Abstract: Obstructive sleep apnea syndrome (OSAS) is a human disease affecting the human breathing of a patient while sleeping. To be studied, a patient has to be screened while sleeping, thus diagnosis is often hard and costly. Polysomnography is the standard method for obstructive sleep apnea diagnosis. However it does not permit a mass screening of patients because it has high cost and requires long term monitoring. Different efforts are reported in literature for finding new diagnostic methods implemented on portable devices. This paper presents a preliminary study for the development of a portable system based on snore signals acquisition and spectral analysis for OSAS identification.

Keywords: Home monitoring, OSAS, Snore analysis.

I. INTRODUCTION

Sleep apnea is a common disorder that affects both children and adults. An obstructive sleep apnea syndrome (OSAS) is defined as a complete cessation of airflow for more than 10 seconds which requires a significant respiratory effort to restart normal respiration. It requires immediate intervention to prevent it from becoming life-threatening [1].

This disease affects a significant percentage of the adult population which varies according to several studies by 15% to 35% in men and from 5% to 20% in women. The most obvious complications arising from OSAS are diminished quality of life brought on by chronic sleep deprivation and cardiovascular problems.

Currently, the ‘gold’ standard method for diagnosing OSAS is polysomnography (PSG) [1]. This diagnostic exam requires that the patients spend a full-night in hospital. Thus it is time consuming and high costly, because usually it is possible to monitor one patient for night for instrument. Furthermore it is labour intensive because the clinicians need to collect and analyze a large number of data (e.g. different and large signals, such as EEG, ECG, oxymetry, EMG, thoracic-abdominal movements).

Efforts are being directed to the identification of alternative methods for OSAS diagnosis to permit clinicians to detect automatically and objectively OSAS events saving time and work. Snore signals have been investigated as an alternate diagnostic tool for the detection of obstructive sleep apnea [1].

This work reports current approaches in OSAS diagnosis based on the analysis of snore signals and outlines a possible approach for developing a system for the automatic acquisition, analysis and classification of snore signals.

Although there exist some approaches to detect snore signals, used to discriminate OSAS patients from snorers, we are not aware of portable devices able to automatically detect apnea events and to discriminate their different sub-types (e.g. central, peripheral and mixed apnea).

The development of such a portable system would allow the diagnosis of OSAS events without using PSG instruments. Thus, our proposed system could be used for home-monitoring of suspected patients who turn to doctors accusing specific symptoms.

To detect apnea events, the proposed system collects only snoring signals, analyzing and classifying them to discriminate between simple snorers and OSAS patients. So the clinician must not examine a full night acquisition but only the portions of signal characterized by apnea events.

The rest of the paper is organized as follows. Section II describes current approaches for OSAS diagnosis focusing on the signal processing techniques. Section III presents a novel approach for the analysis of snore signals. Section IV outlines a possible procedure to analyse data. Finally, section V concludes the paper and outlines future work.

II. METHODS

The polysomnography [2] is a functional exam that permits the monitoring of different biological activities. Numerous physiological sensors are attached to the patient to record night-time breathing, brain activity and physical activity. Although the PSG is the standard approach for OSAS diagnosis, it requires technical expertise and is labour-intensive and time-consuming. Timely access is a problem for many patients, the majority of whom continue...
to have undiagnosed sleep apnea. Thus, alternative approaches to diagnosis, such as portable monitoring, have been proposed as a substitute for polysomnography in the diagnostic assessment of patients with suspected sleep apnea.

Different portable PSGs are used in clinical practice as a first level of screening of OSAS [3]. Although portable PSG allows the home monitoring of patients, it is an invasive technique and the patient remains connected to a lot of sensors. Moreover, as standard PSG, also portable PSG produces a lot of data, which is inefficient to analyze if one relies on manual processing.

Different efforts are underway to find better methods for diagnosing or screening of OSAS. Current alternative methods to PSG are: overnight oximetry, which measures a patient’s oxygen saturations throughout the night, ECG or snore monitoring. Overnight oximetry is not considered completely adequate as a screening test, since the oxygen levels in the blood of many patients with OSAS do not provide the information needed to understand their condition. Thus, there is a growing interest in developing portable snore-based devices for OSAS monitoring.

In [5] the development of a portable device for home monitoring of snoring is described. It performs detection and selection of the snores, while discarding any other events that are present in the sound recording, as cough, voice, and other artefacts. The device performs temporal analysis of signals. It detects snore events by evaluating signal amplitude and detects possible apnea events by measuring the delay between snores.

Another portable device for snore detection is described in [6]. The device itself also serves as a Web server. Doctors and caregivers can access real-time and historical data via a Microsoft Internet Explorer browser or a remote application program for telemonitoring of snoring and OSAS symptoms.

Both systems are able to detect only snore events through time analysis and they do not reach high success rate and sensitivity. They do not exploit frequency-based and time-frequency-based analysis.

