attack.

B. *Paper Organization*

The rest of this paper is organized as follows. In Section II, we glance at a variety of OSA detection methods. Section III contains an overview of our system, including the detection algorithm steps, and details on the analysis methodology of the paper. In Section IV, we provide details of the experiment and the results of our system. Finally, Section V concludes this paper regarding the potential usefulness of our system, and highlights directions for future research.

II. RELATED WORK

Over the past few years, most of the related research has focused on detecting OSA through 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).

In our previous published research, we developed a model based on a linear kernel Support Vector Machines (SVMs) using a selective set of RR-interval features of the ECG signal [5]. In addition, in [6] we further developed a Neural Network (NN) as a predictive tool for OSA using oxygen saturation signal (SpO_2) measurements obtained from pulse oximetry. The authors in [7] assessed a compendium of features extracted from EEG and Heart Rate Variability (HRV) data using advanced signal processing approaches. The detection algorithms in [6-8] assessed and validated their results based on polysomnographic data that was available online from the physionet database, which offers free access to Apnea-ECG Database [8]. Results show that trends detected by those signals features could distinguish and annotate apnea events, and those methods could prove helpful in computer aided detection of sleep apnea.

Nowadays, much of the current apnea research is being done on providing portable devices that monitor those experiencing apnea during the day by alerting them when they stop breathing. The device could act as an inexpensive and convenient way for doctors to diagnose SA patients and as a means for collecting data on apnea sufferers to determine the severity of the condition once diagnosed. More specifically, this may help in the initial assessment of patients with suspected OSA in order to prioritize patients. Patients with utmost need of treatment will go through complete PSG recordings within a sensible time frame; meanwhile those who are free of apnea symptoms will avoid the cumbersome procedure [9].

Various portable monitor devices already exist in the market. ApneaLink™ Plus Home Sleep Apnea Test Device is one of the portable home sleep test diagnostic devices that records up to four channels of information: respiratory effort, pulse, oxygen saturation and nasal flow. The patient can sleep normally while ApneaLink™ Plus monitors his/her sleep, checking breathing patterns and the amount of oxygen in his/her blood and recording possible apneas or other breathing abnormalities [10]. Also, WM ARES is a home sleep test device that records heart rate, airflow, respiratory effort and oxygen saturation [11].

When the patient wakes in the morning, after removing the tube from the nose and the tape and sensor from the finger, he/she returns the device to the clinician for analysis. The device contains a detailed record of the patient's personal sleep patterns, which can be downloaded, analyzed and processed in the clinician's computer. The clinician will then identify if the person is suffering from sleep apnea.

In the current study we have designed a home monitoring system for OSA detection and user notification through the use of a small microphone placed on the neck of the patient to differentiate normal and disrupted breathing, and movement monitoring that will serve as a secondary means of detecting apnea events.

Based on the mentioned related works in this area, our contribution in this work is developing a real time system that is used to alert the patient during an apnea event and remind him/her to breath.

III. New Approach

In this work, the goal is to capture and precisely identify breathing sounds and alert the user/patient whenever the acoustic signal of respiration is paused.

It is important to note that processing and analyzing breath generally includes several fields of analysis. In what follows, our detection system design is described.

A. Overview

The overall design involves acquiring sound from a microphone. This signal is then processed to detect abnormalities in breathing or breathing cessations. Moreover, as a secondary system, image data is continually collected from the environment through webcam. When an apnea event occurs, that is, if the patient is without breath for longer than 15 seconds, and the conditions of surrounding environment is changing, an alarm will be raised immediately.

B. Apnea Detection Prototype

Figure 1 provides an overview for the apnea monitoring system.

The breathing sounds are recorded using a small microphone. We have integrated the microphone with a large stethoscope-like diaphragm in place with a soft band that is fastened gently around the patient's neck to ensure that the sound recordings take place comfortably during the patient's sleep. Figure 2 shows a soft neck band against user view.

During the initialization of the detection, three main modules are initialized simultaneously; the *peak programme meter* (*PPM*), the *analyzer* and the *detector*. The initial sound data is recorded through a signal recorder, which is a peak programme meter (PPM). PPM in general, has the ability to measure peak levels for any input sound. This allows us to have the first raw information about the patient's breath cycles and the peak threshold values for an apnea attack. The values from the PPM meter are named as wav 1 (audio data 1). The wav 1 values are sent to a filter to remove the noise and is then stored in the data-base. While a copy of the sound is stored in the database, another copy of the sound file is sent to the detector; this is a secondary data for detection (system fail trigger) of sleep apnea. The initial data of the PPM are then sent to the analyzer for the development of the classifier. Here, an expert sound analyst or a trained doctor can use the initial input to build the classifier based on the first sound file, namely wav 1. The development of the classifier is the second simultaneous step that is running once our detection process has begun. In the second step, the breathing sounds from the microphone are passed through the analyzer which shows the graphical user interface of the sound wave. These sound waves can then be used to adjust the patient's breath cycle, thus making it possible to design a breathing classifier. This means we can set the pattern for regular breathing and a pattern for irregular breathing.

