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A Proposal for Sleep Disorder Detection System using Deep Learning

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ABSTRACT:*The purpose of this study was to develop a sleep disorder detection system using deep learning. A pressure distribution sensor was used to collect sleep data from all examinees. We can know the movement of sleep from body pressure that happens on the sensor. We did not use the measurement that have to attach to the examinee's body. Thus, they might not feel any strange or uncomfortable. Previous study, we analyzed data using support vector machine (SVM) and the identification ratio was 77.78%. In this study, for more accuracy rate, we used neural network model to classify images of sleeping. Moreover, study participants, sampling rate and study environment is same as previous study. We used deep learning by images processing. Each of image was the average for the pressure on the sensor in 3 hours (superimposed image). We color the average of pressure using 100 level color with 10 tone of color. The identification ratio of this study was 94.44%. The identification ratio has increased from previous study.*
KEYWORDS:*Athens insomnia scale, Deep learning, Detection system, Sleep disorder, Image classifying, Pressure distribution sensor,LeNet model.*

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I. INTRODUCTION

Sleep disorder is a condition of bad sleep that impact our ability to get enough sleeping. Sleep does not depend on the number of hours of sleep. One importance thing is the depth of sleep. Even when sleeping for a sufficient period but sleep fitfully throughout the night, they might feel as fresh as it should be. In general, the appropriate of sleeping also different with the age group. Children also need more sleep time than adults. If people do not sleep enough, they will not feel refreshed during the unrested sleep. The brain may not be fully functional. Moreover, it is hard to remember and learned.

There are many kinds of sleep disorder symptoms. Insomnia is a common sleep disorder problem in all ages group. Insomnia can be cause by many reasons such as; worry before going to bed, insufficient sleep syndrome, medical problems, idiopathic insomnia etc.

Central origin of hypersomnolence (Hypersomnia) is who getting too much sleep. This syndrome caused by neurological disorders. They might have abnormal daytime sleepiness.

Circadian rhythm sleep disorder (CRSD) is a condition of not enough sleep affecting the timing of sleep. There are many kind of CRSD; Advanced phrase sleep disorder (early falling asleep time), Delayed phrase sleep disorder (stay up late-wake up late), Irregular sleep-wake rhythm (do not follow the normal of sleep time at night), Non 24 hours sleep-wake disorder (free running) and Jet-lag disorder.

Parasomnia is a symptom about abnormal movements, behavior, emotions or dream while they are falling asleep or sleeping. Night terror, Sleep walking, Sleep drinking, Sleep talking are symptom in the group of Parasomnia.

Moreover, there are many other diseases associated with sleep disorder problem such as; sleep related breathing disorder and sleep related movement disorder etc.

There are less study or research about sleep disorder detection system[1][2]. Some research used a measurement which attach to examinee's body. Our study did not use any measurement which attach to the body so all of them might not feel any strange or uncomfortable. We think sleep disorder is an important to life. If who get sleep disorder and is not treated, it would be a major health problem in the future. We expect this system would solved this problem.

II. PRELIMINARY

According to previous study[3-8], has been proposed for develop a sleep disorder detection system for solitary person to identify who is a sleep disorder person or who is not. We used 7 value to analysis data. There are average (mmHg), variance (mmHg2), coefficient of variation (%), horizontal center (cm), vertical center (cm), movement distance of center of pressure (cm) and movement angle of center of pressure (degree).

