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Electoencephalography-based Fatigue Assessment for Internet of Medical Things System

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Abstract

This paper presents an electroencephalography (EEG)-based fatigue assessment, abbreviated EFA, for the Internet of Medical Things (IoMT) System. The EFA is designed to classify personal fatigue into four levels by analyzing the EEG data collected from a wearable device equipped with EEG sensors. To this end, the IoMT server analyzes the variation patterns of the EEG data periodically received from the wearable device. Specifically, it estimates the number of eye blinks per minute by counting the number of EEG data whose value is greater than a specific threshold for a certain duration. Then, the IoMT server determines the fatigue levels according to the estimated number of eye blinks. To verify the EFA feasibility, we conducted an experimental implementation using Revolution Board Kit BT Model and Raspberry Pi 4 Model B. The results showed that EFA is one of the practical IoMT applications to assess personal fatigue using EEG with a simple operational procedure.

***Keywords*:** Data analysis, electroencephalography, fatigue assessment, IoMT, wearable device

1. Introduction

Recently, a variety of industries have been interested in the Internet of Medical Things (IoMT) system to efficiently reduce industrial accidents caused by poor physical and mental conditions of workers [1]. In particular, fatigue assessment using electroencephalogram (EEG) has been considered one of the promising IoMT applications. This is because the IoMT system can address the drawback of conventional EEG-based fatigue assessments such as complex operational procedures and expensive machinery. Specifically, the IoMT system can support a simple operating procedure for EEG-based fatigue assessment using wearable devices equipped with biomedical sensors and analysis servers.

In this paper, we focus on the development of an EEG-based fatigue assessment (EFA) for the IoMT system. In order to assess fatigue, EFA analyzes EEG data received from the wearable device to estimate the number of eye blinks per unit of time. To this end, it counts the number of EEG data samples whose value is greater than the threshold for a certain duration. Then, the EFA classifies fatigue into four levels considering the estimated number of eye blinks. To evaluate the EFA feasibility, we conducted implementation using open-source hardware Revolution Board Kit BT Model and Raspberry Pi 4 Model B. The results showed that EFA is a

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practical IoMT application supporting a simple operation.

2. EEG-based Fatigue Assessment

The wearable device periodically generates and transmits the EEG data to the analysis server. The analysis server creates EEG dataset ($\mathbf{X}$) expressed by Eq. (1) every minute.

$$\mathbf{X} = \{x_1, x_2, x_3, .., x_n\} \quad (1)$$

where x_n is the *n*-th EEG data and the unit of each EEG data is expressed in voltage. The number of elements in $\mathbf{X}$ (i.e., *n*) is equal to the number of transmissions per minute.

After creating an EEG dataset, the analysis server conducts EFA consisting of the eye blink estimation and the fatigue level classification. Algorithm 1 shows the procedure of the eye blink estimation in which the number of eye blinks per minute is counted. In the algorithm, *T* is the predefined threshold, *k* is the size of the sliding window, and *cnt* is the estimated number of eye blinks per minute. As shown in Algorithm 1, the estimated number of eye blinks increases by one when the mean of *k* elements is greater than the threshold.

Algorithm 1. Eye blink estimation

```
INITIALIZE i to 1, cnt to 0
WHILE k(i+1) < n
    IF avg(X[ik : k(i+1)−1]) > T
        cnt ← cnt ++
    ELSE
        cnt ← cnt
    ENDIF
        i ← i ++
ENDWHILE
RETURN cnt
```

where $avg(\cdot)$ is the average function. *k* is determined by $\lceil n/120 \rceil$.

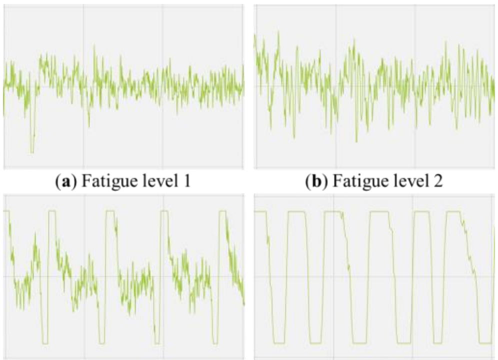
Table 1. Fatigue level calssification rule

Fatigue level	Classification rule
No fatigue [1]	cnt < 20
Low fatigue [2]	$20 \leq$ cnt < 40
Moderate fatigue [3]	$40 \leq$ cnt < 60
High fatigue [4]	$60 \leq$ cnt < 80

Then, the analysis server conducts the fatigue level classification. Specifically, to classify the fatigue level according to the estimated number of eye blinks, it refers to the fatigue level classification rule in **Table 1**.

3. Implementation Results

The wearable device and data receiver were implemented using the Revolution Board Kit BT Model and Raspberry Pi 4 Model B, respectively. In addition, the EFA was implemented using Java and it is executed on the analysis server. The threshold was set to 700 mV, and the EEG data generation period was set to 100 ms. **Fig. 1** shows changes in EEG data for each fatigue level. As shown in the figure, the average value of the EEG data increases as the fatigue level increases.



(**a**) Fatigue level 1 (**b**) Fatigue level 2 (**c**) Fatigue level 3 (**d**) Fatigue level 4

Fig. 1. EEG data for each fatigue level

4. Conclusions

In this paper, we propose an EFA for the IoMT system that consists of two steps: 1) eye blink estimation and 2) fatigue level classification. To verify the feasibility of EFA, the experimental implementation was conducted using open-source hardware. The results showed that EFA has a simple operational procedure and is feasible for a real environment.

References

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