International Journal of Multimedia and Ubiquitous Engineering
Vol.9, No.1 (2014), pp.277-288
http://dx.doi.org/10.14257/ijmue.2014.9.1.26

A Study on the Sleep Analysis Using H-MOTE2420 Sensor and Scene Change Detection

Seong-Yoon Shin[1], Yang-Won Rhee[1], Dai-Hyun Jang[1], Hyoung-Keun Park[2*]
And Hyun-Chang Lee[3]

[1] *Kunsan National Univ., 1170 Daehangno, Gunsan, Kunsan, 573-701, South Korea*
[2*] *Namseoul Univ., 91 Daehak-ro Seonghwan-eup Cheonan, 331-707, South Korea*
[3] *Wonkwang Univ., 460 Iksan-Daero, Iksan, Jeonbuk, 570-749, South Korea*

{s3397220, ywrhee}@kunsan.ac.kr, daijang@gsbtech.co.kr, phk315@nsu.ac.kr, hclglory@wku.ac.kr

Abstract

Sleep is an essentially physiologic phenomenon that compels humans to spend one-third of their lives sleeping. This paper deals with the correlation between sleep and condition data acquired from the data concerning bedroom sleep environments. The first thing we did in order to measure sleep environments was to install and run TinyOS, a compact operating system. Then we collected environmental data using the humidity sensor (SHT11) and the ambient light sensor (GL5507) in the H-MOTE2420 sensor. In this paper, the microphone sensor (WM62A) is not dealt with. Next, the subjects were asked to enter the information about levels of fatigue, levels of drinking, and levels of stomach emptiness as the weighting information affecting sleep. Finally, the difference image, the color histogram, and the χ^2 *histogram, all of which are scene change detection methods, were used to detect scene transitions. The scenes obtained through scene change detection mean the number of the subjects' tossing and turning under different situations for different weights. In this paper, we used tables and figures, in particular, to make it easier to understand how frequently different levels of drinking left the subjects tossing and turning during sleep.*

Keywords: *sleep environment, sensor, weighting information, scene change detection, tossing and turning*

1. Introduction

It is known that humans spend more than one-third of their lives sleeping [1]. As an essential part of our daily lives, sleep helps to keep us healthy since it relieves our fatigue from the day's work and prepares ourselves for tomorrow [2]. For people today, sleeping occupies most of their time spent at home. In general, people are defenselessly exposed to the environment while asleep. In this respect, fostering a comfortable sleep environment is of great consequence [3].

Sleep consists of two different stages: NREM (Non-Rapid Eye Movement) sleep and REM (Rapid Eye Movement) sleep [4]. Healthy young adults are most likely to enter the REM stage within 90 minutes after falling asleep. With each successive cycle, REM sleep lasts longer, and they stay in REM sleep for about 30 minutes right before they wake up [5].

ISSN: 1975-0080 IJMUE

Sleep disorders cause lack of concentration, traffic and industrial accidents, and adjustment disorders with depressed mood [5]. This is why the subject of sleep needs closer examination [6].

2. Related Research

As part of the sleep measure and monitoring system, flexiforce pressure sensors and thermistor temperature sensors were used for measurement, analysis, and estimation of sleeping postures and states [7- 9].

Recently, CCD cameras have been used to ensure the indirect measurement of breathing through the use of image processing of chest x-rays. This method has the advantage of imposing no restrictions on the subject, while it has the disadvantage of low accuracy because there is some difficulty in determining the area, where measurements should be made, due to the sleeping subject's motion [10 -12].

There are several methods available to help overcome the problem of excessive medical checkup costs and spatial limitations. For one thing, the ROI(Region of Interest)-based automated monitoring method is used to indirectly process the images of the sleep apnea suffered by the elderly living alone and accurately measure the respiratory volume of theirs, on a long-term basis, through the use of CCD cameras [13].

Another method of detecting the symptoms of obstructive sleep apnea involves extracting the features of time and frequency domains through analysis of the electrocardiogram signals and heart rate variability induced therefrom, and applying them to the RBF (Radial Basis Function) network, which is a neuropil [14]. This method, however, has low detection rates and is not available for use in households.