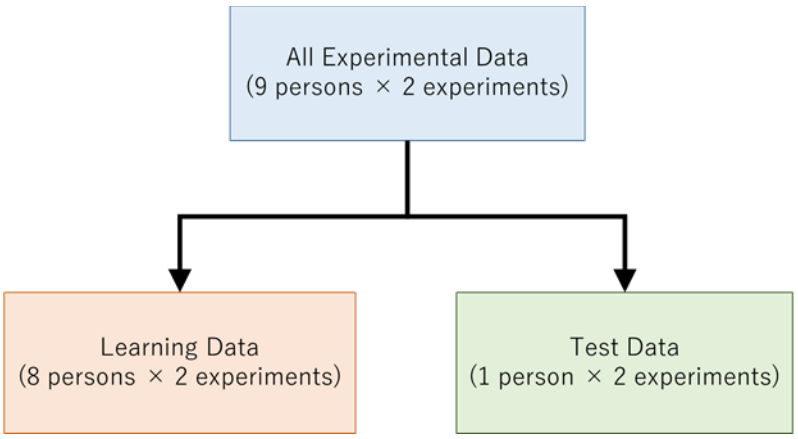

Figure 1: Chart of learning data sets and test data sets

Table 1: Result of previous study

	Below 6	Above 6
Below 6	4	0
Above 6	4	10

To analyze sleep data, Figure1 show how we used machine learning to define test data and learning data set. All experimental data was 18 data sets (9 persons *2 experiments). Then, the data were divided into 16 learning data sets (8 persons *2 experiments) and 2 test data set (1 person *2 experiments). This experiment was a perfectly unknown data set. In Table 1, "Below 6" means healthy person, "Above 6" means sleep disorder person. The number means score of Athens insomnia scale. The details of Athens insomnia scale is explained in next section.

The result of this experiment using Support Vector Machine (SVM) with polynomial kernel was 2 persons is healthy person and 5 persons with sleep disorder as shown in Table 1. The identification ratio was 77.78%

III. MATERIAL AND METHODS

3.1 Athens insomnia scale (AIS)

Athens insomnia scale[9][10] is a basic questionnaire about quality of sleep to measure about insomnia. The AIS is an assessment of how difficult of sleep that has occurred in one month during answer this questionnaire. There are 8 question in the scale. Maximum score is 24 points (1 question with 4 answers). In this study, a person who gets score less than 6 points will be considered as a healthy person. On the other hands, a person who gets score equal to or greater than 6 point will be diagnose as insomniacs.

3.2 Study participants

This study was conducted with solitary person who live alone in dormitory. They are university student. Table 2 shows, study participants are 20 to 27 years old. They have never known that they have sleep disorder problem or not. All of participants said using this sensor, they not feel any strange or uncomfortable with this experiment.

Table 2:Information on the participants

Participant no.	Sex
1	F
2	F
3	M
4	M
5	M
6	M
7	M
8	F
9	M

3.3 Fabric-sheet pressure distribution sensor

Sleep data is collected by fabric-sheet pressure distribution sensor[11]. While sleeping there are many body pressure on the sensor. We can see the sleeping posture, moving of body while sleeping from these pressure. Table 3 shows specification of the sensor. From Figure 2, there are 1,728 sensing point in the sensor sheet. 27 sensing points in width direction (coordinate number A1, B1…, Z1 to a1) and 64 sensing points in the length direction (coordinate number A1, A2…, A63 to A64). This fabric-sheet pressure distribution sensor is match with single bed size. Figure 3 shows example of sleep data collected from the sensor. The color of each points are depend on the pressure pressed in that sensor. A strongly pressure is red and weakly pressure is white as shown is Figure 4.

