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A Study of Simple Sleep Apnea Predictive Device Using SpO_2 and Acceleration Sensor

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Abstract

Sleep apnea is a disease that causes various complications, and the polysomnography is expensive and difficult to measure. The purpose of this study is to develop an unrestricted wearable monitoring system so that patients can be examined in a familiar environment. We used a method to detect sleep apnea events and to determine sleep satisfaction by non-constrained method using SpO2 measurement sensor and 3-axis acceleration sensor. Heart rate and SpO2 were measured at the finger using max30100. After acquiring the SpO2 data of the user in real time, the apnea measurement algorithm was used to transmit the number of apnea events of the user to the mobile phone using Bluetooth (HC-06) on the wrist. Using the three-axis acceleration sensor (mpu6050) attached to the upper body, the number of times of tossing and turning during sleep was measured. Based on this data, this algorithm evaluates the patient's tossing and turning during sleep and transmits the data to the mobile phone via Bluetooth. The power source used 9 volts battery to operate Arduino UNO and sensors for portability and stability, and the data received from each sensor can be used to check the various degree between sleep apnea and sleep tossing and turning on the mobile phone. Through this study, we have developed a wearable sleep apnea measurement system that can be easily used at home for the problem of low sleep efficiency of sleep apnea patients.

Keywords: *SpO_2, 6-axis acceleration Sensor, mpu6050, Sleep Apnea, tossing and turning.*

1. INTRODUCTION

In 2013, about 380,000 people were treated for sleep disorders. In four years, the number of medical personnel increased by 90,000, and the medical expenses also increased by about 7 billion won [1]. Among them, obstructive sleep apnea is a common disease that reports a prevalence rate of 4% for men and 2% for women in the general middle-aged population of the United States [2]. A survey of 1,441 domestic rural populations shows that almost 2.9% of the population Symptoms of sleep apnea were reported daily [3]. Increasingly, patients with sleep disorders require an expert's analysis to diagnose sleep disorders, and the difficulty of accurate diagnosis due to the uncomfortable feelings of wearing a diagnostic device. Because of

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this, sleep apnea is a common disease that can be easily overlooked. In order to solve this problem, this study measures the saturation of percutaneous oxygen (SpO2) and retardation during sleep [4-9].

2. SYSTEM CONFIGURATION

The research system consists of two parts using Bluetooth communication as shown in Figure 1. Both devices are connected to a 9v power supply using a battery cartridge to drive the Arduino UNO. The goal is to attach the SpO2 and heart rate measuring device to the wrist and the accelerometer on the upper part of the body by wearing the device on the wrist and upper body, which are highly available in the human body, to monitor various bio signals without complicated process.

Using the max30100, which measures heart rate and SpO2, the respiratory distress index was measured on the finger and transmitted from the Arduino on the wrist to the mobile phone using Bluetooth (HC-06). In addition, using the mpu6050, which measured acceleration, worn on the upper body, evaluating the patient's torsion during sleep, and the number of the patient's torsion during sleep was transmitted to the mobile phone application via Bluetooth in the same manner as described above.

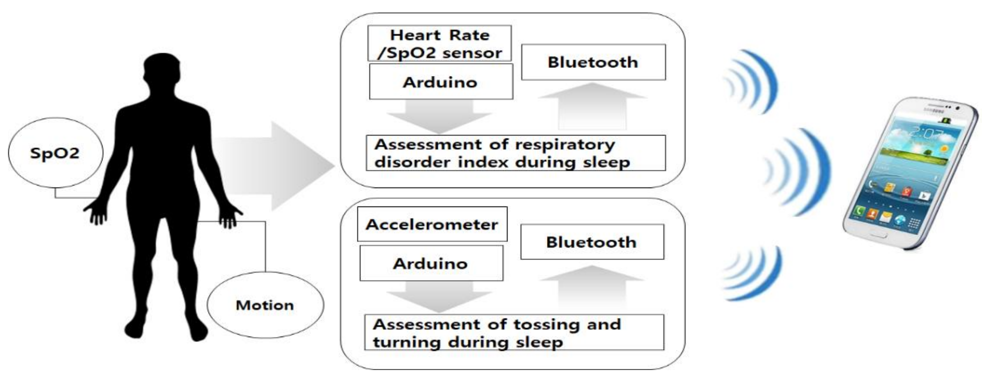

Figure 1. Schematic diagram of sleep prediction device using SpO2 sensor and acceleration sensor

3. SOFTWARE PROCESSING

The total software processing is as Figure 2.