3. TinyOS and Sensor

3.1. TinyOS

As an operating system specifically designed for embedded network systems like a sensor network, TinyOS is used to make event-based applications, core operating systems of about 400 bytes, and ultra-tiny operating systems whose data memory is small. It has the following three features:

① a component-based architecture;

② task- and event-based concurrency; and

③ segmented motions

TinyOS bases its event machine-based programming concept on an event-driven state transition mechanism. It allows for efficient use of limited memory space while ensuring concurrent processing. Due to system resource constraints, however, TinyOS does not use the existing concepts ― IP protocol, socket, and thread.

3.2. Sensor

As illustrated in Figure 1, the sensor used is named H-MOTE2420. It includes the microphone sensor (WM62A), the humidity and temperature sensor (SHT11), and the ambient light sensor (GL5507).

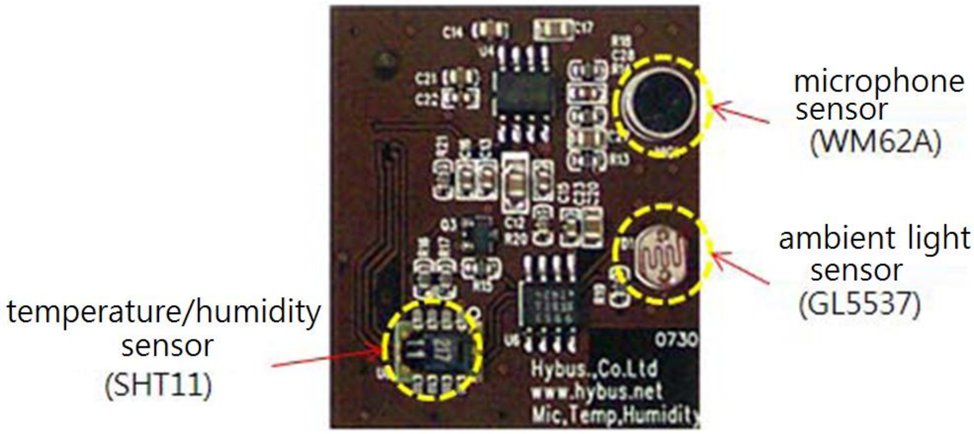


Figure 1. H-MOTE2420 Sensor

This section dispenses with the need for the microphone sensor. The ambient light sensor named GL5537 varies in output voltage, depending on the amount of light. The humidity and temperature sensor named SHT11 is made by SENSIRION, whose reliability and stability has been verified through a number of tests.

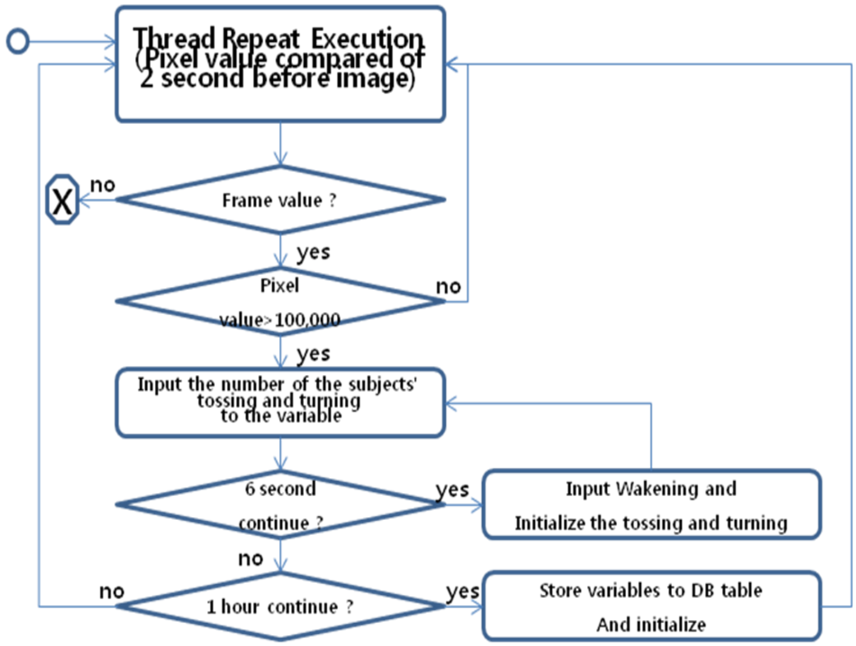
4. Sleep Measurement by Scene Change Detection

