A Portable and User Friendly REM Sleep Detection System Based on Differential Movement of Eyeball Using Optical Sensors

Chi Yeon Hwang[1], Geun do Park[1], Hyang Jun Jeong[1], In Gyu Park[1], Yun Joong Kim[3], Hyeo-Il Ma[2], and Unjoo Lee[1(✉)]

[1] Department of Electrical Engineering, Hallym University, 1 Hallymdaehak-gil, Chuncheon, Gangwon-do, Republic of Korea
ejlee@hallym.ac.kr

[2] Department of Neurology, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, Hallym University, Chuncheon, Republic of Korea

[3] Department of Neurology, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, Anyang, Republic of Korea

Abstract. The REM (Rapid Eye Movement) sleep as one of the five stages of sleep is the restorative part of the sleep cycle. During REM sleep, eyes move quickly in different directions and most dreams occur. Why people need REM sleep, why we dream, and what purpose our dreams serve are not known exactly. RBD (REM Behavior Disorder), a parasomnia, involves abnormal behavior during REM sleep phase, such as loss of muscle atonia. RBD is most often associated with elderly and in those with neurodegenerative disorders such as Parkinson's disease, multiple system atrophy and Lewy body dementia. A portable and user friendly REM sleep detecting system is proposed based on differential shift of the eyeball localization using infrared optical sensor in this study. The system consists of an optical source/detector, current regulator, differential amplification, data acquisition, feature extraction, and classification parts, where a 730 nm light emitting diode and two photo detectors were used in the optical source/detector part, and wavelet transformation was applied in the feature extraction and the classification parts. In the feature extraction part, sleep time series data obtained from the data acquisition part was resampled to a sampling frequency of 256 Hz and then filtered with a 1st order 0.16 Hz high pass filter to remove dc offset and a 2nd order 60 Hz band limit filter. Finally, the filtered data was transformed using Matlab dwt function to detect periods of REM sleep. The performance of this REM sleep detecting system was evaluated with overnight recordings of 5 subjects. The results showed sensitivity of 85% and specificity of 92%, suggesting that this system can be a very practically efficient in automatic detection of REM sleep stages in a mobile environment.

Keywords: REM sleep · Eyeball localization · Optic sensor · Wavelet transformation

C. Stephanidis (Ed.): HCII Posters 2017, Part I, CCIS 713, pp. 224–228, 2017.
DOI: 10.1007/978-3-319-58750-9_32

1 Introduction

REM (Rapid Eye Movement) sleep as one of the five stages of sleep is the restorative part of the sleep cycle. During REM sleep, eyes move quickly in different directions and most dreams occur. Why people need REM sleep, why we dream, and what purposes our dreams serve are not known exactly. RBD (REM Behavior Disorder), a parasomnia, involves abnormal behavior during REM sleep phase, such as loss of muscle atonia. RBD is most often associated with elderly and in those with neurodegenerative disorders such as Parkinson's disease, multiple system atrophy and Lewy body dementia.

There are many devices for monitoring sleep stages by measuring heart rate, respiration, motion, chest movement on breathe, sound of body movement on bed, body temperature, galvanic skin response, etcs using a thin sensor pad under the mattress, bedside sonar, sound sensor clipped onto pillow, or biosensors on wrist [1–5]. However, RBD detection is still accomplished on heavy expensive devices such as polysomnography and/or videographical analysis.

This study suggests a portable REM sleep detecting system based on the localization of eyeball using optical sensors.

2 Method

Figure 1 shows a diagram of the portable REM sleep detecting system in which the principle of the localization of eyeball using optical sensors is represented. Optical sensors used in the system consist of two infrared detectors and one infrared led source in the middle of the detectors. The localization of the eyeball is estimated by the difference of the reflected portion of the light emitted to the surface of the eyelid between the two detectors while eyeball moves.

Figure 2 shows the circuit diagram of the portable REM sleep detecting system. The system consists of an optical source/detector, current regulator, differential amplification, data acquisition, feature extraction, and classification parts, where a 730 nm light emitting diode and two photo detectors were used in the optical source/detector part.

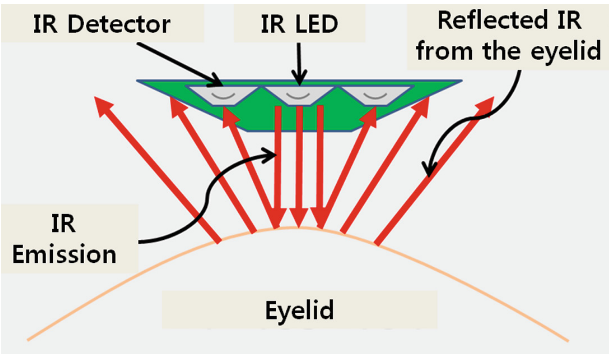

Fig. 1. A schematic diagram of the principle of the localization of eyeball using optical sensors.

