Academic Year of 2017, Submitted on January 30, 2018

Graduate School of Science and Engineering, Aoyama Gakuin University

Title: Study on Estimation Method of Sleep Onset and Arousal Timing using Body Movement and Heart Variability

Student Name: Takayuki OKAMURA
ID Number: 35616144
Degree: Master of Engineering
Course: Intelligence and Information
Thesis Advisor: Guillaume LOPEZ

Abstract

Sleeping disorders include disruption in sleep induction and nocturnal awakening. These symptoms are nevertheless intricate for a person to detect himself as they occur when the person is unconscious. Consequently, it is imperative to automatically analyze one's sleep to detect his sleeping state and evaluate his sleep onset and arousal time. There already exist numerous techniques to detect sleep disorders. However, they mainly use error-prone methods such as the person's sleep movements to estimate onset and arousal durations. Other research estimate sleep states from heart rate. Most of these studies, nevertheless, focus on the heart rate spectral variability and ignore the duration of sleep state transition. This leads to inaccuracies due to the required spectral interpolations and imprecisions in estimating spectral components of short-time signals.

This study proposes to accurately estimate people's sleep onset and arousal time via a combination of time variations in their heartbeat intervals and their body movements. We conducted an experiment on 11 subjects to record variation in their heart rates and used accelerometer sensors to record their motions before during sleep. We then used least squared cosine spectrum analysis methods to estimate the onset and arousal time based on the heartbeat intervals. We found that a mean average estimation error of onset and arousal was 213s and 192s, respectively. Compared to existing mainstream devices, the proposed approach reduces significantly the time estimation error. For instance, a Fitbit Charge 2 error is respectively 512s and 357s for detecting onset and arousal time for a Sleep Meister is respectively 528s and 546s for onset and arousal. In addition, using a Wilcoxon 's signed rank sum test we found that the time estimation error in this method is significantly lower than the two existing devices ($p<.01$).

Proposed method, with a small number of data and without interpolation processing, enables to easy and accurately estimate onset time, using the periodicity of the heart rate and body movement. As a future prospect, wear a pulse wave sensor and acceleration on a belly band, an eye mask to make it more practical can be developed and verify whether results similar to this method can be obtained.