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Normalization Framework of BCI-based Facial Interface

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Abstract

Recently brainwaves are utilized diversely in the field of medicine, entertainment, education and so on. In the case of medicine, brainwaves are analyzed to estimate patients' diseases. However, the applications for entertainments usually utilize brainwaves as control signal without figuring out the characters of the brainwaves. Given that users' brainwaves are different each other, a normalization method is essential. The traditional brainwave normalization approaches utilize normal distribution. However, those approaches assume that brainwaves are collected enough to conduct normal distribution. When the few amounts of brainwaves are measured, the accuracy of the control signal based on the measured brainwaves becomes low. In this paper, we propose a normalization framework of BCI-based facial interfaces for novel volume controllers, which can normalizes the few amounts of brainwaves and then generates the control signals of BCI-based facial interfaces. In the experiments, two subjects were involved to validate the proposed framework and then the normalization processes were introduced.

Key Words: Brain-computer interface, Human-computer interaction, Signal processing, Normalization, Brainwaves.

I. INTRODUCTION

At the beginning, brain-computer interface (BCI) was usually utilized for medical assistant devices. Then the application to control a wheel chair is developed for disable people [2]. The brainwaves are controlled by the intention of a user and then the wheel chair is controlled depending on the controlled brainwaves. However, as low price-based BCI devices [3-4] are released, the research that tries to utilize BCI devices as control interfaces in the entertainment field are conducted [5].

There is BCI-based volume control approach [8]. Based on measured brainwaves, volumes are controlled. Given that measured brainwaves are different each other, the volume control approach requires brainwave normalization approaches. Facial interfaces control a volume of a headphone based on brainwaves with normalization approach is introduced [9]. By utilizing the facial interface, users do not need to use their hands when the volumes of their headphones are changed.

This paper proposes a normalization method for facial interfaces. By referencing own brainwaves, the accuracy of own control signal is increased. The proposed method can be applied to the diverse kinds of HCI fields.

The rest of this paper is consisted as follow. Section II describes related works. Section III proposes a brainwave normalization framework for a novel facial interface. In Section IV, the proposed framework is validated. Finally, Section V concludes.

II. RELATED WORK

Given that the process of brainwaves is complicated and requires multiple functions that handle brainwaves, there are framework-related researches. This section introduces the existing BCI framework researches that process brainwaves.

The BCI++ framework is the framework for laboratory purposes and is comprised of a Hardware Interface Module (HIM) and AEnima [10]. The HIM stores measured brain waves and The AEnima enables the operator to analyze the brain wave changes according to the operation of the AEnima.

BCI2000 is a generic framework that includes is comprised of a Source Module, Signal Processing Module, User Application Module, and Operator Module [11]. By utilizing the Source Module provides and the Signal Processing Module the features of brainwaves are extracted.

Open-ViBE processes the measured brainwaves using a

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BCI device [12]. It provides preprocessing to eliminate noise and strengthen signals and all the functions required in the process, from the extraction and classification of a feature vector to the conversion of a feature vector into commands.

BioSig provides a framework to process brainwaves [13]. BioSig is a biomedical signal-processing tool that provides functions to process diverse brainwaves.

Diverse kinds of BCI frameworks are introduced as above. However, this paper proposes a framework that is suitable for controlling the volume of headphones by including a novel normalization function.

III. BRAINWAVE NORMALIZATION

3.1. Term Definition and Processes

In the proposed framework, there are two types of interface users: one for a standard user and the other for an interface user. The standard user is one whose brainwaves are utilized as the standard of brainwaves. The interface user is one who utilizes a facial interface now.

The whole brainwave normalization processes are divided into two groups as follows. During the prior processes, given that each set of measured brainwaves of the standard user is different, the brainwaves of the standard user are measured *n* times. $b'_{i,t}$ is the *i*th measured brainwave at time *t*. b'_{max} is the maximum of the measured brainwaves. *m* is the number of bins for classifying all measured brainwaves into *m* groups. The interval $b'_{interval}$ of bins is determined by the value divided by the number *m* to the maximum b'_{max}. The range of the first bin is defined by the range from 0 to $b'_{interval}$, the range of the second bin is defined by the range from $b'_{interval}+1$ to $b'_{interval}\times 2$ and so on. $p'_{i,j}$ is the percentage of the included measured brainwaves of the *j*th bin comparing to the totally measured brainwaves until the *i*th measurement.

