Brain Computer Interface Using EEG on Imaging Direction

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ABSTRACT

One of the authors and others have proposed Brain Computer Interface using the brain activities on reading silently four types of arrows without the activities of the motor area. We have further investigated and improved the discrimination method. In this paper, we present the experimental results for the evaluation.

Keywords: Brain Computer Interface, Discriminant Analysis, Electroencephalogram, Silent Reading, Spatial Recognition.

1. INTRODUCTION

Many brain computer interfaces (BCIs) have been developed with the progress of neural imaging technology and computer [1]. Most of them have used the brain activities from the motor cortex on thinking of moving a part of own body. When a person imaged moving own body, this area shows a similar activity to the one observed when he/she actually move the body [2]. These BCIs are based on this fact. However, in these cases, it is difficult that a person who has the lesion in this area cannot use this technology.

In the previous study [3], one of the present authors and others have investigated brain activities on reading silently four types of arrows and they have proposed the BCI without the activities of the motor area. This system uses the brain activities on imaging direction. That way, persons having a problem with motor area can use this BCI. And, the system having proposed uses the only EEG measurement to save the cost. However, there was still room for improvement.

In this research, we further investigated and improved the discrimination method on the basis of the previous study.

2. EXPERIMENT

2.1 Experimental Apparatus and Method

Subjects are six university students from 20 to 23 years old, and they have normal visual acuity and dominant hands are the right. The subjects put on an electrode cap and watched the 21 inch CRT from 30 cm away in front of them. Each stimulus was displayed on the CRT (Fig. 1). Their heads were fixed on a chin rest on the table. The positions of electrodes on the cap were according to the International 10-20 system (Fig. 2) and other two electrodes were fixed on the upper and lower eyelids for eye movement monitoring. Impedances were adjusted to less than 10 kΩ. Reference electrodes were put on both earlobes and the ground electrode was on the base of the nose. Electroencephalograms (EEGs) were recorded on the digital EEG measuring system (NEC Corporation, Synafit EE2500); the amplitude was 5 μV/V, the frequency band was between 0.15 and 100 Hz. Analog outputs were sampled at a rate of 1kHz and stored on a hard disk in a PC.

Fig. 1 Condition of experiment.
2.2 Flow of Experiment

In this experiment, subjects were presented a single character, which has apparent directional meaning, such as “↑”, “↓”, “←”, and “→”. The first period during 3,000 ms, only fixation point was presented. The second period, stimulus was presented in the center of CRT during 2,000ms. In this period, subject memorized the direction of arrow. The third period of 3,000 ms, a fixation point was displayed again. Then, the fourth period of 2,000 ms, as soon as a fixation point disappeared, a subject, read silently the same direction of stimulus just presented in the second period. Each stimulus was presented at random, and measurement was repeated thirty times for each stimulus, so the total was 120 times. In these cycles, we measured EEGs during the fourth period of 2,000 ms (Fig. 3).

3. ANALYSIS OF EEG

3.1 Pre-processing

We have measured EEGs of each stimulus. To improve S/N ratio, we summed and averaged each data according to the directions of stimulus and the subjects. However, EEGs including eye movement and body motion were cut out. These processed data are called the Event Related Potentials (ERPs).

3.2 Comparison of ERPs

We compared ERPs between six subjects. In consequence, these ERPs were divided into two types (Fig. 4). Two of six subjects’ ERPs had a large potential change from 200 ms to 700 ms (Type 1). However, the other ERPs indicated no large potential change (Type 2). We took note of the characteristics of type 1, and compared these ERPs between four directions. We observed that the polarities of peek potential were reversed between opposite directions (Fig. 5). In the case of upward or rightward imaging, the negative peek potential was observed. On the other hand, the positive peek potentials were observed in imaging downward or leftward. So, we assumed that this feature is related to the perception of directions, and researched the brain activities around these latencies.

3.3 Analysis of ECDL Method

To investigate the brain activities, we applied the Equivalent Current Dipole source Localization (ECDL) method to ERPs in the type 1 using the PC-based ECDL analysis software “SynaCenter [4]” (NEC Corporation). As a result, ECDs were localized to the left pre-central gyrus (PrCG), the right middle frontal gyrus (MFG), the right angular gyrus (AnG), the left AnG and the Broca’s area (Table 1, Fig. 6). Particularly, the activities at the right MFG and AnG are important, because these two areas are related to the spatial recognition [5]. Moreover, at the right MFG, one of the authors and others have
observed that the orientations of ECD’s moment were inversed between opposite directions (Fig. 7) [6]. This phenomenon is similar to the polarity of potential on the ERPs.