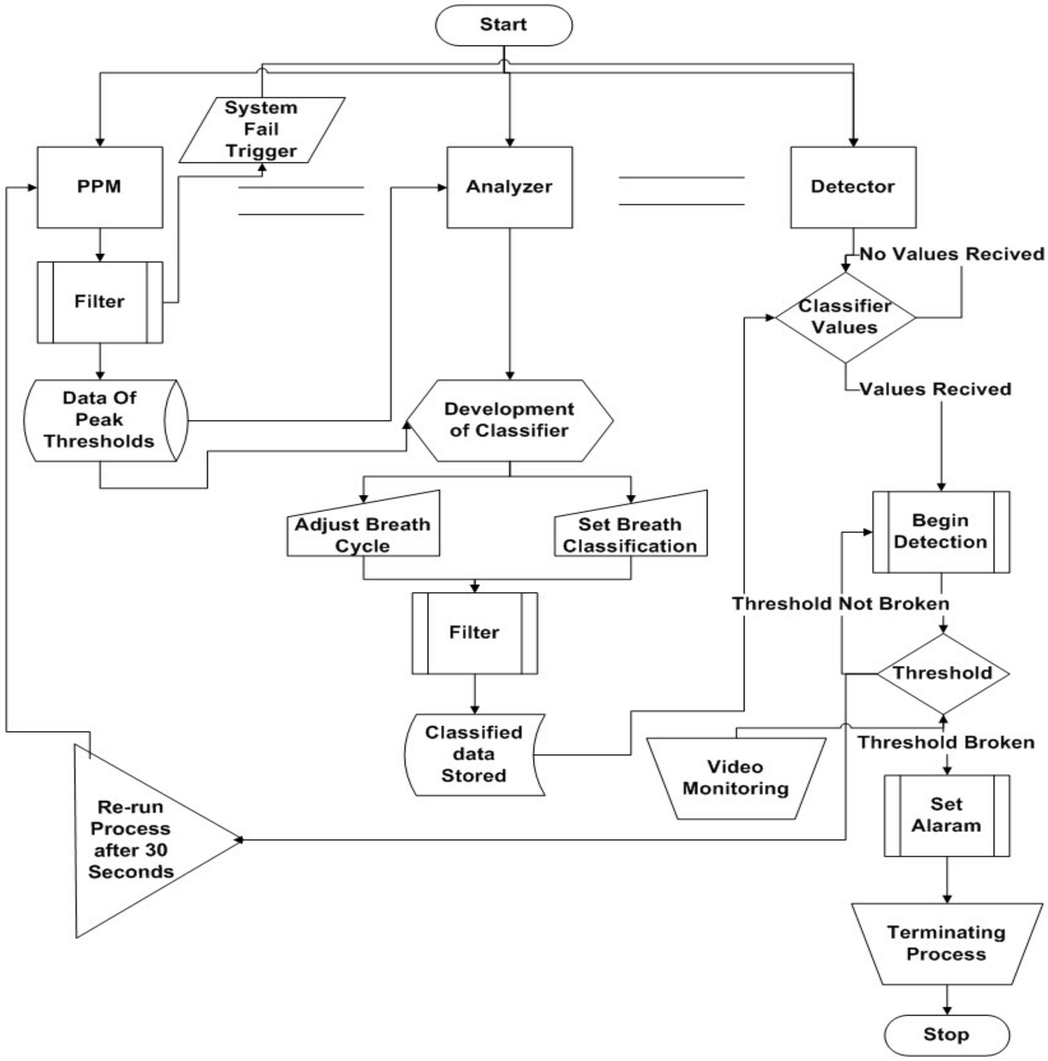

Figure 1. The framework for OSA detection.

Figure 2. The microphone in the stethoscope and its neck band.

Both these patterns are sent through a filter to remove noise and the final data is named wav 2, which is the second sound file for our detection process. This sound is stored in the data base as classified data. This data is more specific for the patient and is improved throughout as more and more data is initialized for a specific patient. This way we have a case history of sound files for a patient and a specialized classifier for each individual patient's apnea disease. The final step in our detection process and the third simultaneous process is the detector module. This detector module receives values from either the PPM which is a secondary value in case a classifier for a patient is not set (our system fail trigger) or receives the primary value from the analyzer module for the detection. During the final step of the detection process, if the threshold values input based on the classifier are exceeded, then an alarm is raised. In case the patient does not have the microphone module around his neck and the system is in the monitoring mode, then it might raise an alarm. To avoid this, there is a video monitoring tool that judges the patient's presence. However, this module is not a primary requirement to our detection process. In case the patient does not have an apnea attack for a time period of thirty seconds, then the whole detection process will run again with the same classified data values. This is a never ending process that keeps on monitoring the patient throughout his sleep cycle while collecting useful data for further analysis and better classification for the future.