During the post processes, the brainwaves of a interface user are measured. $b''_{i,t}$ is the *i*th measured brainwave at time *t*. b''_{max} is the maximum of the measured brainwaves of the interface user. The interval $b''_{interval}$ of bins is determined by the value divided by the number *m* to the maximum b''_{max}. The definition of ranges of the bins of the interface user also follows the rules of a standard ruser. $p''_{i,j}$ is the percentage of the total of the measured brainwaves of the *j*th bin comparing to the totally measured brainwaves until the *i*th measurement. When the first ranges of the bins of the interface user are determined, the ranges of the bin of the standard user are referenced. $p'''_{i,j}$ is the percentage of the total of the the interface user's measured brainwaves of the *j*th bin until the *i*th measurement. From the second measurement of the interface user, the ranges of the interface user are calculated based on own previously measured all brainwaves. For examples, the second ranges of the interface user are based on the first measured brainwaves and the third ranges of the interface user are based on the brainwaves from the first measurement and the second measurement. $c''_{i,t}$ is the control signal the *i*th measured brainwave at time *t* and is assigned by the index j of the bin that has the range from the value smaller than the brainwave $b''_{i,t}$ to the value bigger than the brainwave $b''_{i,t}$.

3.2. Normalization Framework

In the proposed framework, the whole brainwave normalization processes are performed by brainwave collector, range setter, brainwave classifier and control signal generator. Brainwave collector collects brainwaves from a standard user and interface users. Range setter defines the ranges of the bins of measured brainwaves. In the case of a standard user, the ranges are set based on own brainwaves. In the case of an interface user, the ranges of the standard user are utilized for the interface user at the first time and then the ranges are set based on own brainwaves. Brainwaves classifier groups brainwaves depending on the predefined ranges that are based on the brainwaves of a standard user or the brainwaves of an interface user. Control signal generator generates control signals based the ranges of the bins of measured brainwaves.

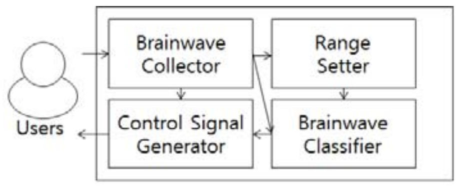

Fig. 1. Brainwave Normalization Framework

3.3. Improved Framework

There are diverse kinds of the possible improvements of the proposed framework. First, as more collected brainwaves of a standard user, the accuracy of the ranges of a standard user is more increased. Next, the brainwaves of a standard user can be utilized partially for an interface user from the second collected brainwaves of an interface user, given that the beginning ranges of the interface user are unstable.

VI. EXPERIMENTS

4.1. Experiment Setting

In the experiment, high alpha selected by experiments was measured per a second during controlling the volumes

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of a headphone. The brainwaves of two subjects as a standard user and an interface user were measured. Figure. 2 shows the measured brainwaves of two subjects. The brainwaves of each subject were measured three times (n=3) and utilized to the proposed method. *m* is set by 30.

After collecting the brainwaves of the standard user, the percentage of the brainwaves of the standard user was calculated as shown in Figure. 3. The percentage of the standard user until the thirdly measured brainwaves was utilized when the control values of the interface user were calculated.

4.2. Brainwave Transformation

Figure.4 shows the percentages of brainwaves of the interface user based on the ranges of the brainwaves of the standard user and the brainwaves of the interface user. First, the range of the first measured brainwaves of the interface user was determined based on the ranges of the brainwaves of the standard user as shown in Figure. 4 (p'''_1).

