A New Model for Diagnosing Sleep Apnea Through Features Extraction of the SpO2 Signal

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Abstract

Obstructive Sleep Apnea (*OSA*), is the most common form of different types of sleep-related breathing disorders. It is characterized by repetitive cessations of respiratory flow during sleep, which occur due to a collapse of the upper airway at the level of the oropharynx.

The traditional diagnosis of OSA requires an expensive and complex overnight procedure called polysomnography (PSG). PSG contains several biomedical signals recording set, such as EEG, EOG, EMG, ECG, respiration and SpO2. In contrast, simple monitoring systems can be built as cheaper alternatives to the current PSGs in the diagnosis of OSA, which can also reduce the abundant burdens of hospital sleep centers.

In this study, we develop a comprehensive feature set based on the arterial oxygen saturation signal measured by pulse oximetry (SpO2) to obtain high quality signal features in discriminating the OSA.

The three features of SpO2 signal which are *Delta Index, Central Tendency Measure with radius 0.5 (ctm50) and Oxygen Desaturation Index(odi3)* are extracted, tested and evaluated using the MATLAB toolset. It was found that SpO2 signal characteristics could be helpful in order to evaluate sleep quality.

Figure 1. Normal Unobstructed Breathing

Figure 2. Complete Obstruction - OSA

New Investigations

PhysioNet provides a variety of physiological signal for biomedical research. The database we used is available from the web site, which offer easy validation and assessment of our approach.

Apnea-ECG database: This database contains 8 recordings with SpO2 signals.

SpO2 is the amount of oxygen being carried by the red blood cell in the blood. SpO2 is given in as a percentage, very simply, SpO2 goes up and down according to how well a person is respiring (breathing) and how well the blood is being pumped around the body.

Figure 3 depicts a common OSA negative subject. Figure 4 shows a SpO2 record with OSA positive subject. However, diagnosis of the disease by visual inspection is not evident.
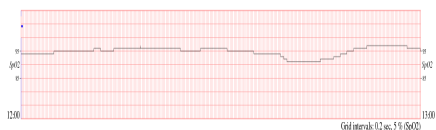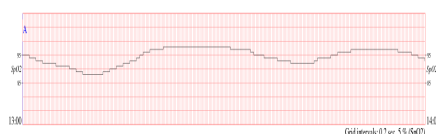

Figure 3. SpO2 record with OSA negative subject

Figure 4. SpO2 record with OSA positive subject

In our work, the SpO2 signals were saved to separate files and processed off-line by a computer program we have developed to compute the delta index (Δ index), central tendency measure with radii 0.5 (ctm50) and oxygen desaturation index (odi3), each for 1 minute epoch.

- Δ index is used as a measure of signal variability, it is usually computed for 12 s intervals. The Δ index was computed as the sum of the absolute variations between two successive points, divided by the number of intervals.

- Central tendency measure is computed by selecting a circular region of radius 0.5 round the origin, counting the number of points that fall within the radius, and dividing by the total number of points. Given N data points from a time series, N – 2 would be the total number of points in the scatter plot. Hence, CTM can be computed as (Jeong et al 2002);

$$CTM = \frac{\sum_{i=1}^{N-2} \delta(di)}{N-2}$$

Where,

$$\delta(di) = \begin{cases} 1 \text{ if } [(x(i+2) - x(i+1))^2 + (x(i+1) - x(i))^2]^{1/2} < 0.5 \\ 0 \text{ otherwise.} \end{cases}$$

- Oxygen Desaturation Indices of 3% (ODI3) was obtained by calculating the number of times per hour that the SpO2 goes 3% or lower from baseline. Baseline was set initially as the mean level in the first 3 minutes of recording.

Results

To assess the diagnostic accuracy of the SpO2 features we extracted, we calculated the sensitivity and specificity pair for these features depending on the character of the values provided by each feature. The sensitivity of a test is the percentage of patients in the OSA positive group correctly diagnosed, whereas the specificity is the percentage of subjects in the OSA negative group correctly classified by the test.

Using Δ index we obtained a sensitivity of 65%, and a specificity of 60%.

ODI3 provided 75% sensitivity, and 64% specificity.

Sensitivity and specificity of CTM with radius 0.5 was higher than those provided by Δ index and ODI3, the test results were 93%, and 91% respectively.

Significant differences <0.01 were found between OSA positive and OSA negative patients.

With this feature we achieved higher accuracy values in SpO2 signals recorded from subjects affected by OSA syndrome.

Conclusion

In this work we present features extraction analysis of blood oxygen saturation.

The best results were achieved applying CTM. CTM significantly improved the accuracy for the diagnosis of OSA syndrome; with CTM we obtain high sensitivity and we maintain good specificity values.

However, we believe that this initial study, which correctly recognized OSA+ subjects using SpO2 alone, indicates that our approach will have clinical utility.

Future direction to this work would be to apply our methodology to a larger population to validate the results obtained with this radius.

In the future, we are planning to compute the CTM with several radii for every SpO2 signal in both OSA positive and OSA negative groups. Then, we select the optimum radius that achieve the most significant differences.

In addition, we are planning to analyze the ECG features signals, in order to use it with SpO2 signals to build two parameters technique and apply that as a system for automated recognition of OSA.

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