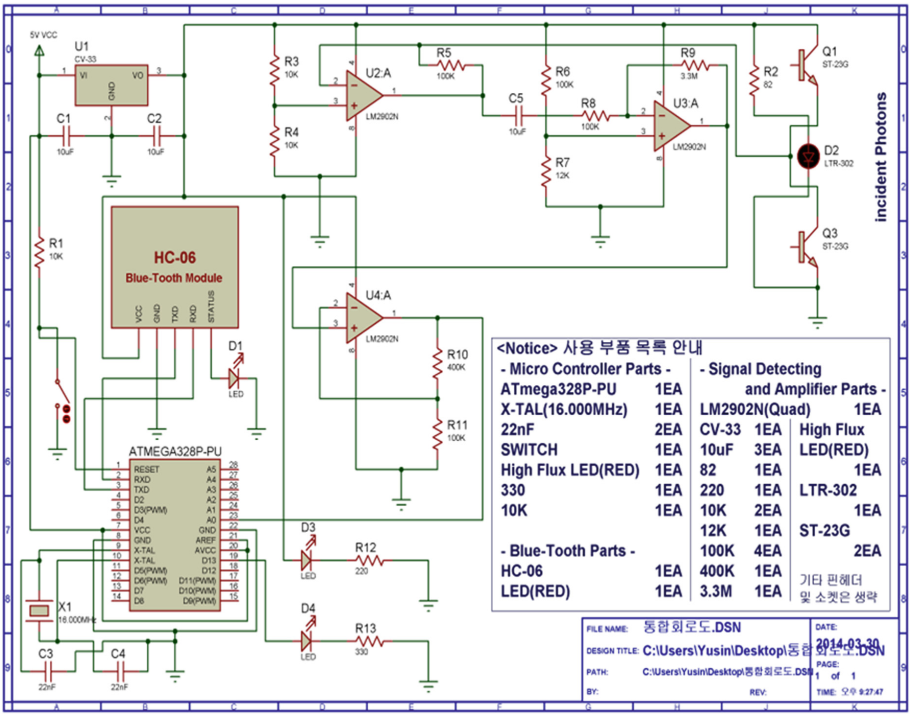

Fig. 2. The circuit diagram of the portable REM sleep detecting system.

3 Results and Discussions

A simulation study was carried out by the human eyeball model constructed using 3D printer based on the design verified through rendering. Figure 3 shows the design and the constructed human eyeball model.

The invasiveness of the system to human was tested for various durations of the emitting of the optical source. The test was accomplished to the arm with the similar skin type to that of eyelid. Table 1 describes the temperature measured on the skin for various durations of the emitting of the optical source. The results showed the variation of the temperature is not significant on the duration of the infrared led emitting as shown in Table 1. The result suggests that the system has no harmful side effect on human skin and proves its invasiveness and usefulness during real life sleep hours.

Wavelet transformation was applied in the feature extraction and the classification parts of the system. In the feature extraction part, sleep time series data obtained from the data acquisition part was resampled to a sampling frequency of 256 Hz and then filtered with a 1st order 0.16 Hz high pass filter to remove dc offset and a 2nd order 60 Hz band limit filter. Finally, the filtered data was transformed using Matlab dwt function to detect periods of REM sleep. Figure 4 represent the difference of the spectrogram according to the speed of the eyeball. The performance of this REM sleep detecting system was evaluated with overnight recordings of 5 subjects. The results

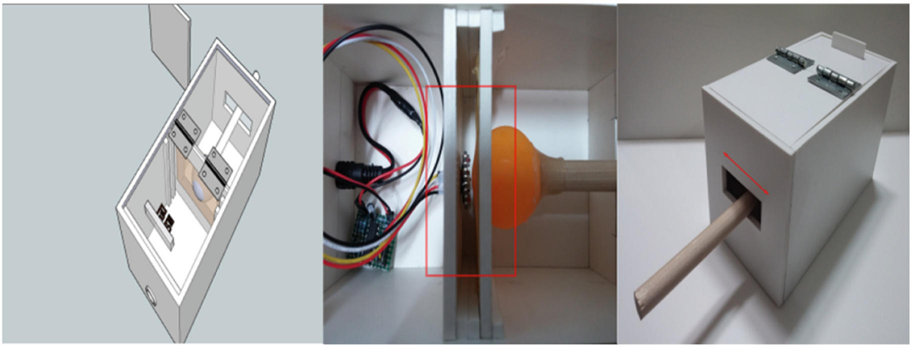

Fig. 3. A human eyeball model constructed using 3D printer based on the design verified through rendering.