4.1. Difference image

The difference-image method is used to extract the video clips of the subjects tossing and turning in their sleep. Scene change detection is made by using the difference image between the reference image and the input image. The difference-image technique here is commonly used in the field of image processing [15]. Below is the Equation (1) for the difference-image technique:

$$\delta I(x,y) = |I_t(x,y) - I_{t-1}(x,y)|$$
$$D(x,y) = \begin{cases} 1, & \text{if } \delta I(x,y) > T_h \\ 0, & otherwise \end{cases} \quad \text{Equation (1)}$$

In Equation (1), (x, y) indicates the difference in the brightness value of the pixels positioned on the x-coordinate and y-coordinate. In addition, $I_t(x, y)$ refers to the current image, $I_{t-1}(x, y)$ to the previous image, D(x, y) to the binary difference image, and T_h to the threshold value. As in Figure 2, the modules needed to carry out the difference-image technique are accumulated in the database if the conditions are met.



How to obtain a difference image?

(1.1) Brings the information of the image
To compare values in 2 seconds.

(1.2) Regarded more than 10 million pixels as the value of tossing and turning.
Store it as variable.

(1.3) Consecutive pixel change detection when more than three times (6 seconds)
Shall be deemed to have woke, and store it variable
Variable of tossing and turning -3

(1.4) Initialization performed after the hour stored in the DB

Figure 2. How to obtain a difference image

4.2. Color histogram

The color histogram method, a scene change detection method, is used to extract the images of the subjects tossing and turning during sleep. For the color histogram method, Equation (2) is shown below [16]:

In comparing the color histogram ($d_{r,\ g,\ b}(f_i,\ f_j)$), each $R{\cdot}G{\cdot}B$ color space for two adjacent frames (f_i, f_j) is calculated by using Equation(2). $H_i^r(k)$ $H_i^g(k)$ $H_i^b(k)$ indicates the number(N) of bin(k) for each color space ($_{r,\ g,\ b}$) at the ith frame(f_i)).

$$d_{r,g,b}(f_i, f_j) = \sum_{k=0}^{N-1} \Big(\left| H_i^r(k) - H_j^r(k) \right| + \left| H_i^g(k) - H_j^g(k) \right| + \left| H_i^b(k) - H_j^b(k) \right| \Big) \quad \text{Equation (2)}$$

4.3. χ^2 Histogram

Equation (3) shows the χ^2 histogram method, a scene change detection technique [17].

$$d(f_t, f_{t-1}) = \sum_{i=0}^{k} \frac{(H_t(i) - H_{t-1}(i))^2}{H_t(i)} \quad \text{Equation (3)}$$

The χ^2 histogram method ($d(f_t, f_{t-1})$) is a statistical scene change detection technique for the two adjacent frames(f_i, f_j). It is defined as Equation (3) and obtained through comparing histograms. $H_t(i)$ indicates the histogram value of a given frame at the point in time t. Also, $H_{t-1}(i)$ indicates the histogram value of a given frame at the point in time $t-1$.

5. Experimental Result

Sleep experiments were implemented using Visual C++ 6.0 and MySQL running on Microsoft Windows XP. We were able to get data for the 30 subjects, the video footage of whom was taken for five hours after they fell sound asleep. The 30 subjects were assigned different conditions for different groups: 10 subjects who didn't drink; 10 who got half drunk; and 10 who were dead drunk. Figure 3 shows how TinyOS is installed and tested.