Table 1 Relationship between localized source and its latency (Subject A).

<table>
<thead>
<tr>
<th></th>
<th>l-PrCG</th>
<th>r-MFG</th>
<th>r-AnG</th>
<th>l-AnG</th>
<th>Broca’s area</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>233</td>
<td>308</td>
<td>480</td>
<td>531</td>
<td>607</td>
</tr>
<tr>
<td>↓</td>
<td>240</td>
<td>306</td>
<td>472</td>
<td>544</td>
<td>604</td>
</tr>
<tr>
<td>←</td>
<td>233</td>
<td>318</td>
<td>491</td>
<td>521</td>
<td>601</td>
</tr>
<tr>
<td>→</td>
<td>229</td>
<td>291</td>
<td>488</td>
<td>545</td>
<td>612</td>
</tr>
</tbody>
</table>

[ms]

Fig. 6 Spatiotemporal transition of estimated ECDs.

<table>
<thead>
<tr>
<th></th>
<th>Subj.</th>
<th>Dir.</th>
<th>Up and Down</th>
<th>Left and Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>83.3</td>
<td>80.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>85.0</td>
<td>81.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Results of the discriminant analysis between opposite directions.

In this research, to investigate the optimal parameters for EEG discrimination, we improved the discrimination method. We tried to discriminate EEGs in the type 1 by the discriminant analysis by the Mahalanobis generalized distance. On the basis of the preceding research [7], we selected four channels; F4, C4, F8 and T4. Furthermore, EEGs were sampled from 200ms to 700ms from the start of silent reading, because these latencies completely contain the remarkable change of ERP. In addition, these data were sampled at 10ms, 25ms or 50ms intervals to reduce the numbers of variates. Then, we applied the backward stepwise selection method to EEG channels in each three types of sampling rates to optimize the set of EEG channels. The discriminant rate was calculated by the leave-one-out cross validation method.

4.2 Results of the Discriminant Analysis

Most of BCIs aimed at the distinction of two types of brain activity. To compare with these BCIs, we discriminated between two directions; up and down or left and right. As a result, when all four channels data were used and were sampled at 25ms intervals, the discriminant rate showed the best score in the both subjects (Fig. 8). The discriminant rates were about 80.0% (Table 2).

Then, we discriminated between four directions. The condition of EEG channels and sampling rate were the same before (Fig. 9). In consequence, the discriminant rates were about 60 %; subject A: 62 %, subject B: 65 % (Table 3).
Fig. 9 An example of the results of the backward stepwise selection in case of discrimination between four directions (Subject B).

Table 3 An example of the results of the discriminant analysis (Discriminant rate: 65%, Subject B).

<table>
<thead>
<tr>
<th>Obs./Pred.</th>
<th>Up</th>
<th>Down</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>16</td>
<td>0</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Down</td>
<td>4</td>
<td>21</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Left</td>
<td>4</td>
<td>4</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>19</td>
</tr>
</tbody>
</table>

5. CONCLUSION

To develop the BCI without imaging of own body moving, we measured EEGs on imaging direction, and researched these brain activities.

In two of six subjects’ ERPs, large potential change was observed from 200ms to 700ms. In addition, the polarities of its peak were inversed. Then, to investigate the brain activities around these latencies, we applied ECDL method to ERPs. As a result, ECDs were estimated at the area processing the spatial recognition (the right MFG). These results were almost the same as those of the preceding research.

Then, we discriminated EEGs using the brain activities from the right frontal and temporal robe. To investigate the optimal parameters for EEG discrimination, we applied the backward stepwise selection method to EEG channels in each three types of sampling rates. As a result, when all four channels data were used and were sampled at 25ms intervals, the discriminant rate showed the best score. In the discrimination between opposite directions, this rate was about 80%. This is enough for practical use. The discriminant rate was about 60% in case of four directions. This result is not enough for the BCI. However, there is a possibility that the discriminant rate improves by modifying the experimental or discrimination method.

6. REFERENCES