Next, the ranges of the second and third measured brainwaves of the interface user were determined based on the ranges of the first measured brainwaves of the interface user and the merged brainwaves from the first measured and on the ranges of the second measured brainwaves of the interface user as shown in Figure. 4 (p'''_2) and Figure. 4 (p'''_3).

Figure. 5 shows the difference between p' and p'''. Given that p'''_1 is calculated based on p'_3, the difference between p'_1 and p'''_1 was smaller than the difference between p'_2 and p'''_2. Figure. 6 shows the control values by applying the proposed method. High alphas were converted into the range from 0 to *m*. The distribution of the control signal was shown in Figure. 7.

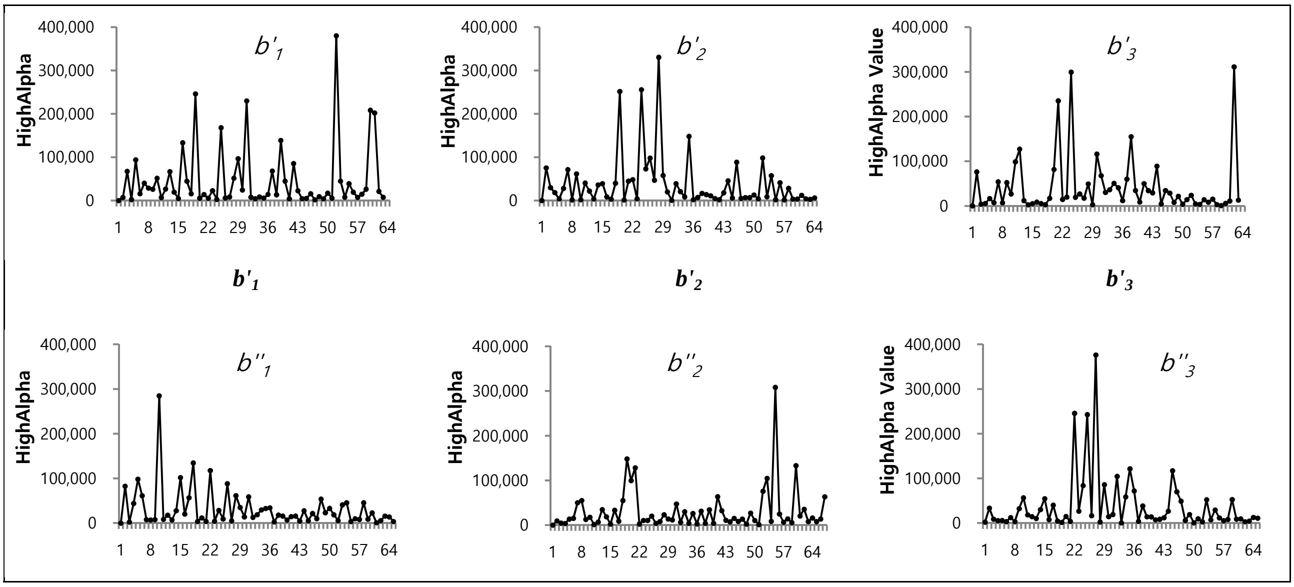


Fig. 2. The measured brainwaves.