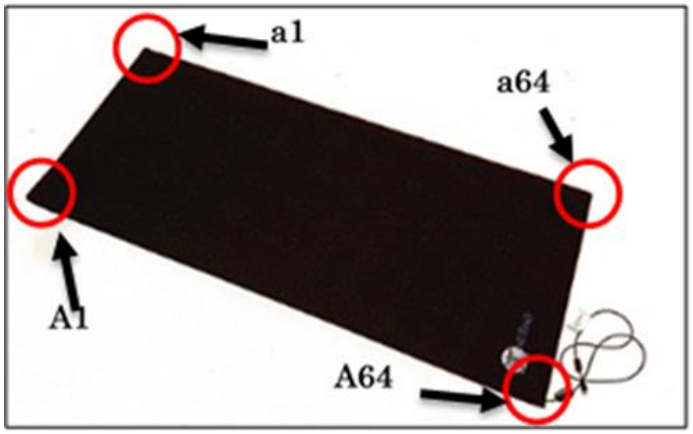

Figure 2: Fabric sheet pressure distribution sensor

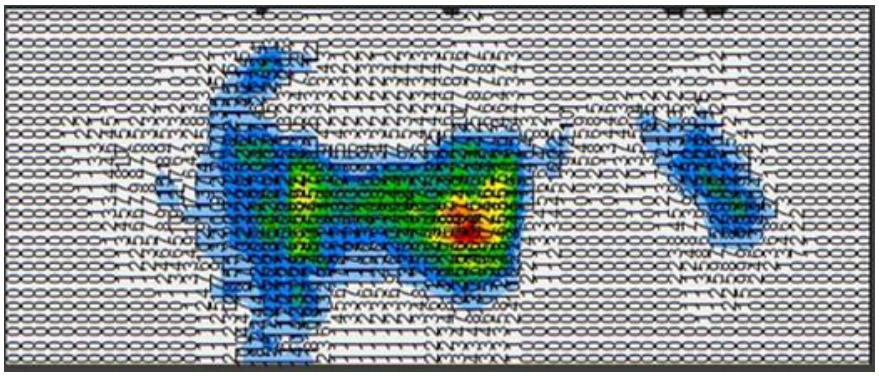

Figure 3: Example of sleep data collected from sensor

Figure 4: Level of color of pressure

Table 3: Specification of the sensor

Sensor size (mm)	2032 * 863
Sensing area (mm)	1854 * 762
Number of sensing point	64 * 27 = 1,728
Sensing point size (mm)	25.4 * 25.4
Sensor pitch (mm)	3.6 * 2.93
Maximum sensing period (Hz)	50
Thickness (mm)	2.5

3.4Deep learning

Deep learning[12] is a branch of machine learning that mimics the neural networks of the human brain. Therefore, its abilities in the future it may be above human because machine learning can add unlimited processing power. Deep learning can have many hidden layers. Thus, deep learning can calculate a lot of complex data. The most important thing is deep learning can be thoughtfully step-by-step.

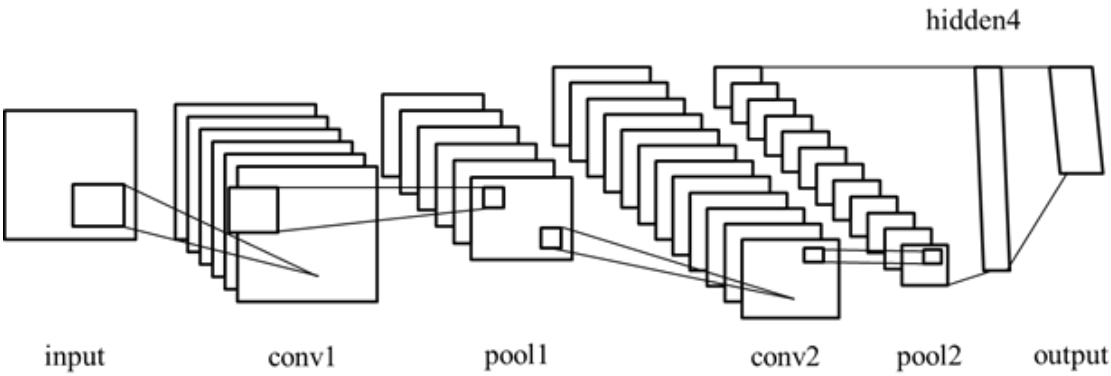

Figure 5: An architecture of LeNet model

In this study, data processed using LeNet model. LeNet model is one of the first neural networks of deep learning. In image classifying, they usually use LeNet model to distinguish data of images. LeNet is small and easy to understand. Architecture of LeNet model as shown in Figure 5. The LeNet architecture consists of two sets of convolutional, activation, and pooling layers, followed by a fully-connected layer, activation, another fully-connected, and finally a softmaxclassifier[11].

IV. EXPERIMENT

4.1 Experiment environment

Figure 6 shows how all of equipment was set for running the experiment. The sensor is put on the bed mattress. Then bed sheet is put on the sensor. There was nothing abnormal from the ordinary bed after set bed cover. In this experiment, Figure 7 shows the environment was held at each person's bedroom to avoid strange feelings or any uncomfortable things.

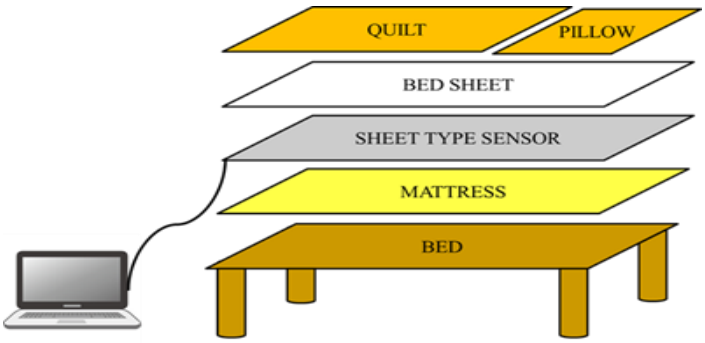

Figure 6: Installation of experimental equipment

Figure 7: Experiment environment

4.2 Athens insomnia questionnaire

Table 4 shows information on the AIS questionnaire. From the rule of this study, a person who got score below 6 is healthy person and a person who got score over 6 is diagnosed as insomniac. Thus, there are 5 person was insomniacs and 4 person was healthy person in this study.

