Monitoring Sleep Posture based on Temperature and Humidity Sensor

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Abstract— **In this paper, we proposed a method of attaching seven temperature and humidity sensors to a pillow and monitoring changes in temperature and humidity to determine sleeping posture. The existing method of determining sleep position is to monitor changes in pressure using FSR sensors mounted inside a pillow. Changes in pressure are limited to simply identifying changes in head movement, but changes in temperature and humidity have the advantage of being able to identify physical changes in the subject. For machine learning modeling, the temperature and humidity dataset accumulated during sleep was subjected to a data labeling process through discrimination of sleep posture images. With the CNN-based modeling the accuracy of discriminating sleep posture reached about 95%. This confirms that temperature and humidity sensor-based sleeping posture monitoring is sufficiently applicable.**

***Keywords*— sleep posture, temperature and humidity sensor, CNN, data labeling**

I. Introduction

In recent years, research in the field of sleep research and monitoring has been actively progressing due to technological advancements. As people became more interested in their health due to the COVID-19 pandemic, it was also necessary to analyze the effects of comfortable sleep on health. As we navigate these uncertain times, understanding how external factors impact sleep patterns has become more important than ever[1]. In this context, this study attempted to design and implement a machine learning-based sleep posture monitoring system (Fig. 1) using temperature and humidity sensors to determine the relationship between sleep quality and duration. We built a sleeping posture monitoring system to determine sleeping posture status through machine learning using the data collected by the temperature and humidity sensor, and analyzed the sleeping posture through the temperature and humidity sensor in a non-constrained and unconscious state to determine the sleeping posture of upright posture, left posture, and right posture. (Fig. 2) A machine learning-based sleep monitoring system was built to determine

In this paper, image recognition-based deep learning is applied to collect data at 10-second intervals through a temperature and humidity sensor, visualized, preprocessed the corresponding graph through a data labeling process, and then performed image classification to determine whether sleeping posture can be determined. I wanted to do it.

This paper is structured as follows. The main body of Chapter 2 explained the necessity and purpose of this study and data labeling. Chapter 3 explained CNN. In Chapter 4, the conclusion explains the results derived from image classification using CNN.

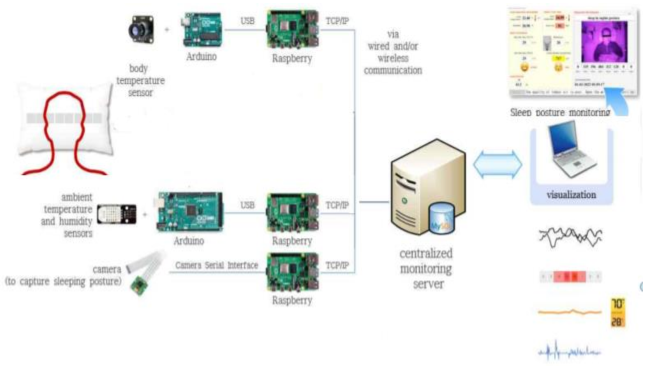


Fig. 1. Monitoring system

Fig. 2. Three sleeping positions (upright, left, right)

II. Related Works.

This study began with the recognition that sleep is a fundamental aspect of human health and well-being, and that getting a good night's sleep is not only essential for cognitive function, but also plays a pivotal role in maintaining overall physical health. was analyzed. Several previous studies have proven that lack of sleep can lead to problems such as poor concentration, decreased exercise capacity, and increased risk of obesity. Conversely, excessive sleep can have negative effects of its own. Therefore, understanding and optimizing your sleep posture patterns is of utmost importance if you want to pursue a healthier and more productive lifestyle.

Accordingly, this study provided a new approach to sleep posture monitoring using a temperature and humidity sensor to analyze and determine sleep posture patterns[2]. The temperature and humidity sensor measured data about the sleeping environment in 10-second increments, labeled them, and identified three sleeping positions through machine learning. Complex patterns within the data were identified through data-based machine learning algorithms.

All measurements were limited to non-binding and non-self-aware methods, and data were collected by embedding seven temperature and humidity sensors (Fig. 3) in a memory foam pillow as shown in Fig. 4, and predicted data through machine learning. An infrared camera was installed as an auxiliary device to verify the accuracy of the sleeping position results. However, the images captured by the infrared camera were used only for verification of the sleeping position prediction results (Fig. 5).