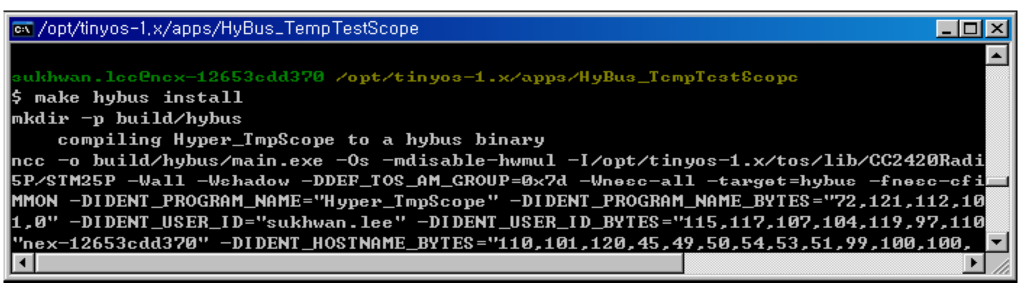


Figure 3. TinyOS Install and Test

In order to get the results of the experiment arising from alcohol consumption, experiments were conducted under several experimental conditions in which levels of fatigue and stomach emptiness were set to 0, and drinking levels were set to 0, 50, and 100, respectively. Temperature, illumination, and humidity data were inputted using the sensors. The mean values detected by the sensors are shown in Table 1

Table 1. The average value detected by the sensor

item	Average of measured values
Temperature	22
Illumination	159
Humidity	55

As in Figure 4, the system was set to collect environmental data through the sensors for the purpose of identifying and analyzing sleep stages.

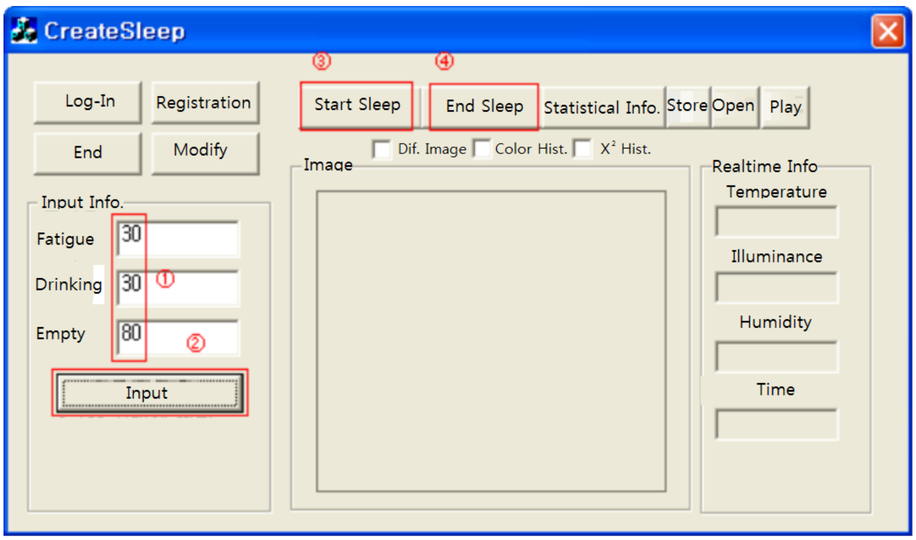


Figure 4. Main User Interface

As shown in Figure 4, the subjects enter the preset input information including fatigue levels, drinking levels, and levels of stomach emptiness (①) before pressing the Input Completion(②) button, followed by the Start Sleeping(③) button. When awake from their sleep, they have to press the Sleeping Completion (④) button.

5.1. Difference image experiment

The daily information about the subjects that is inputted onto the system includes fatigue levels, drinking levels, and levels of stomach emptiness. This information carries weight because it is likely to have effects on the simple data input and output as well as on their sleep. When awake from their sleep, the subjects themselves input the evaluations of the sleep they have that day. From the operations of the relevant weights, they learn about how their daily sleep is evaluated. In addition, accumulated data enable them to identify the sleeping environment best suited for themselves. Figure 5 shows an image of the difference image.

