Chapter 67
A Measure to Detect Sleep Onset Using Statistical Analysis of Spike Rhythmicity

B.R. Purnima
Center for Medical Electronics and Computing, M.S. Ramaiah Institute of Technology, India

N. Sriraam
Center for Medical Electronics and Computing, M.S. Ramaiah Institute of Technology, India

U. Krishnaswamy
M.S. Ramaiah Hospitals, India

K. Radhika
M.S. Ramaiah Medical College, India

ABSTRACT

Electroencephalogram (EEG) signals derived from polysomnography recordings play an important role in assessing the physiological and behavioral changes during onset of sleep. This paper suggests a spike rhythmicity based feature for discriminating the wake and sleep state. The polysomnography recordings are segmented into 1 second EEG patterns to ensure stationarity of the signal and four windowing scheme overlaps (0%, 50%, 60% and 75%) of EEG pattern are introduced to study the influence of the pre-processing procedure. The application of spike rhythmicity feature helps to estimate the number of spikes from the given pattern with a threshold of 25%.Then non parametric statistical analysis using Wilcoxon signed rank test is introduced to evaluate the impact of statistical measures such as mean, standard deviation, p-value and box-plot analysis under various conditions.The statistical test shows significant difference between wake and sleep with $p<0.005$ for the applied feature, thus demonstrating the efficiency of simple thresholding in distinguishing sleep and wake stage.

INTRODUCTION

Sleep is a physiological state of rest during which eyes are closed leading to state of unconsciousness. The stages of sleep are categorized as wake, non-rapid eye movement sleep (NREM), and rapid eye movement sleep (REM). The second stage, NREM, can be subdivided into the following three different stages as stage I: transition from wake to asleep (drowsy), stage II: light sleep stages III: deep sleep stages. Detection of sleep onset involves pattern recognition of EEG waveforms by trained

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experts. Polysomnography is a multichannel recording of physiological parameters during sleep to recognize the multiple physiological parameters recorded during sleep. Continuous periods of EEG waveform patterns such as alpha and delta activity as well as isolated waveforms including K complexes, spindles, and vertex waves posterior occipital sharp transients have been identified during the detection. Several methods for the detection of Sleep onset have been explored by various researchers.One of these methods is to calculate the elapsed time between the light off to the first slow eye movements(SEM). SEM are known to be typical phenomena during sleep wake transition (Luigi De Gennaro,2000).By computing the relative EEG spectral powers in the occipital area, sleep onset interaction the sleep onset is detected corresponding to the intersection point between the lower and higher frequencies(Luis Estrada, Joan Santamaría, Valentina Isetta, Alex Iranzo, Daniel Navajas& Ramon Farré,2010). Also Sleep onset detection is done by calculating the power values across different frequencies of EEG signal (De Gennaro, 2001).Assessment of physiological and behavioral changes occurring during sleep onset period was done by examining beat-to-beat (RR interval) changes in heart rate during the transitions between wakefulness, initial Stage 1, and subsequent Stage 2 sleep in normal subjects (Davis et al., 1937; Dement and Kleitman, 1957). Other proposed techniques were based on the detection of correlation between EEG and EOG signals where a strong correlation EOG (one EOG channel) and EEG was observed and the agreement reached 91.16% and sensitivity is 93.33% using the combination of two-threshold method (Blink and SEM)(Ren-Jing Huang et all, 2012). The identification of an ideal quantification method for the detection of sleep onset is rather a challenging task for the biomedical research community. With this background the objective is to prove that, spike rhythmicity (Srinivasan et.al., 2005) based feature is a significant approach for discriminating the wake and sleep stage.

PREPROCESSING

The polysomnography datasets from which Electroencephalogram is extracted is acquired from the sleep laboratory of M S Ramaiah Hospitals. As the EEG changes during onset of sleep occur first in the occipital lobe of the brain, channels O1 and O2 are considered for the data acquisition process. The sampling frequency of the acquired data is 256 Hz used for feature extraction. The system that is used for the analysis of the data is Sandman analysis system, the portion of which utilizes Primo Burner Technology © 2003-2006 Primo software. For the proposed study, three subjects' recordings are considered for analysis. EEG being a non-stationary signal is segmented into 1 second patterns by applying different windowing as discussed:

1. Assuming that the given time series is divided into 1sec, there is no overlap between any two consecutive 1 second EEG patterns (SR1)
2. Retaining the first segmented 1 second pattern, a 50% overlap is introduced in such a manner that the second EEG pattern comprise of 0.5 sec i.e. half of first EEG pattern and first half of second EEG pattern of SR1 (SR2).
3. The third and fourth windowing is based on 60% (SR3) and 75% (SR4) of the overlap. The procedure is same as discussed in (2).

FEATURE SELECTION

Spike Rhythmicity

In order to detect the signature of wake and sleep in the EEG signals a time domain feature, spike rhythmicity is applied. The extraction of this feature recognizes the EEG spikes and helps in classifying the transition between wake and sleep stages. The segmentation procedure helps in