For the detection of OSAS events, the analysis of snoring signals has been performed in time or in frequency domain [7, 8]. In the time domain the evaluated parameters are duration of snores, mean value/standard deviation of pitch and max/average intensity sound. In the frequency domain the parameters of interest are fundamental frequency, formants, median frequency, central frequency and max frequency. The spectral parameters are extracted from the power spectrum that is evaluated by parametric (AR model) or non parametric methods (FFT, Welch periodogram) [8].

For the discrimination between simple snorers and OSAS patients, it has been reported some variability between frequency parameters from simple snorers and OSAS patients [9]. This variability is evident not only in the segments after apnea event but also in all the snores of OSAS patients. It has been, also, reported variability relative to formants. Formants estimated for snoring signals coming from simple snorers show lower variance than those coming from OSAS patients [10].

From a biomechanical point of view, snoring sounds are caused by many factors: the strength of respiratory-related airflow, vibrations on the soft palate, the shape of upper airway, and the airway obstruction due to tongue subsidence. Moreover vibration parts are not held by some cartilage or bones. Thus in [11] the authors suggest to consider that snoring sounds are nonlinear acoustic vibrations caused by various factors. That makes it difficult to solve the unique eigenfrequency of snoring sounds by a traditional linear frequency analysis, generally adopted in [7, 8]. If such nonlinear properties can be extracted by some other methods and their relation to some degree of OSAS syndrome (e.g. Apnea/Hypopnea Index) is demonstrated, it would be possible to establish a new screening method which replaces the costly PSG.

III. RESULTS

Taking into account the results and approaches available in literature, we propose a novel signal processing workflow to analyze snore signals and outline the design of a portable device for snore analysis and OSAS diagnosis.

The development of a snore-based OSAS detector (Fig. 1) requires a good design of the acquisition stage because the snoring signal acquisition is affected by several problems. Different types of noise can contaminate the signals, such as background acoustical noise or electromagnetic interferences [11]. Although the use of unidirectional microphone can improve signal acquisition, however, noise reduction is needed to eliminate interferences. Therefore to build a reliable system, a robust pre-processing stage before signal analysis to improve signal to noise ratio and to allow a more accurate extraction of features is needed.

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![Fig. 1: Architecture of the system](image)

To identify the occurrence of obstructive sleep apnea, as discussed previously, different features can be extracted from time and frequency domain. We have chosen to identify unambiguously apnea events through frequency analysis of post-apneic snore events.
In the following we report some first experimental results related to the analysis of a vocal signal acquired, in the polysomnographic laboratory of the Institute of Neurology at University Magna Graecia of Catanzaro, from a patient affected by a moderate sleep apnea.

The vocal signal has been acquired with a digital audio recorder (Micro Track II Professional Audio Recorder) able to register mono and stereo signals at different acquisition rates. In this experiment, a signal long about 1 hour at 44 KHz has been recorded.

In this initial stage of the analysis, we have separated in a manual way the snoring events from the respiratory ones. In this phase the separation between snoring and respiratory events has been performed with the help of doctors.

After this separation we have performed FFT analysis and power spectra evaluation on the selected portion of original signals. Figure 2 and Figure 3 report, respectively, the power spectrum resulting from the analysis of snoring signals acquired from a patient affected by a moderate sleep apnea. In particular, the first plot is the power spectrum of a (generic) snore, whereas the second one represents the power spectrum of a post-apneic snore. The two spectra show significant differences because the post-apneic spectrum presents a larger number of frequency components at higher frequencies than the first one.

IV. DISCUSSION

The differences between the power spectra of regular and post-apnea snores suggests us a possible method to differentiate snores from post-apnea snores by comparing in both spectra the number of frequency components above a certain power threshold.

The procedure to analyse the recorded signal has to extract snores, verify if they are post-apnea snores, then extract the characteristics of apnea events happening before such snores. The characteristics of such apnea events (e.g. number of events, duration, etc.) can be evaluated by the doctors to help the diagnosis of OSAS.

The signal analysis can be implemented by using the following procedure described in pseudo code:

```
PROCEDURE snoreAnalysis (VoiceSignal S)
BEGIN
  // preprocess S to increase signal-to-noise ratio;
  S.Preprocess();
  // S_i is a snore identified in S
  Snore S_i;
  // apneaEventsList is a list of apnea events in S
  apneaEventsList [] apneaEvents;
  // analyse the Apnea events
  AnalyzeApneaEvents (apneaEvents);
END.
```

V. CONCLUSION

The paper presented a first approach for the automatic detection and characterization of snore signals related to the Obstructive Sleep Apnea Syndrome.

The proposed system is currently under development and a first prototype will be tested in the polysomnographic laboratory of the Institute of Neurology at University Magna Graecia of Catanzaro.
A first goal of the system is to extract from the signal only post-apnea snore events and then apnea events. The reduced signal will be validated by the doctors in a manual way avoiding the examination of all signal registrations as happens in present setting.

A set of signals registered in the Institute of Neurology will be used to further investigate and eventually validate the discriminatory characteristics of the power spectra of apnea and post-apnea snores with respect to respiratory and snoring events. After validation, a next step will regard the automatic classification of sleep apnea.

REFERENCES