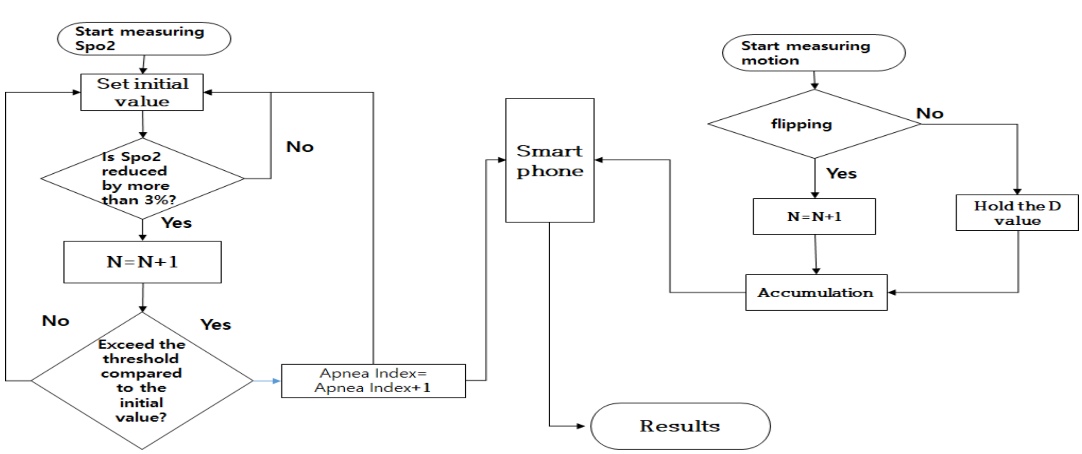

Figure 2. Software processing for apnea measurement

Apnea syndrome refers to a case of 30 or more apneas that last 10 seconds or more during long hours of sleep of 7 hours or longer. In this study, sleep apnea syndrome was determined when SpO2 decreased by 4% or more during 5 hours and 10 seconds during sleep. Also, sleep apnea is characterized by repeated apnea and low breathing. During sleep, apnea with 4% SpO2 drops by 10% and low breath with 3% SpO2 drops by 10 seconds are detected. Through this, in order to measure sleep apnea, SpO2 is measured for 10 seconds to detect whether a respiratory event (apnea, low apnea) occurs, and the apnea syndrome can be determined by adding the number of respiratory events occurring during 1 hour. The user′s SpO2 value obtained continuously through max30100 is transmitted to Arduino. Use Arduino to check if the SpO2 value is reduced by more than 3% compared to the previous SpO2 value. If not, go back to the initial value calculation process. If it is decreased, the reduced value is called Sub SpO2 value and stored. When comparing the initial value with the Sub SpO2 value stored for 10 seconds, the apnea index increases if the difference persists. Repeat this operation for one hour and store the sum of your Apnea Index. After repeating the operation continuously, when the user wakes up, the maximum value of the apnea index obtained by the hourly interval is transmitted to the smartphone application via Bluetooth communication.

The less the number of flips during sleep, the higher the sleep satisfaction. The 3-axis acceleration sensor mpu6050 sensor obtains the values of the X, Y, and Z axes that detect the movement of the patient during sleep, and uses these values to check the current patient's condition, to compare the value, and to observe the patient's backwardness. In addition, after waking up, it is set to accumulate until the end button is pressed. So that the user can check how much he has fallen during sleep.

With the same mechanism as in Figure 3, the mpu6050 is placed in the upper abdomen near the diaphragm, which is the easiest to measure. When the sleeper moves his body or changes his posture, the output value of each axis changes. Therefore, we can estimate how many times he or she tossed and turned during sleeping.

