Restless Leg Syndrome Detection Using Kinect Sensor

Nada Nabilah Hernawati, Fiky Yosef Suratman, Achmad Rizal

Abstract: Sleep activity is a critical factor in determining the quality of human life. Sleep activity is closely related to sleep quality, which is influenced by several factors, including daily activities, physical conditions, and emotional conditions. The sleep monitoring device that is commonly used is polysomnography. This device is commonly used to monitor sleep by attaching electrodes to the patient's head. This tool's weakness is the feeling of discomfort in the patient, resulting in disruption of sleep monitoring analysis because too many devices are attached to the patient's body. Sleep Disorder is a disorder that makes it difficult for sufferers to regulate their sleep patterns. There are several characteristics for people with sleep disorders: not fresh when waking up, fast drowsiness, difficulty concentrating, fatigue, and memory that continues to decline. In this study, a sleep pattern monitoring system was built using Microsoft Kinect Sensor v.2 for Restless Leg Syndrome (RLS). This device has sensors that can capture every movement of movements produced by the human body. Among the indicators to determine sleep disorders are sleep breathing and sleep posture. The output of this sleep disturbance detection system is a change in the movement of nine joints. The system test has a duration of 120 minutes and changes in subject joint movement per 5 seconds. Sleep disorders are classified into three parts: mild, moderate, and severe, based on the PLMS index. PLMS index values were obtained based on the value of joint movement divided by total sleep time. The system designed has a relative error value of 0.39% in determining the PLMS index.

Index Terms: Polysomnography, restless leg syndrome, Microsoft Kinect Sensor v.2, Sleep Disorder

1. INTRODUCTION

Sleep activity is one crucial factor in determining the quality of human life [1]. Sleep quality is essential for human health. The latest developments in sleep monitoring techniques are to detect sleep disorders and improve sleep quality. Among the indicators for determining sleep disorders are sleep breathing and sleep posture [2]. Sleep Disorder is a disorder that makes it difficult for sufferers to regulate their sleep patterns [3]. There are several characteristics for people with sleep disorders such as not feeling fresh when waking up, fast drowsiness, difficulty concentrating, fatigue, and memory that continues to decline. Common sleep disorders include narcolepsy, hypersomnia, parasomnia, sleep paralysis, restless leg syndrome, sleep apnea, and insomnia. The sleep disturbance that will be analyzed in this final project is restless leg syndrome. Sleep Disorder Analysis is usually done by observing a patient's nighttime sleep through a polysomnography test [4]. The signals that are usually processed for sleep disorders such as polysomnography (PSG), electroencephalogram (EEG), and electrocardiogram (ECG) signals [5]. In previous studies, there were various kinds of tests and equipment such as EEG, EMG, EOG, ECG, snoring microphones, and nasal air circulation sensors that had to be attached to the user's body. Many sensors attached in the body make an increase in space or place, making the user uncomfortable to rest [6].

- *Nada Nabilah Hernawati was graduated from bachelor degree program in electrical engineering in Telkom University, Indonesia. E-mail: hernawatinadanabilah@gmail.com*
- *Fiky Yosep Suratman is currently a senior lecturer in School of Electrical Engineering, Telkom University, Indonesia. Email: fysuratman @telkomuniversity.ac.id*
- *Achmad Rizal is currently a senior lecturer in School of Electrical Engineering, Telkom University, Indonesia. E-mail: achmadrizal@telkomuniversity.ac.id (correspondence author)*

In this study, a system was developed to detect one sleep disorder called Restless Leg Syndrome (RLS) using Microsoft Kinect v.2. RLS is a neurological disorder and causes an irresistible urge to move the legs to feel an uncomfortable sensation deep within the legs [7]. Microsoft Kinect v.2 is a sensor device that consists of a 3D depth sensor camera, an RGB camera, and multiple microphones [8]. This device has sensors that can capture every movement of movements produced by the human body. The system built using the Kinect sensor does not require any sensors to be installed on the subject's body so that it does not interfere with the observation process and create a natural feeling of sleep.

