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Implementation of communication system using signals originating from facial muscle constructions

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Abstract

A person does communication between each other using language. But, In the case of disabled person, cannot communicate own idea to use writing and gesture. We embodied communication system using the EEG so that disabled person can do communication. After feature extraction of the EEG included facial muscle signals, it is converted the facial muscle into control signal, and then did so that can select character and communicate idea.

Key Words : EEG, artifact, BCI, power spectrum, Facial muscle signals, disabled person

1. Introduction

Innate and posterior physically handicapped and language-disabled people (caused by stroke, trauma, spinal lesion, etc.) have difficultly in dealing with basic desires and physiological phenomena, as well as communication with others. For these seriously handicapped people, an auxiliary device for expressing their basic opinions is indispensable. In this study, a communication device has been created by using a brain-computer interface, which is based on electroencephalography (EEG), including facial muscle signals among human body signals, as an accessible method that can be easily applied to handicapped people as an auxiliary device without the use of hands.

Brain-computer interface (BCI) is a system-related technology, which measures a specific state of brain wave signals through an electroencephalograph and draws characteristics of the EEG to classify them according to their characteristics. Then, it controls a computer or other equipment after transforming the characteristics into general control signals. Such a BCI principle looks simple; however, since EEG varies among people, and it is not easy to discover the properties of EEG according to diverse mental states, a number of studies are required to achieve the ultimate goal for BCI that aims to manipulate equipment with only human thought. Austrian Prof. Pfurtscheller's team researched the characteristics of EEG when left/right hands movements are imagined through a study using only pure EEG based on thought [1][2]. The US professor, Wolpaw's team, carried out an experiment in which the cursor on a monitor moves up and down by using a mu wave that diminishes when behavior is conducted or imagined [3]. With another approach, Degermann implemented an Eyegaze system in which information can be delivered in real time between a user and computer through drawing information from the eye movement after installing a video camera to the monitor [4]. Tecce, et al. invented a spelling device using an electrooculogram (EOG) signal [5].

In this study, a communication system was embodied by using the EEG including facial muscle signals in order to realize a reliable and applicable device for seriously handicapped people. Even seriously handicapped people can easily and intentionally generate facial muscle signals and the signals show characteristic waveforms. Thus, it is distinguishable from other waves (artifact) and can be used as a control signal, which can raise the accuracy of the system. The EEG, including facial muscle signals, has been classified into five states, by using channel and recognition sections.

After pre-treatment of the power spectrum and regularization, the measured EEG was classified by using ANN and then was transformed into control signals. The cursor on the computer screen has been made to move up and down and left to right by using the five classified signals. According to the movement of the cursor, nine sentences can be selected, to deliver the intention of the user. The nine sentences were composed of the words often used in daily life by those who cannot speak or cannot move properly, so that the disabled can use the system conveniently.

2. System Configuration

The general system configuration that embodies the brain-computer interface is shown in Figure 1. First, the human body signal generated from a person is measured and is used as

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data. The signal acquired in analogue form is applied to the application field after adequate signal treatment through various methods; then the feedback is provided to the user.

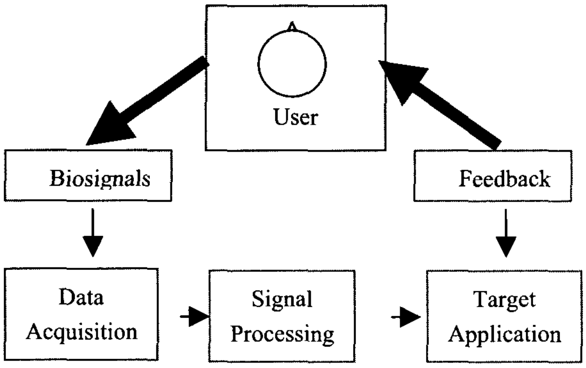

Fig. 1. System Composition

In the first stage, the EEG that was obtained from a subject was measured using the four-channel digital electroencephalograph (LXE-RS232) and the measured data was saved as ASCII code. Brain waves are very sensitive to noise and the artifacts that are mixed while measuring the waves are very diverse. The kinds of artifacts those are available as control signals are very diverse. In this study, facial muscle signals were used and test subjects were able to generate them intentionally in a normal state. The time when facial muscle signals occur is clearly distinguished from the time in a general state, especially when EOG signals, such as eye movement and eye blinking occur. Although the EOG signals have merit in that they can be generated intentionally, they are not suitable for control signals because unconscious movements can take place numerous times a minute.