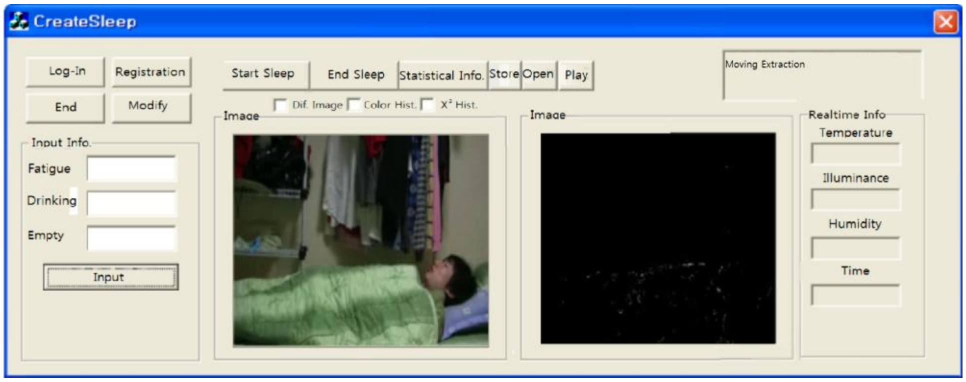


Figure 5. Difference image

Data are converted into another form before being saved. Thus the subjects can access statistical data at their discretion, which, in turn, helps solve sleep problems. This leads to extracting ideal values for different subjects, thereby allowing them to receive flexible data about their surroundings and environmental factors that contribute to sleep disorders. In other words, they can be aware of the steps they take before falling asleep, and of a sleep environment suitable for their current situation. This helps them create an optimal sleep environment and state, depending on the situation they are in. Fig. 6 shows the environment chart that was drawn on a daily and hourly-incremental basis.

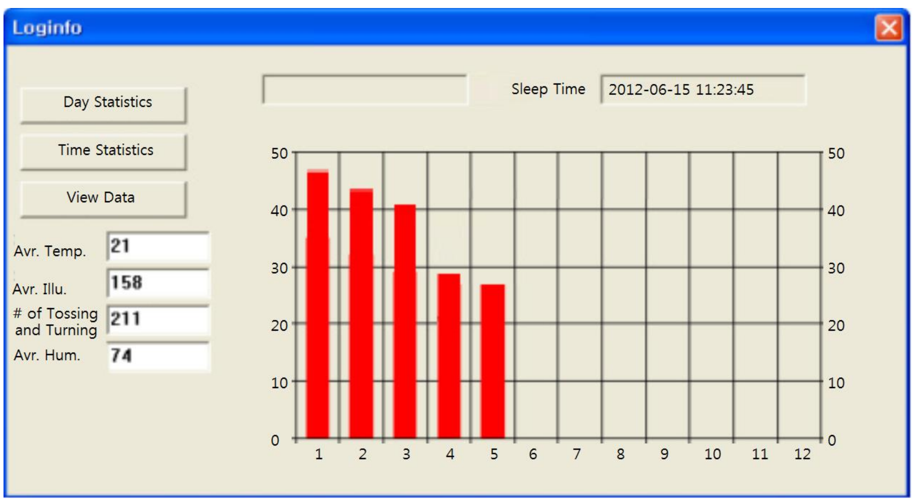


Figure 6. Hourly cumulative graph

5.2. Color histogram experiment

The color histogram method, which is a scene change detection technique as in Figure 7, is used to extract the video clips in which the subjects are seen tossing and turning while sleeping. User information as well as sensor information is inputted onto the system before carrying out the histogram method.

Figure 7. Color Histogram

Figure 8 exemplifies the key frame obtained through the scene transition, for which the threshold value was set to 400.