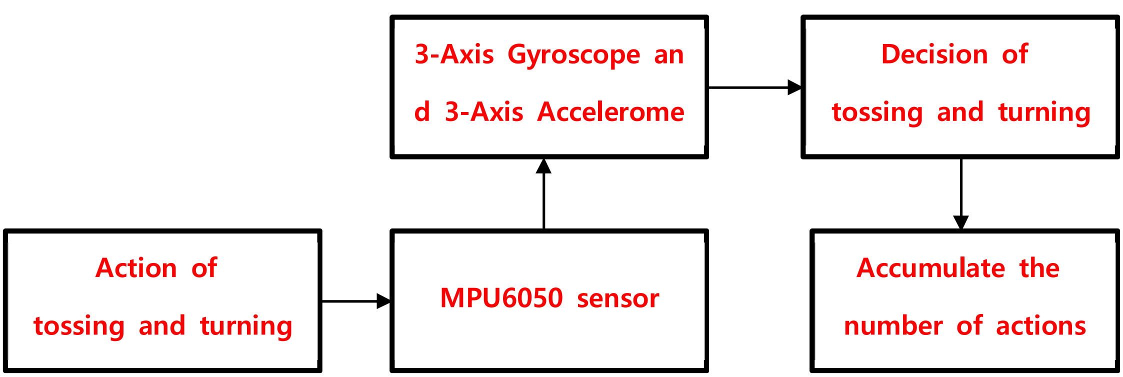

Figure 3. Flipping motion measurement process

When the pitch value (centered on the Y-axis line) was found to be sufficient to be an indicator of the tossing and turning motion, the pitch was set as the criterion when the pitch value changed to 70 or more. The initial value was set to accumulate after the start was pressed and the count was terminated when the stop was pressed. ″D″ be a random constant that will count the number of reps. When recording starts, check how much the value of Y-axis fluctuates so that the number of D does not rise unless the value changes more than 70. If the value of Y-axis fluctuates more than 70, it counts as one Tossing and turning motion and adds 1 to the existing D, and does not count backwards until the number of Y-values fluctuates more than 70. Repeat this for 10 minutes and store the D value for 10 minutes as the accumulated value obtained by repeating this operation, and then send the accumulated value to the smartphone application when the user wakes up.

4. IMPLEMENTATION

Data processing sent to smartphone is planned to be processed by applications that are easily accessible to the general public. Designed through 'App inventor', an application production site. After pressing the 'Start Recording' button, the sensor receives the value sent from the sensor through the Bluetooth function. After sending the command to complete the measurement, the sensor received the sensor to read the degree of sleep apnea and sleep retardation.

In the case of sleep apnea, the sleep apnea index was read by comparing the sum of sleep apnea index values transmitted during sleep time. The reading was divided into 'normal' if less than 5, 'hardness' if more than 5 and less than 15, 'moderate' if more than 15 and less than 30, and 'depth' if more than 30.

In case of the acceleration sensor, if the angular velocity changes more than 90 degrees within 10 seconds, the number of times is measured by tossing and turning. The cumulative number is increased after starting the measurement. In case of sleep, if the number of tossing and turning is more than 2 and less than 8, it is regarded as ′satisfactory′, and the case of normal, 8 or more is read and indicated as ′discomfort′.

In order to verify the normal operation of the fabricated sensor system and application, the PCB circuit was attached to the user's upper and upper abdomen, and the measured values of the two sensors were transmitted to the PC and the fabricated application.

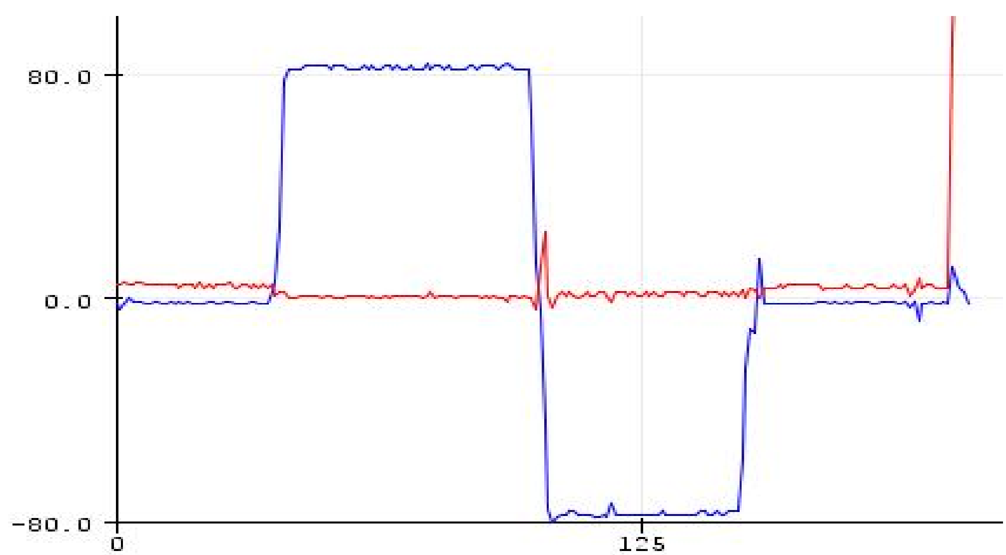

Figure 4. Result graph value after actual wearing of acceleration sensor

Figure 4 shows the graph received by the acceleration sensor after being worn by the user. The information about the user's tossing and turning measured using the acceleration sensor can be viewed in digital form indicating the tossing and turning through the Y value.

This is the result graph value transmitted from the sleep apnea measurement sensor worn by the user. Continuously measure SpO2 of user, and 3% decrease of SpO2 measured 1 second before is called SubSpO2, and if SpO2 is lower than SubSpO2 for 10 seconds, apnea count increases by 1, and 1 hour The maximum number of apneas may be updated after comparing the current number of apneas accumulated as a reference with the previous maximum cumulative number of apneas.