As a second stage, the measured data underwent a pre-treatment process such as filtering and the power spectrum. The power spectrum transforms the time domain to a frequency domain by calculating the size of complex numbers from the frequency, after the Fourier transformation of EEG.. The power spectrum analyzes the frequency components of the signals by indicating which frequency components are superior to brain signals. This study shows the power spectrum using the method of Weelch [9].

In the third stage, preprocessed EEG data are classified and recognized by a sorter. In this study, each state was classified by using the error-back propagation algorithm (BPN) and that implementation supervised learning through the feed-forward neural network in the artificial neural network (ANN). This network consists of three layers: Input layer, hidden layer, and output layer. This study employed the BP learning, which obtained the output by inputting a learning pattern, and changed the weight of the hidden layer and output layer by using an error signal in the output layer.

It also changed the weight between the input layer and the hidden layer by doing the back propagation of the error signals in the output layer. Although it takes considerable time to learn the neural network through the BPN, the result is output very quickly in the application stage, once the learning has finished. Various parameters are needed to compose this network and six configuration components were studied in order to determine which parameter contributes to an optimal network:

First, is the number of neurons in the input, hidden, and output layers. Second, is the number of hidden layers. Third is the transfer function of the weighted sum. Fourth, is the learning method and fifth is the network training method. Sixth, is the number of learning data.

At a fourth stage, the equipment can be controlled by applying classified control signals to an apparatus that turns a light bulb on and off, a telephone and a direction controller. When each stage is complete, it is supposed to receive other control signals after again measuring the EEG of the user.

3. Measurement and Classification of the EEG

The objective of this study is to develop a system that controls equipment by using the facial muscle signals of a subject, which could be easily given by the subject. We have taken four factors into consideration. First, the location where EEG is measured should be easily available for the measurement. The EEG was measured according to the International 10/20 Electrode System. Second, the artifact that could occur should possess distinguishable characteristics. Since there are various kinds of artifacts with similar characteristics, each artifact should be less affected by other artifacts. Third, the number of artifacts should be small. In identifying each artifact, the reliability might be decreased when various kinds of artifacts are used, due to the influence by each artifact. Fourth, everybody should be able to generate signals with no difficulty. This system is developed in order to help the handicapped, especially the heavily handicapped such as those with general paralysis and speech disorders, rather than for ordinary people.

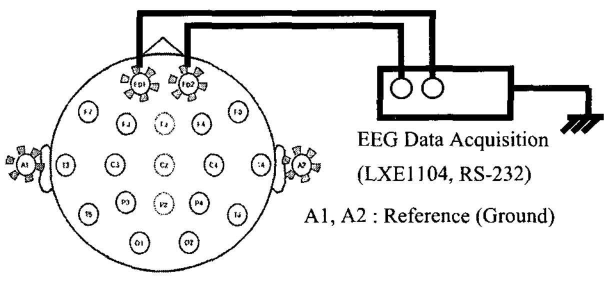

Fig. 2. 2-channel EEG acquisition system

This study employed the International 10/20 Electrode System. Fp1 and Fp2 were used for the locations for measurement. The measurement system is shown in Figure 2.

The signals were classified into three different signals, based on facial muscle signals. All the signals were generated in one-second sections and the signals with a single occurrence, two occurrences, and long-time occurrences in the section were used, respectively. Figure 3 shows the three different facial muscle signals.