Fig. 3. DHT22 (temperature and humidity sensor)

Fig. 4. Pillow with temperature and humidity sensor

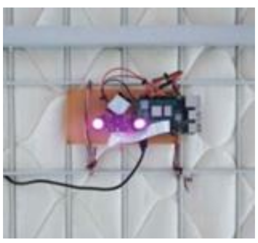


Fig. 5. Posture verification assistance device (infrared camera module)

We developed a smart pillow based on seven temperature and humidity sensors, which are key elements of the monitoring system, and implemented a sleep monitoring system to analyze sleep patterns by temperature and humidity and evaluate whether or not you sleep well[3].

In conclusion, this study presents the results of a measurement analysis of a journey that leverages the power of machine learning and sensor technology to revolutionize our understanding of sleep and provide practical solutions for achieving better sleep[4]. To ensure that the monitoring system presented in this paper can contribute to improving the sleep quality and well-being of individuals across a variety of backgrounds and situations, we plan to develop a sleep pillow that can be commercialized through further research based on this design implementation[5].

The purpose of this paper is to collect sleep-related temperature and humidity data to determine the correlation between the user's sleeping posture pattern and temperature and humidity elements, and to analyze it through machine learning as a method to determine sleeping posture, to develop a smart pillow that can determine sleeping posture. Implementing the system.

In this study, a sleeping posture pattern monitoring system was established by focusing on temperature and humidity sensors, and a system was built to measure temperature and humidity data to check sleeping posture. To establish and maintain the experimental environment, experiments were conducted in the mobile computing laboratory of the Department of Computer Science and Engineering at Incheon National University.

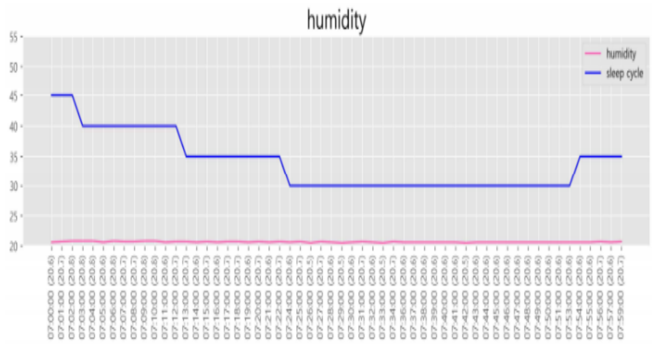
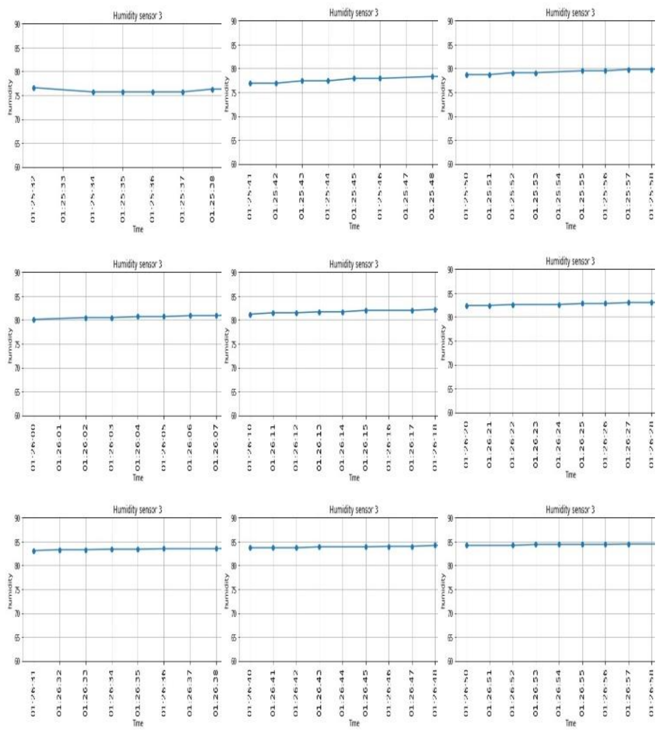
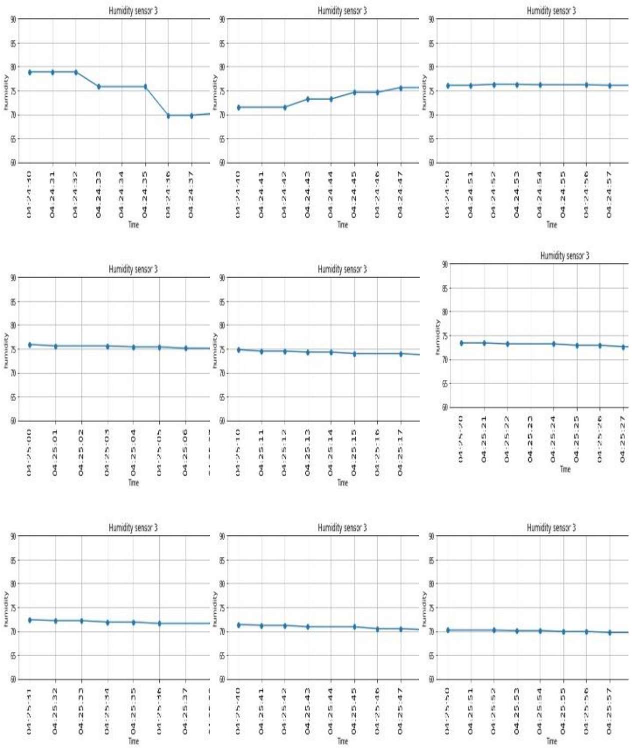


