Classification of Sleep Apnea using Cross Wavelet Transform

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***Abstract*—In this paper, a novel approach for classifying sleep apneas using cross wavelet transform has been proposed. This is the first time that cross wavelet transform has ever been applied to sleep apnea type classification. The developed method takes the airflow and thoracic effort signals, as an input, which are then transformed to time-frequency and phase plane in order to extract the information of correlation between the two signals during different apnea condition. As the cross-wavelet returns large number of coefficients, which may be difficult to handle in some automated detection system, therefore dimension reduction was necessary. In the work,*kernel principal component analysis* (KPCA) based dimension reduction technique has been applied, and four Eigen values from each of the cross-wavelet amplitude and phase coefficients found to be effective for detection of apnea into three categories i.e.,obstructive, central and mixed. The proposed system has been tested on the recordings obtained from23subjects. The average classification rate obtained using simple threshold technique was 85%±0.78%, and the values for each class were 85.2% (obstructive), 86.4% (central) and 83.6% (mixed). The results show that cross-wavelet is useful in order to distinguish the apneas, as it looks into the phase and amplitude coherence between the two signals.**

Keywords—Central sleep apnea (CSA), cross wavelet, obstructive sleep apnea (OSA), polysomnography (PSG), thoracic effort signal

I. INTRODUCTION

With a growing recognition of adverse effects from poor sleep and sleep disorders, there has been more interest in developing physiological monitoring techniques in sleep medicine that can provide effective diagnosis and treatment of patients with sleep related complaints. Among the different sleep disorders, such as insomnia, sleep apnea, narcolepsy, and periodic leg movements, sleep apnea syndrome (SAS) is one the common one, characterized by the recurrent cessation of breathing during sleep. This is also accompanied by a decrease of oxygen saturation in arterial blood over time. When the breathing does not pause but the volume of air entering into the lungs is reduced then the respiratory event is called hypopnea. The prevalence of SAS is estimated as 4% in adult men and 2% in adult women whose age raging from 30 to 60 years [1]. People suffering from SAS may have excessive day time sleepiness, lethargy,poor concentration, and impaired cognitive performance, leading to impaired quality of life. These symptoms can significantly increase the risk of car and work place accidents. Further, previous studies have reported SAS generates systematic hypertension, diabetes, obesity, cardiovascular pathologies, and to decrease in the efficiency in the immunity system [2]. In children, chronic sleep disturbances can cause diminished growth, impaired learning and poor cognitive performance.

Polysomnography (PSG) is the gold standard method for sleep apnea diagnosis. PSG consists of an overnight recording of different physiological signals such as electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), airflow, oxygen saturation in arterial blood, respiratory efforts, snoring, and body position etc [3]. PSGs are carried out in sleep laboratories with attending systems and specialized staff. The identification of possible apneic events and its types is performed manually by sleep experts through the observation of the recorded signals. A patient can be diagnosed as having sleep apnea if the rate of apnea and hypopnea events per hour of sleep i.e., Apnea-hypopnea index (AHI) is ≥5. AHI of 5-15 events/h is considered as mild, an AHI of 15-30 events/h is moderate, and an AHI above 30 events/h is severe [4]. According to the American Academy of Sleep Medicine Task Force (AASM) criteria [4], an apnea is an event that lasts 10 s or longer and is characterized by drop in the peak thermal excursion by 90% of baseline. Apnea is classified into three basic types:

***Obstructive sleep apnea(OSA)*:** This is associated with continued or increased inspiratory effort throughout the entire period of absent airflow.

***Central sleep apnea(CSA)*:** This is associated with absent inspiratory effort throughout the entire period of absent airflow.

***Mixed sleep apnea(MSA)*:** This is associated with absent inspiratory effort in the initial portion of the event, followed by resumption of inspiratory effort in the second portion of the event.

However, PSG is expensive, time consuming, and labor intensive procedure. A significant number of apnea cases remain undiagnosed and untreated which leads to an increasing interest for the development of reliable diagnostic alternatives using fewer biological signals and having usability. Portable polysomnography systems are also available. Several other methods exist for the diagnosis and screening of

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