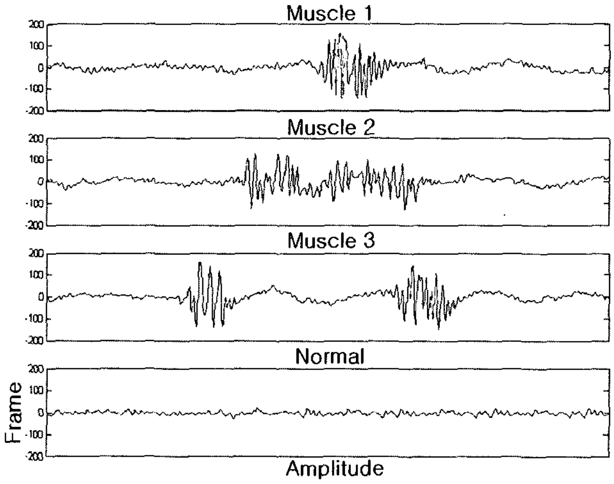

Fig. 3. 3-state facial muscle signals

For the experiment, the EEG of 20 males and females in their 20's was measured and then the results were applied to the system. Prior to the measurement, each subject received training in facial muscle signals. They made control signals for five different states and the control signals were measured. For each subject, the signals were measured three times for each state. The duration of each measurement was 25 seconds each time. The frequency for creating the artifact was 7 times during a single measurement. Through this process, 105 data (3 times * 5 states * 7 times) were collected on each subject, which totals 2100 data (20 subjects * 105 data).

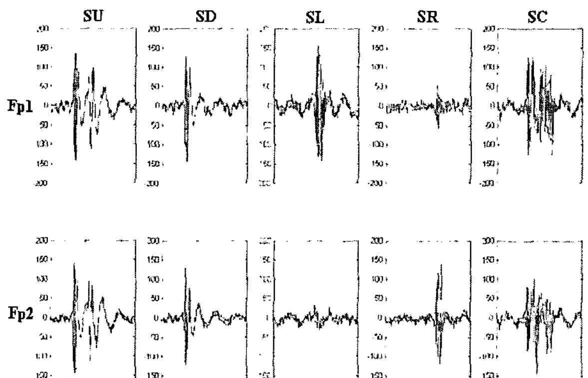

Fig. 4. Facial muscle signals to each state

The control signals used in the system were 5 states - up, down, left, right, and select. By using the signals measured in two channels with the signals of 3 states as shown in Figure 3, they were composed as shown in Figure 4.

The SU signal gives two consecutive short signals through two channels. The SD signal gives a single short signal through two channels. The SL signal gives one signal through the Fp1 channel, the left side, while the SR signal gives a signal through the Fp2 channel, the right side. The SC signal gives two long signals from both channels and they are shown in Figure 4.

4. Simulation and System Performance Analysis

In the system, the nine sentences that are frequently used by the handicapped were selected. Figure 5 shows the numbers that were given to the selected nine sentences.

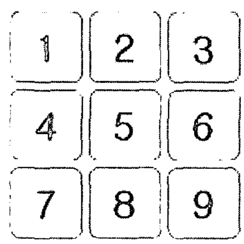

Fig. 5. Number composition

A subject can choose the number that he/she wants by freely moving the cursor. By inserting the sentence applied according to the numbers, the subject can choose the sentences that he/she wants. The selected number is shown in a different color. If the subject recognizes the selected number and the sentence that is chosen is the one that the subject wants, the signal would be sent which enables the receiver to understand what the subject is trying to say. Figure 6 shows the state diagram according to the process of number selection.

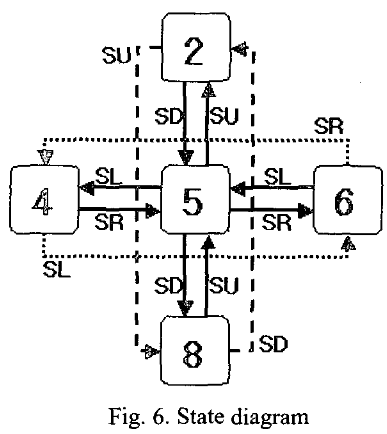

Fig. 6. State diagram

The signals are SU, SD, SL, and SR signals that move in 4 directions and the SC signal which selects the number. As it is shown in the figure, one could move in four directions of up, down, left, and right from Number 5, and this applies to all the numbers in the same way. As for the numbers on the sides, for instance, if the SR signal is given on Number 6, the cursor moves to Number 4. And when the SD signal is given on Number 9, it moves to Number 3. When the SC signal is given, the sentence related to the selected number will be printed on the screen.