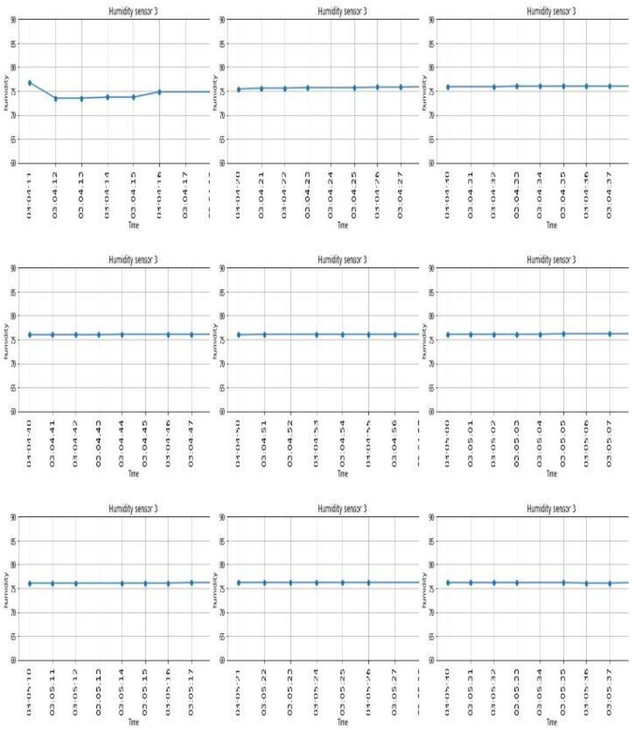
Fig. 6. humidity raw data and sleep cycle



(a)



(b)



(c)

Fig. 7. Sleep Posture Labeling (a): Upright posture labeling, (b): Left posture labeling, (c): Right posture labeling

The subject's head was used to determine sleeping position by analyzing the distribution of temperature and humidity data collected from the smart pillow[6]. The dataset used to analyze sleeping posture consists of 2,565 pieces of data. Afterwards, image classification was performed using CNN to determine the subject's sleeping position. The smart pillow's temperature and humidity data is collected every 10 seconds. Sleeping position is determined using temperature and humidity data accumulated every hour. The sleep position determination cycle is variable, and among the seven temperature and humidity sensors, the data from the third sensor, which showed the largest change in raw data value depending on sleeping position, was used as the center for classification[7].

III. How The Study Was Implemented

The CNN[8] algorithm has been mainly used in the image and video fields, but has recently been widely applied in natural language processing, and the schematic diagram of the CNN algorithm used in this paper is shown in Fig. 8.