IV. EXPERIMENT AND RESULTS

The complete apnea detection system is implemented in Visual C# in MS-Windows platform. The Olympus ME-52W noise canceling microphone to capture breath and a standard web-camera with 60/sec to capture video frames are used. The experimental results were conducted on a Pentium 2.4 GHz computer system.

Figure 3 shows the interface used in our sound analyzer module, where the user can study and classify the breathing cycle of the patient.

Figures 4 and 5 respectively show the results of SA detection from the abnormal breathing and movement detection. The graphical results screen illustrates the results in real time based on the values fed to our application from module 1, module 2 and module 3. The resultant graph is based on the RMS (root mean square) of the first three graphs. A user can access this application to get the analytical report as a print out with the inbuilt function.

The developed system was confirmed to allow for a comfortable, continuous and real time monitoring of sleep apnea disorder at home, which can trigger an alarm if the apnea is detected.

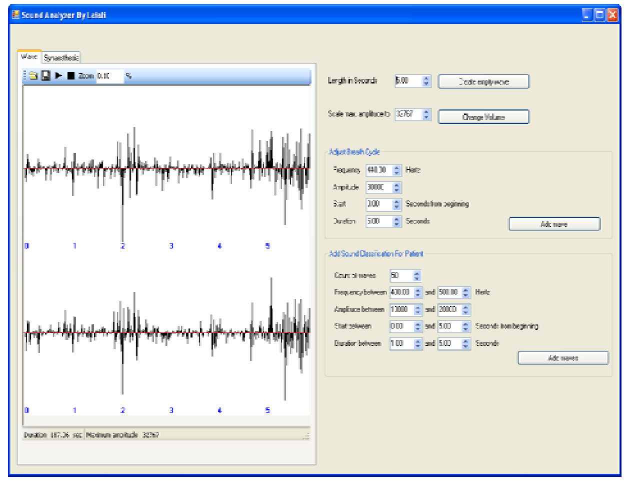

Figure 3. The Analyzer

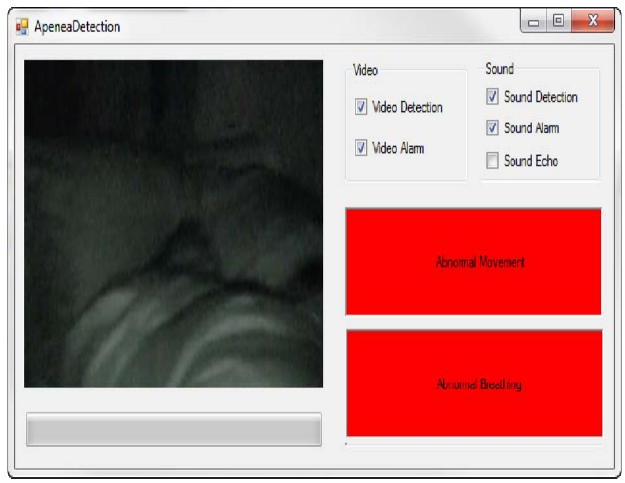

Figure 4. The detector

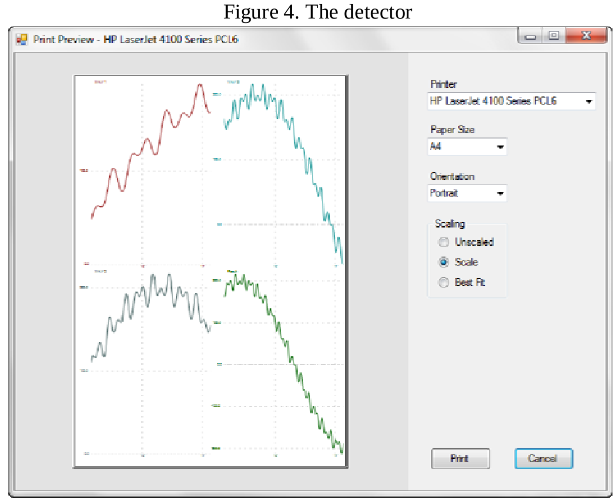

Figure 5. The SA detection framework results graph.

IV. CONCLUSIONS AND FUTURE WORKS

In this work, we presented a sleep apnea detection system which is capable of performing real time monitoring and visualization of sleep data. In the future, we plan to add other physiological data like SpO_2, and then send sleep data wirelessly via Bluetooth to a nearby cell phone for processing and storage. We plan to build a cloud application to keep health information with personal information of the individual's records, which will offer access to a large pool of sleep data for further investigations.

Our aim is to establish a simple and helpful at home OSA screening system by which data can be uploaded to cloud and transmitted to a hospital for sleep data analysis.

This research direction of accumulating patients' data will augment the efforts in this challenging field through providing benchmark data that can be used by researchers to enhance their used mechanisms and tools.

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