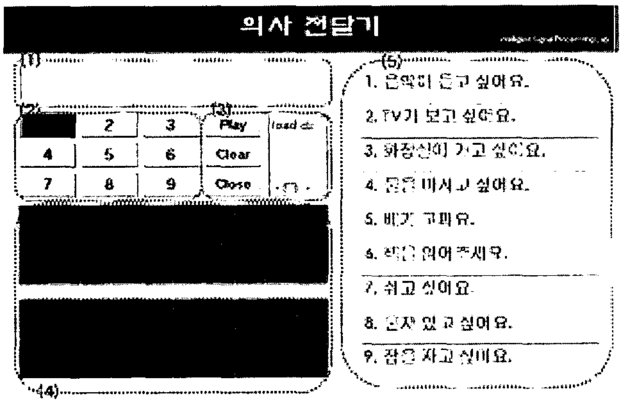

Fig. 7. Communication-system initial screen

The system for transferring the user's intentions consists of 5 parts; the window that shows the selected sentences; the menu selection part; the number pad that shows the selected number; the sentences according to each number; and, the brain wave signal that is being measured according to each electrode. The 5 parts are shown in Figure 7.

After running the system, if one selects Number 6 'Please read the book', Number 1 will be selected on the initial screen as a default value. Number 6 could be achieved in two different ways. When the SR signal that is the shortest path is given twice, the cursor is leaded to Number 3. Then one could use the SD for downward and the SC signal for selection, which leads to Number 6. Otherwise, one could use the SD signal to move to Number 4 and generate the SR signal twice to move to Number 6, and then use the SC signal to select Number 6. These processes are shown in Figure 8.

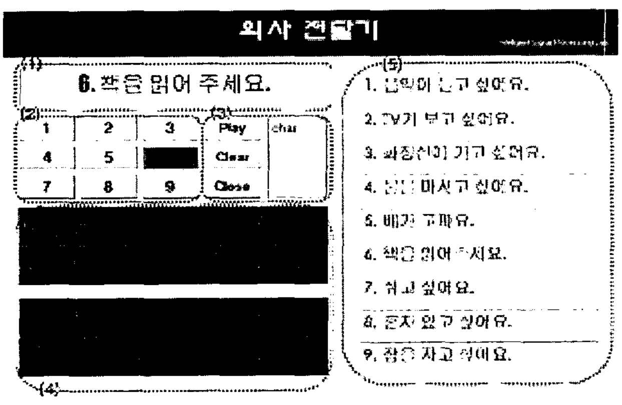

Fig. 8. Communication-system simulation

Table 1. System Application Rate

Subject	Recognition rate(%)				
	SU	SD	SL	SR	SC
1	95	90	95	95	95
2	95	85	90	95	90
3	95	90	95	100	90
4	100	90	95	100	95
5	100	90	95	100	90
6	95	95	100	100	100
7	100	90	100	100	100
8	95	95	100	95	95
9	100	95	95	95	95
10	90	95	95	95	95
평균	96.50	91.50	96.00	97.50	94.50

The data from 10 of the 20 subjects represents the results of the experiment. As shown in Table 1, the 10 subjects showed a success rate of over 95% on an average after getting a little training. The success rate was relatively low when the signals were given by using a single facial muscle signal on the left or right side when compared with using other facial muscle signals.

5. Conclusions

This study implemented a communication system that could help the heavily handicapped, who has not only physical handicaps but also those who cannot talk, by using an EEG that contains facial muscle signals.

The facial muscle signals show a characteristic wave form which enables the handicapped to make signals intentionally without any difficulty. This leads to a highly accurate and reliable system. It can classify signals into 5 signals according to the channels and recognition section, which organizes the system efficiently. In this study, nine sentences for communication could be delivered using five signals. The five facial muscle signals were preprocessed with power spectrum and filtering and achieved more than 99% of the recognition rate by classification using the ANN. The results of the simulation using test data showed the recognition rate to be over 95%.

This system enables the handicapped to deliver nine sentences that are frequently used in their everyday lives. In addition to the nine sentences, they could add extra sentences. This will help the handicapped communicate better and more easily.

Although the communication system in this study focuses on the handicapped, this could also help non-handicapped people and could be used in other applied fields that use control signals.

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