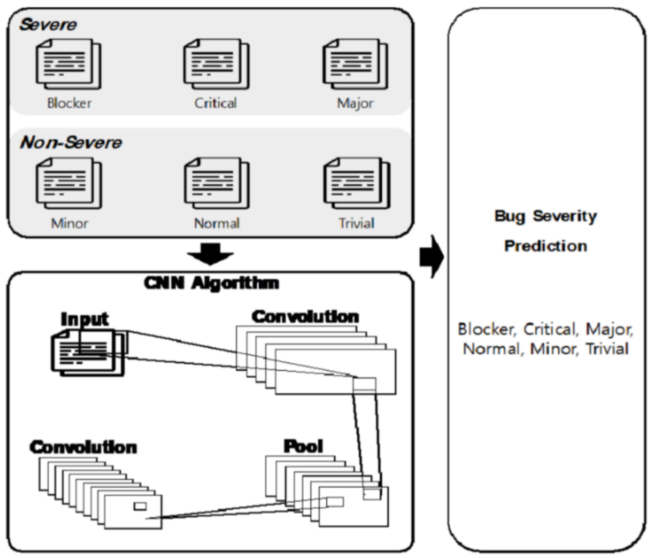


Fig. 8. Schematic diagram of CNN algorithm

The key element of the CNN algorithm is the pooling layer applied after the convolutional layer. The pooling layer subsamples the input value. This is a method of performing pooling to take the maximum value for the results of each filter. The convolution layer is the core layer of CNN and derives classification and necessary feature information. Additionally, when used with other words, it creates a structure that allows the word to be understood. CNN can easily extract local features using this structure. In CNN, the vanishing gradient phenomenon occurs in which the error value decreases significantly as more hidden layers are passed. To solve this, we used a sigmoid gradient loss problem using the ReLU function. In this paper, the following results were derived through CNN learning.

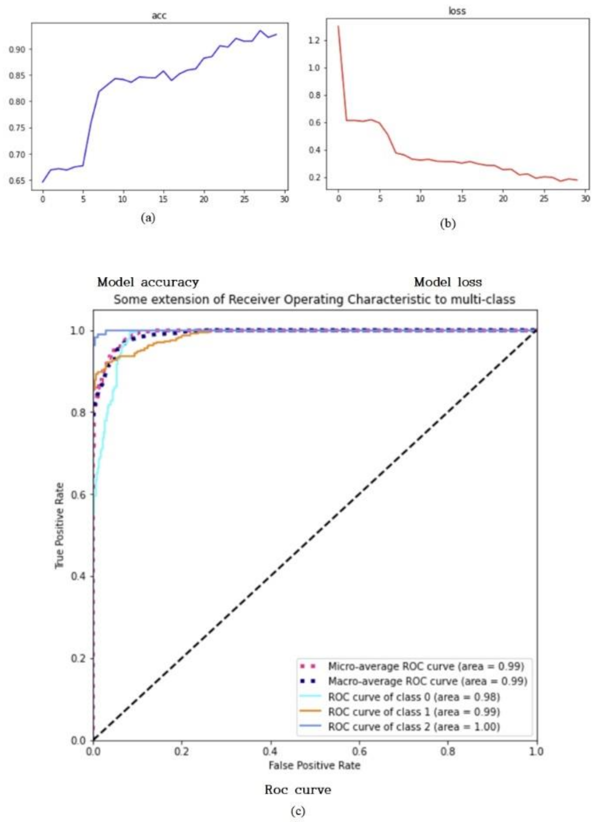


Fig. 9. CNN Results (a): Accuracy graph, (b): loss graph, (c): Roc graph

As a result of the learning, it can be seen that the training loss is decreasing and the accuracy exceeds 95%, indicating that the discrimination is working well.

IV. Conclusions

If lack of sleep, insomnia, or poor sleep quality becomes chronic, it can cause health problems such as various cardiopulmonary diseases, uncontrolled high blood pressure or diabetes, and cardiovascular diseases known as vascular complications. Furthermore, poor memory and lack of sleep in some people can be risk factors for dementia. In addition, polysomnography conducted in hospitals involves wearing sensors and a belt on the nose, chest, and abdomen to measure brain waves and breathing levels to measure sleep stages, eye movements, limb movements, jaw muscle tension, and electrocardiogram electrodes on the chest. Although it is possible to identify exact sleep disorders by conducting a sleep test in a restrictive manner, such as attaching a Three types of prediction were classified: upright posture, left posture, and right posture. We collected a variety of data centered on temperature and humidity sensors, and used machine learning and data analysis technology to derive meaningful results. The derived data was classified and the secondary measurement results were verified using an infrared sensor based on the data measured from the temperature and humidity sensor through machine learning. In this paper, data is collected using a temperature and humidity sensor to determine sleeping posture and the correct posture. A CNN algorithm was used to analyze left and right posture discrimination. The CNN[9] model was trained and showed an accuracy exceeding 95%. Existing research has shown that sleep posture can be determined using multiple sensors. It is expected that it will be possible to distinguish and define the interaction between sleep measured by the temperature and humidity sensor and the sleep environment, and to suggest individual measures to improve sleep quality and sleep position education for personal prescription.

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