Identification of Obstructive Sleep Apnea Using Artificial Neural Networks and Wavelet Packet Decomposition for Heart Rate Variability Signal

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Abstract

Obstructive sleep apnea (OSA) is one of the most common breathing-related sleep disorder affecting individuals of different age group gender and ethnic origins. It is characterized by short-duration cessations in breathing during sleep due to the collapse of the upper airway. Until now, it is estimated that 70-80% of the affected individuals remain undiagnosed. OSA is associated with other major co-morbidities such as cardiovascular diseases, arrhythmias, strokes, obesity, depression, hypertension and diabetes. The golden and reliable standard test for the diagnosis of OSA is done by specialized physicians and technicians using overnight polysomnography (PSG), also known as sleep study. However, this test is time consuming, expensive and cumbersome. Analysis of a Heart Rate Variability (HRV) signal that is obtained from the Electrocardiograph (ECG) signal in the time or frequency domain is an effective, non-invasive and promising method for the detection of OSA.

The aim of this thesis is to analyze the Sultan Qaboos University Hospital (SQUH) ECG database signals using frequency and time domains methods for screening OSA patients. Electrocardiographic records of 60 patients with OSA and 20 normal subjects HRV Signals are obtained by extracting the RRI data using validated QRS detection software provided by Physionet website. Smoothing and filtration is then performed for false-intervals removal and missed-intervals substitution.

In this research, Wavelet Packet Decomposition was used to extract the power spectrum from the HRV signals at the very low frequency (VLF) (0.0033-0.04) Hz, low frequency (LF) (0.4-0.15) Hz, high frequency (HF) (0.15-0.4) Hz bands and their ratios. Moreover, the efficiency of 11 statistical features extracted from the RRI signal in time domain was also evaluated. The single perceptron, feedforward with back propagation and probabilistic artificial neural networks were considered for classification purposes.

The efficiency of these features in classification was evaluated according to the following classification cases: a) normal vs. severe classification, b) normal vs. mild classification, c) normal vs. patient (including: mild, moderate and severe subjects in one group) classification and d) normal vs. mild vs. moderate vs. severe classification. The highest achieved accuracies were obtained when using VLF feature with the probabilistic network at 95% accuracy in both of (a) and (b) classification cases. While feedforward network with the VLF/HF feature provided the highest performance at 87.5% accuracy in (c) classification case. Finally for OSA
severity classification in (d), a combination of two time domain features provided the highest accuracy of 77.5%.

These results are considered promising besides the network is efficient and full automatic. The waiting times suffered by individuals to perform a PSG test at SQUH is estimated to be 6 months; our proposed methods is recommended to enhance the screening process of individuals suspected with OSA such that only affected individuals to be scheduled for PSG test.