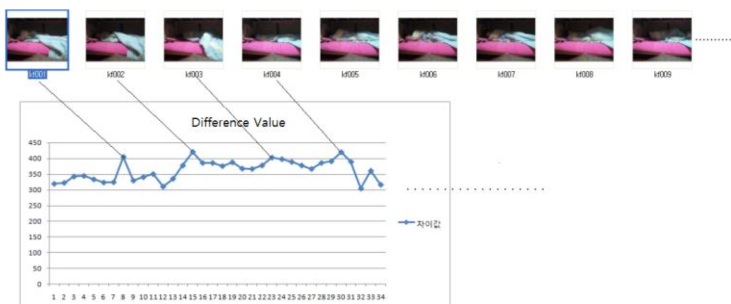


Figure 8. Extracted key frame of color histogram

5.3. X^2 histogram experiment

User information as well as sensor information is inputted onto the system, and the X^2 histogram method, a scene change detection technique as in Figure 9, is then carried out.

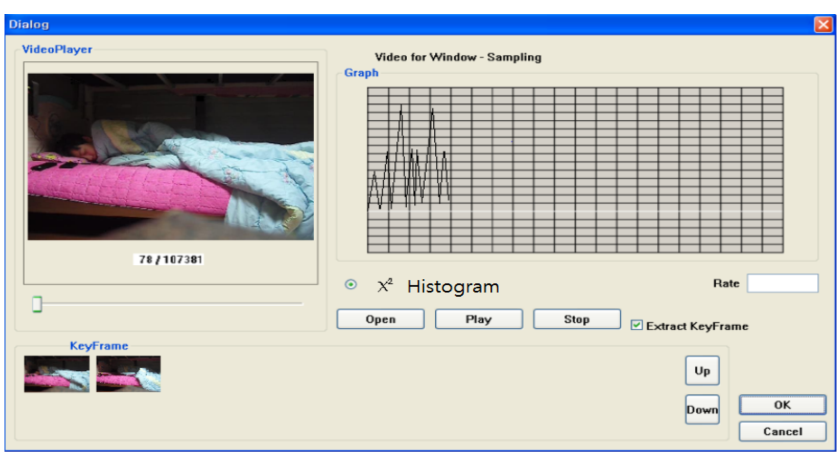


Figure 9. X^2 histogram

Figure 10 exemplifies the key frame obtained through scene transitions, for which the threshold value was set to 600.

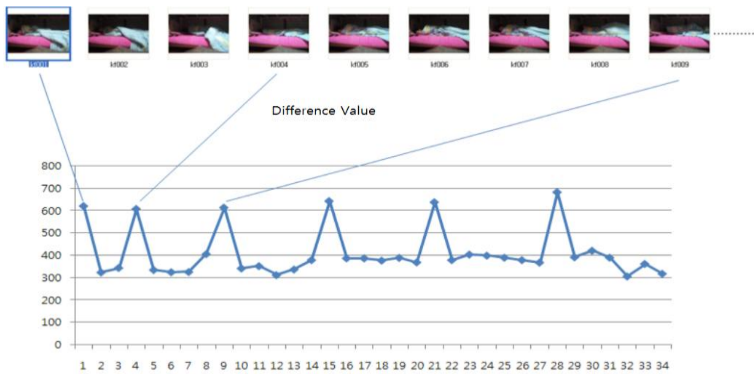


Figure 10. Extracted key frame of X2 histogram

5.4. The results of the experiment

Using the difference-image color histogram and X^2 histogram, Table 2 exemplifies the frequency with which the subjects toss and turn in their sleep after they have drunk. In Figure 11, the graph allows for further comparison.

Table 2. A result of the No. of toss and turn in their sleep

Histogram	Level of drinking	1 hour	2 hour	3 hour	4 hour	5 hour
Difference image	0	3	3	2	2	2
	50	14	12	10	8	4
	100	31	29	29	19	20
Color histogram	0	2	2	2	2	1
	50	10	8	6	5	3
	100	25	22	23	13	11
X^2 histogram	0	2	2	1	2	2
	50	8	8	6	4	2
	100	21	18	17	10	8