Table 4: Result of Athens insomnia scale

Participant no.	Age	Sex	AIS	O/B*
1	24	F	7	O
2	25	F	10	O
3	26	M	9	O
4	21	M	5	B
5	24	M	2	B
6	26	M	4	B
7	25	M	6	O
8	24	F	10	O
9	27	M	3	B

4.3 Sleep data

We created superimposed image from sleep data. Figure 8 shows architecture of superimposed image. From sleep data, there are numerical value of the pressure that pressed on all sensing point every 1 second. We calculated the average of pressure on each sensing point for each image. In this study, each image of superimposed image was 3 hours (10,800s,) of sleep data. Then, color the superimposed image using 10 of levels color. There are white-grey, blue, green, yellow, orange, pink, red, purple, brown and black. Moreover, there are 10 levels color in each level. Thus, we have 100 colors in this experiment. Figure 9 shows a superimposed image with 100 colors. We think if there are lot of level color, the system will be able to distinguish images well. Besides, this is the first color separation in this study. Thus, we think 100 levels color are sufficiently.

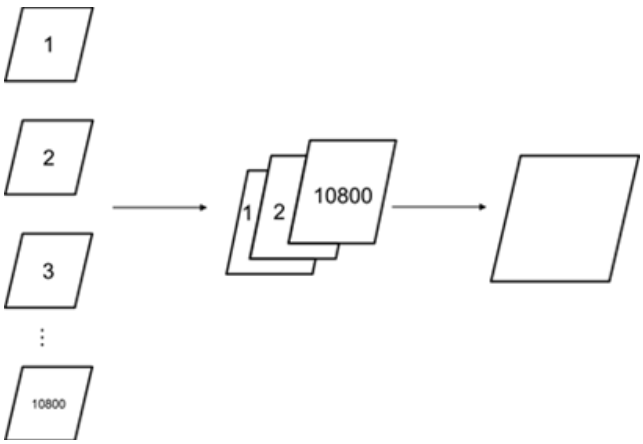

Figure 8: Architecture of superimposed image

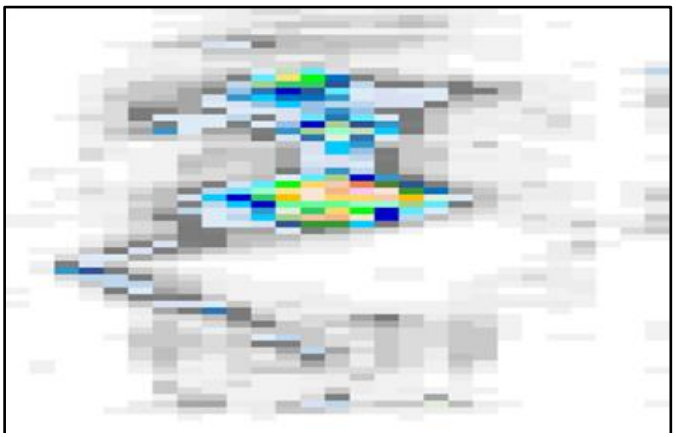

Figure 9: Example of superimposed image

4.4 Identification method

In this study, we used machine learning to test data and learning data. Form Figure 10, there are 36 superimposed images in learning data (1 experiment with 2 superimposed images) and 18 superimposed images (1 experiment with 1 superimposed image) for test data. In learning data part, we divided data into 2 groups. There are sleep disorder group and healthy group. Data was trained using LeNet model.