2 MATERIAL AND METHOD

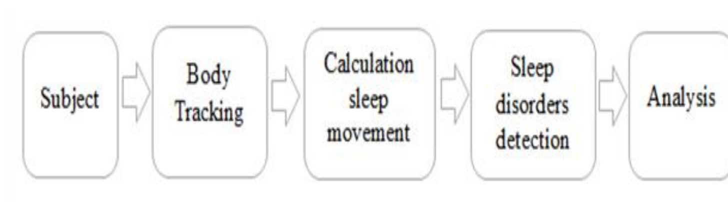

Figure 1. *Block diagram of the proposed method.*

The proposed system in this study is as in Figure 1. The system designed consists of five main parts, namely: (1) Subjects, subjects to be monitored and analyzed, (2) Body tracking, Kinect sensor get the location nine joints that will be the reference point and analyzed, (3) Calculation of sleep movement, is the calculation of sleep movement during the process, (4) Sleep Disorders Detection, sleep disturbance detection on the subject, (5) Analysis, changes in motion to determine the level of sleep disturbance. In this study, the sleep disorder detected was restless leg syndrome (RLS). RLS also is known as Willis-Ekbom disease (WEB) is a common sensorimotor disorder characterized by a desire to move and is associated with uncomfortable sensations in the legs (legs) [9] [10]. Clinically RLS is characterized by unpleasant leg sensations and often occurs during sleep onset, which triggers a strong desire to move the legs. Patients with RLS usually complain of itching, creeping, tingling in the legs, and usually between the ankles and knees. This sensation occurs when the individual is at rest and is more prominent at night. RLS prevalence based on frequency and severity ranges from 2.2% to 7.9% [11]. A detailed explanation of the process described in Figure 1 will be illustrated in the following subsection.

2.1 Data

The experiments were carried out on eight subjects aged 20-23 years, wearing blankets, dressing did not change posture, and was carried out in the same room for 135 minutes per one attempt. Out of 135 minutes of observation, 15 minutes were not taken as measured because they were assumed to be a transition to sleep. Joint movement measurements were carried out for 120 minutes. The subject was not an RLS patient but simulated the movement in RLS patients with a certain severity. This is done so that it is easy to calculate the movements manually and automatically using the system.

2.2 Hardware Configuration

Microsoft Kinect is a sensor device with a 3D depth sensor camera, an RGB camera, and multiple microphones. Kinect provides the ability to capture motion in 3D, recognize faces, and recognize sounds [12]. One component of the Kinect is the Depth Sensor, which functions as a reader and identifier of 3D objects. Kinect improves technical color camera 1920x1080 pixels, depth sensor 512x424 pixels for tracking the movement system with a speed of 30 frames per second, FOV (700H 600V), and sensor reading range 0.5 - 4.5 m. The results of reading the Kinect sensor are units in meters [13]. In our proposed sleep disorder detection system, the Kinect sensor must be perpendicular to the subject. Thus, the sensor was mounted directly above the subject with the height set based on the Kinect sensor reading of 0.5 m - 4.5 m. Configuration of the Kinect sensor placement is as shown in Figure 2.

***Figure 2**. Configuration of the hardware*

2.3 Body Tracking

The system determined the movement of the nine joints during sleep in time duration. The system used the Microsoft Kinect v.2 sensor to detect and determine the nine joints' movement. In this study, only 9 out of 20 joints were used because they caused significant RLS motion. The joint tracked is detecting hip center, hip left, hip right, knee left, knee right, ankle left, ankle right, foot left, and foot right.

2.4 Joint Movement

The value of movement during sleep was calculated using the Euclidean distance. The movement was determined by calculating the joint's previous position, and the current joint position, all movements of the joint value are calculated every 15 minutes. Joint Movement (JM) was the distance that is changed to the coordinates of nine joints. The system would automatically calculate each joint displacement to determine sleep disorder. JM is expressed by Equation (1).

$$JM = \sum_{i}^{9} \sqrt{(Xib - Xia)^2 + (Yib - Yia)^2 + (Zib - Zia)^2} \quad (1)$$

where X_{ia} is joint's previous position and X_{ib} in joint's current position.

2.5 RLS Classification

Severity measurement of RLS is called periodic limb movements in sleep (PLMS) [7]. The PLMS index is expressed by Equation (2).

$$PLMS\ index = (\sum Joint\ Movement)/(\text{total sleep time (s)}) \quad (2)$$

Classification of RLS based on PLMS as:

Mild has a PLMI index value of 5 to 25 per hour,
Medium has a PLMI index value of 25 to 50 per hour,
Severe has a PLMI index value of more than 50 per hour

3 RESULTS AND DISCUSSION

The body tracking result is shown in Figure 3, while the results of joint movement measurements on eight subjects are shown in Table 1. In accordance with the initial design, only nine joints were detected, as in Figure 3—the results of the JM measurement for 2 hours for subject 1, as shown in Figure 4.

***Figure 3**. Number of joint movement every five minutes for subject 1*

***Table 1** Experiment results for 8 subject*

No of Subject	Sex	Duration (s)	Total Joint Movement	PLMS Index
1	F	7200	1481.83	1.03
2	F	7200	3473.05	2.41
3	F	7200	1608.51	1.12
4	F	7200	933.08	0.65

5	F	7200	1921.87	1.33
6	M	7200	2002.26	1.39
7	M	7200	3333.83	2.31
8	M	7200	3554.91	2.47

Table 2 *comparison of JM measurement by system and manual*

	Automatic by system		Manual counting	
No of Subject	Total JM	PLMS Index	Total JM	PLMS Index
1	1481.83	1.03	1492.83	1.04
2	3473.05	2.41	3410.26	2.37
3	1608.51	1.12	1581.66	1.1
4	933.08	0.65	930.4	0.65
5	1921.87	1.33	1921.24	1.33
6	2002.26	1.39	2001.27	1.39
7	3333.83	2.31	33.49.05	2.33
8	3554.91	2.47	3590.53	2.49