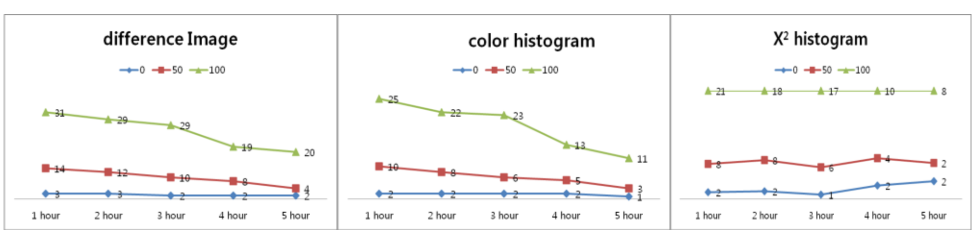


Figure 11. Graphical comparison

As you can see from the graph, in the color histogram, the frequency with which the subjects tossed and turned in their sleep was lower than in the difference image. In the case of the X^2 histogram, the frequency with which they tossed and turned during sleep was lower than in the color histogram. Furthermore, in the initial stages of sleep after they fell sound asleep, the subjects tossed and turned more often than in other stages. They might have had an upset stomach or a hangover headache from drinking alcohol. The graph shows, however, that over time, they get back to normal and fall asleep.

6. Conclusion

This paper examines several ways to measure sleep environments and enhance the quality of sleep. Sleep environments were measured when temperature, humidity, and illuminance data were inputted into the sensors. In addition, the subjects were asked to input levels of drinking so as to measure the number of their tossing and turning during sleep after drinking alcohol. The difference image, color histogram, and χ^2 histogram, all of which are scene change detection methods, were used to measure the number of the subjects' tossing and turning. The number of their tossing and turning during sleep was measured by using the data inputted into the sensors as well as the levels of drinking inputted by the subjects. According to this paper, the more the subjects drank, the more often they tossed and turned during the initial stage of sleep, but as sleep deepened, they tossed and turned much less frequently. In addition, the frequency with which the subjects tossed and turned during sleep was much lower in order of the difference image, color histogram, and χ^2 histogram. In conclusion, this study shows that drinking too much can ruin sound sleep. Moderate drinking is good for your health and sleep.

References

[1] H. M. Parsons, "The Bedroom", Human factors, vol. 14, no. 5, **(1972)**.

[2] K. S. Kwon, J. S. Kim and S. J. Park, "Recognizing Sleeping Posture on Bed by using the Measurement of Body Pressure Distribution", Journal of Society of KSIE, vol. 22, no. 52, **(1999)**, pp. 211-219, http://scholar.ndsl.kr/schArticleDetail.do?cn=JAKO199911921341309.

[3] M. Kim, M. Kim and C. Chun, "The Research on Sleep Environment and Sleep Quality in Winter and Spring", Proc. of KIAEBS, **(2008)** October, pp. 125-128, http://www.sustainablehealthybuildings.org/PDF/2nd/Chungyoon%20Chun.pdf.

[4] A. N. Rama, S. C. Cho and C. A. Kushida, "NREM–.REM sleep", Handbook of Clinical Neurophysiology, vol. 6, **(2005)**, pp. 21-29.

[5] http://www.seumi.com/bbs/board.php? &bo_t able=nb1&wr_id=514.

[6] R. D. Chervin, J. E. Dillon, C. Bassetti, D. A. Ganoczy and K. J. Pituch, "Symptoms of Sleep Disorders, Inattention, And Hyperactivity in Children", Sleep, vol. 20, no. 12, **(1997)**, pp. 1185-1192, http://www.ncbi.nlm.nih.gov/pubmed/9493930.

[7] S. R. Lee, "A Study of Sleeping State Sensing System", Graduate School, Dankook University, **(2010)** February.

[8] N. Kazuki, M. Yoshiaki and T. Toshiyo, "A monitor for posture changes and respiration in bed using real time image sequence analysis", Proceeding of the Annual EMBS International Conference, **(2000)**, pp. 51-54, http://dx.doi.org/ 10.1109/IEMBS.2000.900665.

[9] N. Hiroaki, I. Ken, M. Yoshio and W. Mutsumi, "Non-restrictive visual respiration monitoring, pattern recognition", Proceedings 15th International Conference, **(2000)**, pp. 647-651, http://dx.doi.org/ 10.1109/ ICPR.2000.903001.