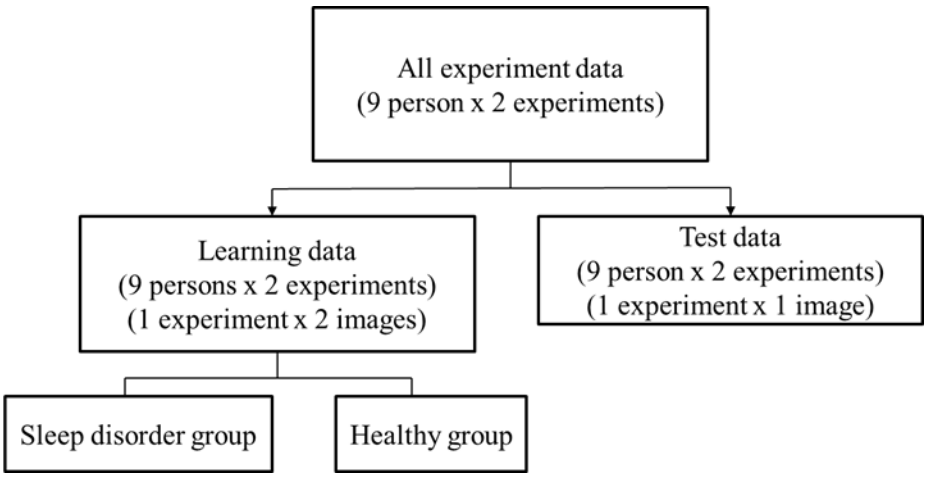

Figure 10: Chart of learning data set and test data sets for deep learning

V. RESULT

Figure 11 shows the loss of train model, accuracy value and loss value. Left hand of vertical axis is loss and right hand of vertical axis is accuracy. While horizontal axis is round of epoch. There are 3 lines in the graph. Blue line is loss of train model. Orange line is accuracy of validation. Green line is loss of validation. After 30 rounds of train program, a graph of accuracy has increased. On the other hand, both of loss graph has decreased. Table 5 shows result of test program in confusion matrix. There are 18 data sets in test data. The program produced 9 data is sleep disorder person and 8 data is healthy person. The accuracy per class sleep disorder was 90% and 100% for class healthy. The identification ratio of this study was 94.44%

Table 5: Result of test program

	Sleep disorder	**Healthy**	**Per class accuracy**
Sleep disorder	9	1	90.00%
Healthy	0	8	100.00%

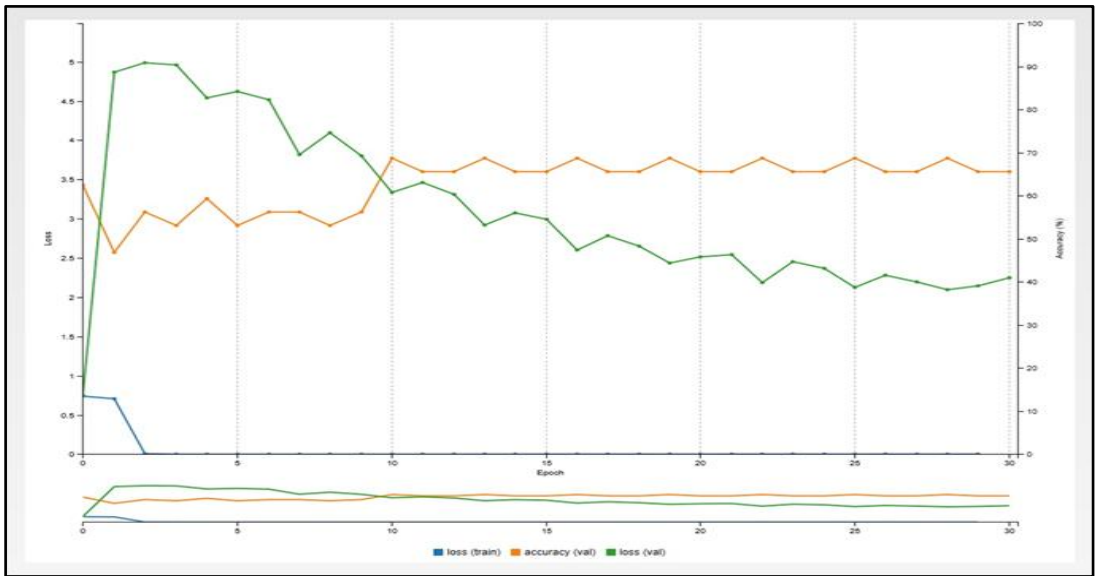

Figure 11: Graph of train model

VI. CONCLUSIONS AND FUTURE WORK

We are developing a sleep disorder detection system. In this study, we use machine learning (deep learning) for more accuracy rate of the program. All of data trained by LeNet model. The identification ratio of this study is 94.44%. This experiment is better than previous study. We accept the result of this experiment to a certain extent because when we compare with the previous study[8], the identification ratio has increased. Although, the number of learning data and test data in this experiment is still small. If we can increase the number of subject or other age group, we think the system will be able to learn and distinguish better.

In the future work, we would like to merge sleep disorder detection system and other system together to be the one of guidelines for solving sleep disorder problem. We realize if we can detect abnormalities, everyone will have better health.

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