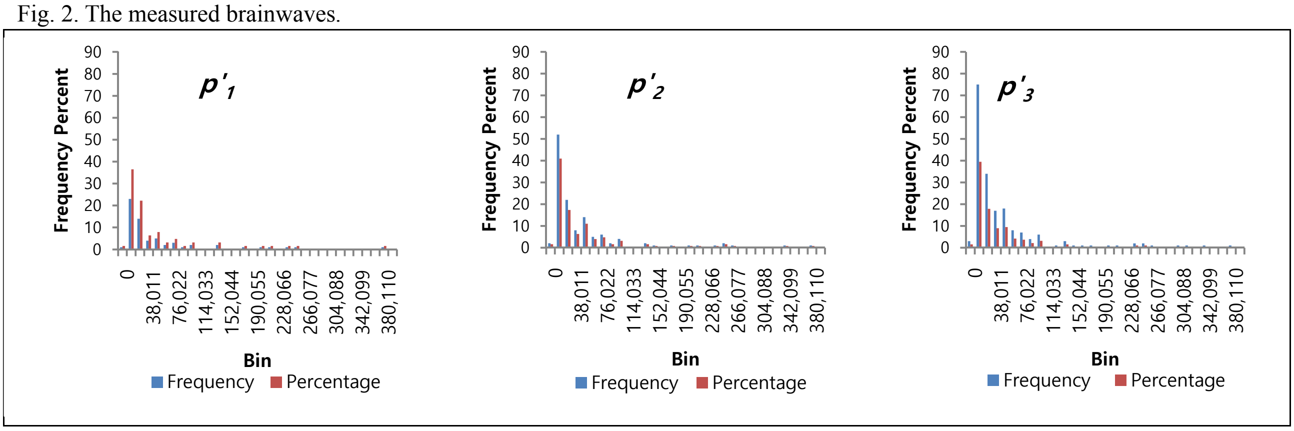


Fig. 3. The percentages of the brainwaves of a standard user

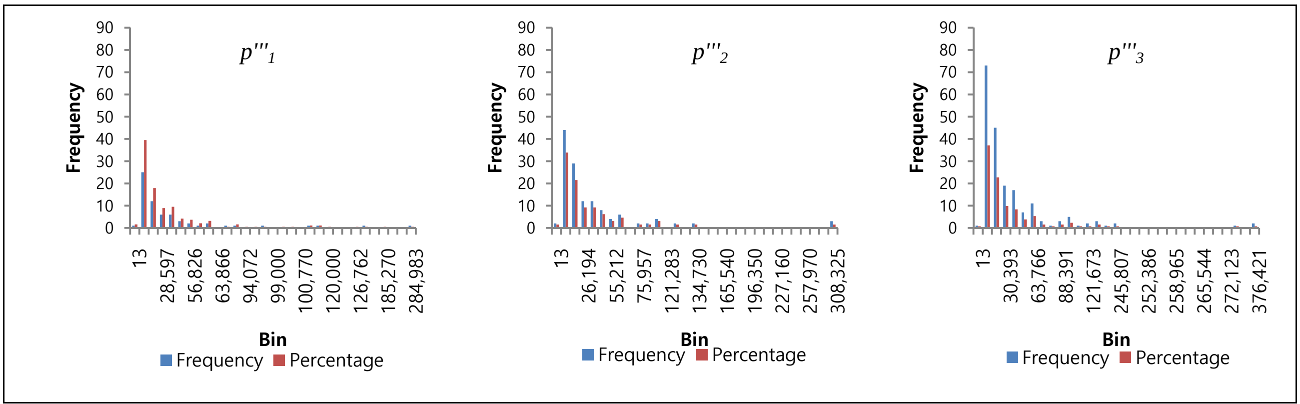
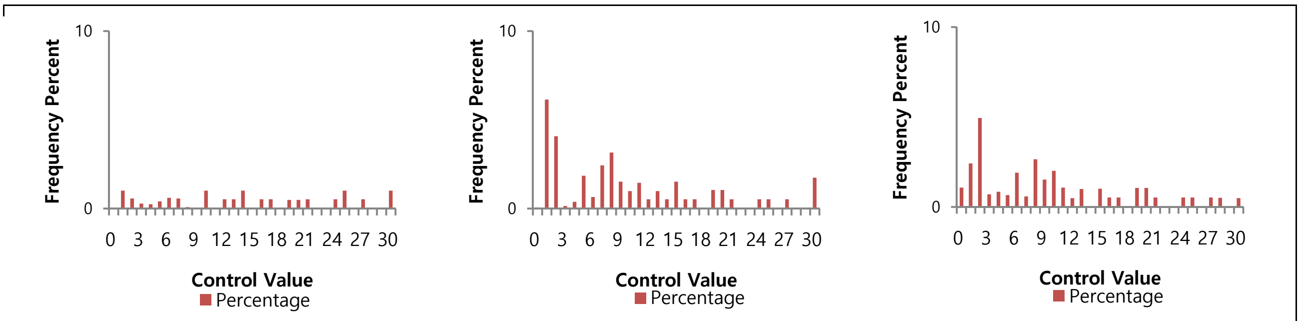


Fig. 4. The percentages of the brainwaves of an interface user.