[10] A. Hirooki, T. Yasuhiro, M. Kazuhiro and N. Masato, "Development of non-restrictive sensing system for sleeping person using fiber grating vision sensor", International Symposium on Mircomechatronics and Human Science, **(2001)**, pp.155-160, http://dx.doi.org/ 10.1109/MHS.2001.965238.

[11] S. -W. Lee, H. -Y. Choi, D. -J. Lee and M. -G. Chun, "Development of Real-Time TCP/COF Inspection System using Differential Image", Journal of Korean institute of intelligent systems, vol. 22, no. 1, **(2012)**, pp. 87-93, http://dx.doi.org/ 10.5391/JKIIS.2012.22.1.87.

[12] S. Y. Shin, "Detection of Assault and Violence Using Color Histogram in Elevator", Journal of The Korea Society of Computer and Information, vol. 17, no. 12, **(2012)**, pp. 95-100, http://dx.doi.org/ 10.9708/jksci/2012.17.12.095.

[13] S. Y. Shin and Y. W. Rhee, “Scene Change Detection with 3-Step Process”, Journal of The Korea Society of Computer and Information, vol. 13, no. 6, **(2008)**, pp. 147-154, http://www.koreascience.or.kr/article/ArticleFullRecord.jsp?cn=CPTSCQ_2008_v13n6_147.
[14] M. S. Rahman and K. -D. Kim, “Indoor Location Estimation Using Visible Light Communication and Image Sensors”, International Journal of Smart Home, vol. 7, no. 1, **(2013)**, pp. 99-114, http://www.sersc.org/journals/IJSH/vol7_no1_2013/10.pdf.
[15] M. M. Soliman, A. E. Hassanien, N. I. Ghali and H. M. Onsi, “An adaptive Watermarking Approach for Medical Imaging Using Swarm Intelligent”, International Journal of Smart Home, vol. 6, no. 1, **(2012)**, pp. 37-50, http://www.sersc.org/journals/IJSH/vol6_no1_2012/4.pdf
[16] S. Biswas, T. -h. Kim and D. Bhattacharyya, “Features Extraction and Verification of Signature Image using Clustering Technique”, International Journal of Smart Home, vol. 4, no. 3, **(2010)**, pp. 43-56, http://www.sersc.org/journals/IJSH/vol4_no3_2010/4.pdf **.**

Authors

Seong-Yoon Shin

He received his M.S. and Ph.D degrees from the Dept. of Computer Information Engineering of Kunsan National University, Kunsan, Korea, in 1997 and 2003, respectively. From 2006 to the present, he has been a professor in the same department. His research interests include image processing, computer vision, and virtual reality.

Yang-Won Rhee

He received his M.S. from the Dept. of Computer Science of Yonsei University, Ph. D. degree from the Dept. of Computer Science of Soongsil University. From 1986 to the present, he has been a professor in the Dept. of Computer Information Engineering, Kunsan National University, Korea. His research interests include image processing, computer vision, and virtual reality.

Dai-Hyun Jang

He received his M.S. degree from Kunsan National University’s Department of Computer Information Engineering, Kunsan, Korea, in 2011. From 2011 to the present, he has been in the doctoral program of the same department. His research interests include image processing and pattern recognition.

Hyoung-Keun Park

He received the M. S. and Ph. D. degrees in electronic engineering from Wonkwang University, Iksan, Korea in 1995 and 2000, respectively. He is currently a professor department of the electronic engineering at Namseoul University, Chungnam, Korea, in 2005. His research interests are in embedded system, applied ubiquitous sensor network and semiconductor manufacturing equipment.

Hynn-Chang Lee

He received his M.S. and Ph.D degrees from the Department of Computer Science of Hongik University, Seoul, Korea, in 1996 and 2001, respectively. From 2008 to present, he has been a professor in the Division of Information and Electronic Commerce in Iksan, Korea. His research interests include image processing, the semantic Web, ontology, and ubiquitous computing.