Table 1 displays the results of JM measurements for 8 subjects and PLMS index calculations. In accordance with the calculation in Equation (2), the PLMS index produced is relatively low or under mild criteria. To see the performance of the system being built, the measurement results are automatically compared with the measurement manually. A comparison of automatic JM calculations and manual JM measurements are shown in Table 2. From Table 2 the system performance can be calculated as in Equation (3).

$$\text{Relative error (\%)} = \sum_{i=1}^{i} \frac{|\Delta x_i|}{x_i} \text{ x } 100\% \qquad (3)$$

with :
Δx_i = PLMS index manual – PLMS system
x_i = PLMS manual

From the calculations, a relative error of 0.39% can be generated. This shows that the system built can calculate the JM well; a low error value indicates this result. From this study, the system designed has advantages in terms of monitoring carried out without requiring a device mounted on the subject's body [6]. In addition, monitoring can be done over a long period or monitoring. The measurement results are always the same for different measurement times. Meanwhile, the weakness of the system being built is due to the absence of other sensors; it cannot be precisely determined when the subject enters the sleep phase. Using blankets or clothing with a matching color with the mattress will cause potential errors in joint detection. Because using the camera, if the subject exits the frame, the movement will not be detected. Performance measurements of new devices are compared with measurements of the number of movements manually. To overcome this weakness, calibration with standard equipment needs to be done at the next research stage.

4 CONCLUSION

In this study, an RLS detection system was designed using a Kinect sensor. The Kinect Sensor detects the amount of movement during sleep for a certain amount of time. From the number of movements, parameters are stated by PLS. From the need to calculate PLMS, only nine joints are used in the Kinect sensor results. From measuring the number of movements automatically and calculating the movements manually, it produces a relative error of 0.39%. The proposed method has its main advantages in the cheapness of the devices used and the flexibility in using the tools. Because in this study, the subjects were not RLS sufferers, the PLMS index produced tended to be low compared to RLS sufferers. Calibration using standard tools for measuring RLS levels becomes an exciting research topic at the opportunity ahead.

REFERENCES

[1] J. Lee, M. Hong, and S. Ryu, "Sleep Monitoring System Using Kinect Sensor," Int. J. Distrib. Sens. Networks, vol. 2015, pp. 1–9, 2015.
[2] A. Tolaymat and Z. Liu, "Sleep Disorders in Childhood Neurological Diseases," Children, vol. 4, no. 84, pp. 1–11, 2017.
[3] F. Deng et al., "Design and implementation of a noncontact sleep monitoring system using infrared cameras and motion sensor," IEEE Trans. Instrum. Meas., 2018.
[4] B. Jafari and V. Mohsenin, "Polysomnography," in Encyclopedia of Sleep, 2013.
[5] A. A. Khatami, M. A. C. Sebayang, A. Rizal, and D. T. Barus, "Obstructive Sleep Apnea Detection using ECG Signal: A Survey," Technol. Reports Kansai Univ., vol. 62, no. 04, pp. 1267–1274, 2020.
[6] N. Febriana, A. Rizal, and E. Susanto, "Sleep monitoring system based on body posture movement using Microsoft Kinect sensor," in 3rd Biomedical Engineering's Recent Progress in Biomaterials, Drugs Development, and Medical Devices, 2019, vol. 020012, no. April, p. 020012.
[7] A. Roebuck et al., "A review of signals used in sleep analysis," Physiol. Meas., vol. 35, no. 1, pp. R1–R57, Jan. 2014.
[8] Z. Zhang, "Microsoft kinect sensor and its effect," IEEE Multimedia. 2012.
[9] C. L. Comella, "Treatment of Restless Legs Syndrome," Neurotherapeutics. 2014.
[10] L. Klingelhoefer, K. Bhattacharya, and H. Reichmann, "Restless legs syndrome," Clin. Med. J. R. Coll. Physicians London, 2016.
[11] M. M. Ohayon, R. O. Hara, and M. V Vitiello, "Epidemiology of restless legs syndrome : A synthesis of the literature," Sleep Med. Rev., vol. 16, no. 4, pp. 283–295, 2012.
[12] D. B. Guerrero and L. B. Villaluenga, “Microsoft Kinect,” in Universidad Politécnica de Catalunya, 2013, pp. 1–15.
[13] L. Costa, P. Trigueiros, and A. Cunha, "Automatic Meal Intake Monitoring Using Hidden Markov Models," Procedia Comput. Sci., vol. 100, pp. 110–117, 2016.
[14] A. Culebras, "Sleep Disorder and Neurologic Disease," in Sleep disorder and neurologic disease, M. Dekker, Ed. New York: Basel, 2007, pp. 173-203.