Table 1. The temperature measured on the skin for various durations of the emitting of the optical source.

Duration (hrs)	1	2	3	4	5	6	7	8
Temperature (°C)	34.5	33.8	33.9	34.1	33.8	34.2	34.5	34.2

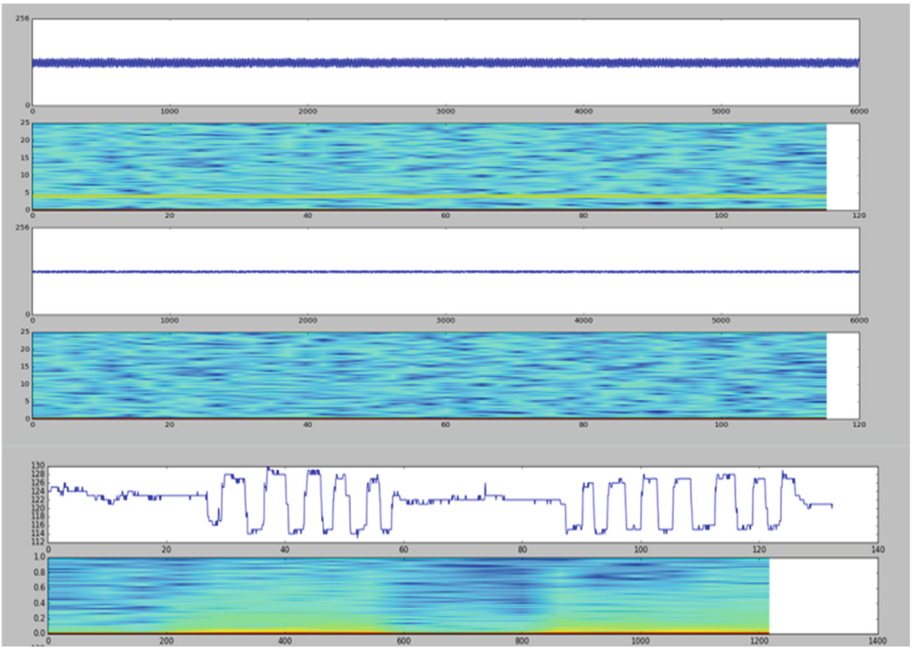

Fig. 4. The difference of the spectrogram according to the speed of the eyeball.

showed sensitivity of 85% and specificity of 92%, suggesting that this system can be a very practically efficient in automatic detection of REM sleep stages in a mobile environment.

4 Conclusions

A portable and user friendly REM sleep detecting system is proposed based on differential shift of the eyeball localization using infrared optical sensor in this study. The system consists of an optical source/detector, current regulator, differential amplification, data acquisition, feature extraction, and classification parts, where a 730 nm light emitting diode and two photo detectors were used in the optical source/detector part, and wavelet transformation was applied in the feature extraction and the classification parts. In the feature extraction part, sleep time series data obtained from the data acquisition part was resampled to a sampling frequency of 256 Hz and then filtered with a 1st order 0.16 Hz high pass filter to remove dc offset and a 2nd order 60 Hz band limit filter. Finally, the filtered data was transformed using Matlab dwt function to detect periods of REM sleep. The performance of this REM sleep detecting system was evaluated with overnight recordings of 5 subjects. The results showed sensitivity of 85% and specificity of 92%, suggesting that this system can be a very practically efficient in automatic detection of REM sleep stages in a mobile environment.

Acknowledgement. This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1A2057199, NRF-2017R1A2B1009234) and the Original Technology Research Program for Brain Science through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (NRF-2016M3C7A1947307).

References

1. Imtiaz, S.A., Rodrigues-Villegas, E.: A low computational cost algorithm for REM sleep detection using single channel EEG. Ann. Biomed. Eng. **42**(11), 2344–2359 (2014)
2. Herscovici, S., Pe'er, A., Papyan, S., Lavie, P.: Detecting REM sleep from the finger: an automatic REM sleep algorithm based on peripheral arterial tone (PAT) and actigraphy. Physiol. Meas. **28**, 129–140 (2007)
3. Mendez, M.O., Matteucci, M., Castronovo, V., Ferini-Strambi, L., Cerutti, S., Bianchi, A.M.: Sleep staging from heart rate variability: time-varying spectral features and hidden markov models. Int. J. Biomed. Eng. Tech. **3**(3/4), 246–263 (2010)
4. Nam, Y., Kim, Y., Lee, J.: Sleep monitoring based on a tri-axial accelerometer and a pressure sensor. Sensors **16**, 750 (2016)
5. Hao, T., Xing, G., Zhou, G.: iSLeep: unobtrusive sleep quality monitoring using smartphones. In: SenSys 2013, Rome, Italy, 11–15 November (2013)