5. CONCLUSION

This study proposed a method to detect sleep apnea by detecting sleep apnea events and retarding sleep using SpO2 measuring sensor and 3-axis acceleration sensor. After acquiring the data from the sensor, it is transmitted to the smart phone application through Bluetooth to determine the sleep apnea and sleep satisfaction by comparing the number of apnea events and the number of reversals with preset values. In this non-constrained method, the general public can confirm that sleep apnea can be accessed and checked by mobile phone. In addition, it is necessary to reduce the noise of the sensor to reduce the performance and to reduce the battery cartridge to reduce the user's discomfort. However, it may be useful to improve the sleep quality in the future considering the difficulty of the existing sleep disorder test.

REFERENCES

[1]. T. Young, M. Palta, J. Dempsey, J. Skatrud, S. Weber, and S. Badr, “The Occurrence of Sleep-Disordered Breathing among Middle-Aged Adults,” *New England Journal of Medicine*, Vol. 328, No. 17, pp. 1230–1235, Apr. 1993. DOI: 10.1056/nejm199304293281704.

[2]. C. Guilleminault, S. J. Connolly, and R. A. Winkle, “Cardiac arrhythmia and conduction disturbances during sleep in 400 patients with sleep apnea syndrome,” *The American Journal of Cardiology*, Vol. 52, No. 5, pp. 490–494, Sep. 1983. DOI: 10.1016/0002-9149(83)90013-9.

[3]. K. M. Rex, D. F. Kripke, M. R. Klauber, and S. Ancoli-Israel, “Sleep-Disordered Breathing in Middle-Aged Adults Predicts No Significantly Higher Rates of Traffic Violations,” *Chest*, Vol. 119, No. 5, pp. 1623–1624, May 2001. DOI: 10.1378/chest.119.5.1623.

[4]. B. A. Phillips, “Prevalence of Sleep-Disordered Breathing in Middle-Aged Korean Men and Women,” *Yearbook of Pulmonary Disease*, Vol. 2006, p. 218, Jan. 2006. DOI: 10.1016/s8756-3452(08)70178B

[5]. Mostafa, Mendonça, Ravelo-García, and Morgado-Dias, “A Systematic Review of Detecting Sleep Apnea Using Deep Learning,” *Sensors*, Vol. 19, No. 22, p. 4934, Nov. 2019. DOI: 10.3390/s19224934.

[6] D.H. Kim, E. Lee, J. Kim, P. Park, and S. H. Cho, “A Sleep Apnea Monitoring IC for Respiration, Heart-Rate, SpO2 and Pulse-Transit Time Measurement Using Thermistor, PPG and Body-Channel Communication,” *IEEE Sensors Journal*, pp. 1–1, 2019. DOI:10.1109/jsen.2019.2950367.

[7] M. Deviaene, D. Testelmans, B. Buyse, P. Borzee, S. Van Huffel, and C. Varon, “Automatic Screening of Sleep Apnea Patients Based on the SpO2 Signal,” *IEEE Journal of Biomedical and Health Informatics*, Vol. 23, No. 2, pp. 607–617, Mar. 2019. DOI: 10.1109/jbhi.2018.2817368.

[8]. F. Zhai and J. Chen, “The Comparison of Polysomnography, Sleep Apnea Screening Test and Cardiopulmonary Coupling in the Diagnosis of Pediatric Obstructive Sleep Apnea Syndrome,” *Sleep Medicine*, Vol. 40, pp. e361, Dec. 2017. DOI: 10.1016/j.sleep.2017.11.1065.

[9] K. Satoh and S. Mitachi, “Screening of Sleep Apnea Syndrome During a Full Medical Checkup: A Comparison Between an Optical Fiber-Type Sleep Apnea Sensor and an Overnight Pulse Oximetry,” *Sleep Medicine*, Vol. 14, pp. e259, Dec. 2013. DOI: 10.1016/j.sleep.2013.11.631.

[10] T. Tengis, A. Batmunkh, “Quadcopter Stabilization Using State Feedback Controller by Pole Placement Method” *International Journal of Internet, Broadcasting and Communication,* Vol.9 No.1 pp.1-8, 2017

[11] M.Lim Choi , T. H. Ahn , N. C. Paik, Y. M. Kwon, M.J. Lim, D. K. Chung, “Implementation of Digital Hearing Aid Using Bluetooth Audio Digital Signal Processor”*, International Journal of Internet, Broadcasting and Communication,* Vol.9 No.2, pp.58-63 , 2017.