(1) The difference between p'_1 and p'''_1 (2) The difference between p'_2 and p'''_2 (3) The difference between p'_3 and p'''_3

Fig. 5. The difference between p' and p'''.

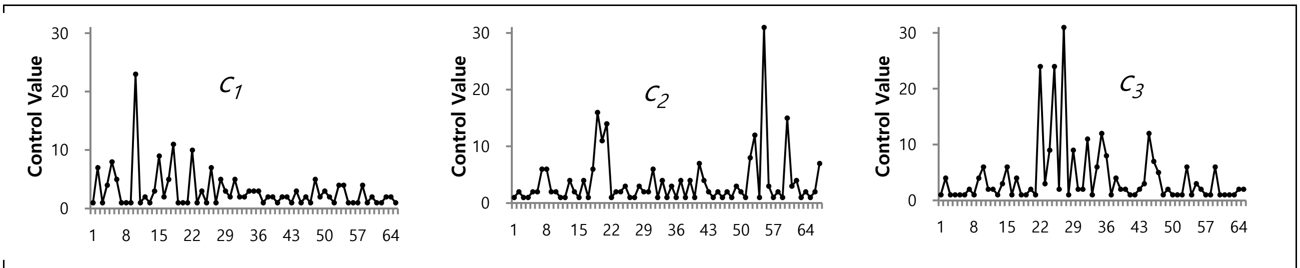


Fig. 6. Control values of an interface user.

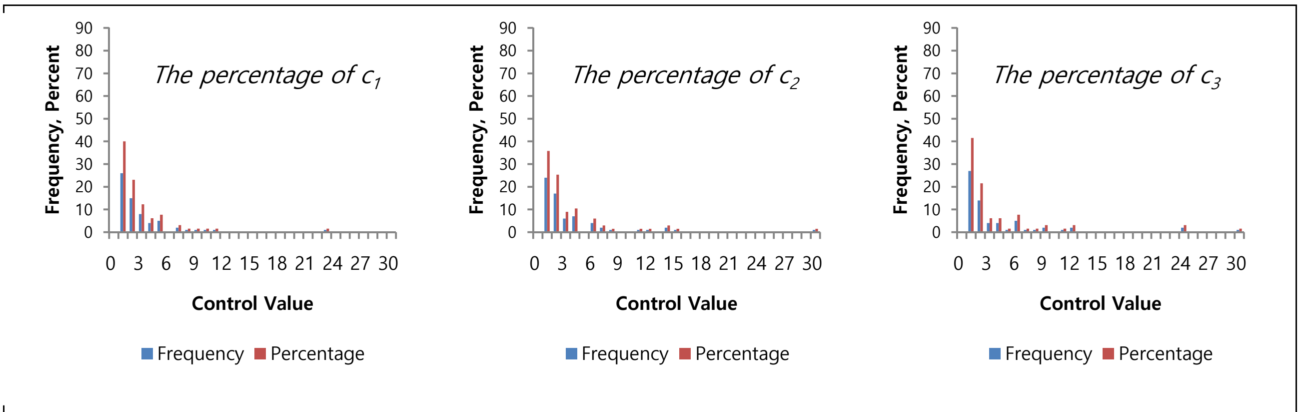


Fig. 7. The percentage of the control values of an interface user.

V. CONCLUSION

This paper proposed a normalization framework that converted measured brainwaves to utilize the measured brainwaves as control signals. When the measured brainwaves were converted, given that not only the measured brainwaves of a standard user but also the measured brainwaves of an interface user were utilized, more accurate control signals can be obtained.

In the experiment, two subjects are involved to validate the proposed method: one as a standard user and the other as an interface user. Based on the brainwaves of the standard user and the interface user, the brainwaves of the interface user were converted into control signals.

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