研究論文

MICRO ROBOT CONTROL BY EEG ON MENTAL TRANSLATION WITH DIRECTIONAL SYMBOLS

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ABSTRACT

In order to develop a brain machine interface, the authors have investigated the brain activity during human recognition of symbols representing directional meaning. The authors have recorded electro-encephalograms (EEGs) from subjects viewing four types of arrows that were presented on a CRT. Each of the four symbols denoted direction for upward, downward, leftward and rightward, respectively. Subjects were asked to read the symbols silently. The authors have investigated a single trial EEGs of the subject precisely after the latency at 400ms, and have determined effective sampling latencies for the discriminant analysis on four types of arrows: ↑, ↓, ← and →. We sampled EEG data at latency from 400ms to 900ms at 25ms interval by the three channels in the right upper frontal gyrus. So the number of the variates is twenty one by three channels, therefore the sum is sixty three variates. Results of the discriminant analysis on four type objective variates, discriminant rates were mostly more than 80%. By four type codes of infrared rays according to the discrimination results from a PC, the authors have controlled a micro robot the e-puck in four types of orders; forward, turn clockwise, turn counterclockwise and stop.

1. INTRODUCTION

From many researches on the human brain, it has been cleared that the processing of visual stimulus is done at first on V1 in the occipital lobe. In the early stage of it, the process on the right visual field is processed on the left hemisphere and the left visual field is processed on the right hemisphere. Then the process goes to the parietal associative area [1].

Higher order process of the brain thereafter has its laterality, for instance, 99% of right-handed and 70% of left-handed have their language area on the left hemisphere as the Wernicke's area and the Broca's area [2], [3]. Besides these areas, language is also processed on the angular gyrus (AnG), the fusiform gyrus (FuG), the inferior frontal gyrus (IFG) and the prefrontal area (PFA).

By use of the equivalent current dipole localization (ECDL) method, some of the present authors have found that ECD was localized to the right middle temporal gyrus with arrow symbols in the early stage, and then it was estimated in areas related to the working memory for spatial recognition, such as the right inferior or the right middle frontal gyrus, etc. Further, as with kanji characters, ECD was localize to the prefrontal area and the precentral gyrus.

However, in case of the mental translation, activities were observed on the area around the same

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latency regardless to the Kanji or the arrows. After on the right frontal lobe, which is so called the working memory, ECDs were localized to the Broca's area which is said to be the language area for speech. Like in our preceding researches, the moments of ECD was almost opposite in each case of opposite meanings (Fig.1).

Applying this fact to the brain machine interface (BMI), the authors compared each channel of EEG and its latency. The authors fined that the channel No.4 (F4), No.6 (C4) and No.10 (F8) according to the International 10-20 system were effective to discriminate the four type of EEG in mental translation. Each discrimination ratio was more than 80%.

2. EXPERIMENT WITH ARROW STIMULLI

2.1. Experimental apparatus and method

Subjects are four university female students from 21 to 22 years old, have normal visual acuity and dominant hands are the right ones. The subjects put on an electrode cap and watched the 21inch CRT 30cm in front of them. Each stimulus was displayed on the CRT. Stimulus had been stored on the disk of a PC as a file and they were presented in random order. Their heads were fixed on a chin rest on a table. Positions of electrodes on the cap were according to the International 10-20 system 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 5μV/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.2)

2.2. Stimulus presentation of experiment

In this experiment, subjects were presented a single character, which has apparent directional meaning, such as "↑", "↓", "←", and "→". In the first masking period, during 3000ms stimulus was not presented. In the second period, stimulus was presented in the center of CRT during 2000 ms, and it was followed by a masking period of 3000 ms: the third period. Then in the forth period during 2000 ms, visual stimulus was hidden and subject translated the direction of stimulus mentally. Each stimulus was

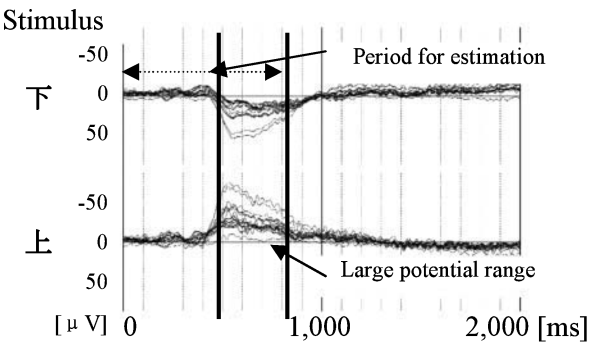

Fig.1 Comparison between ERPs for Downward (up) and for Upward (below)

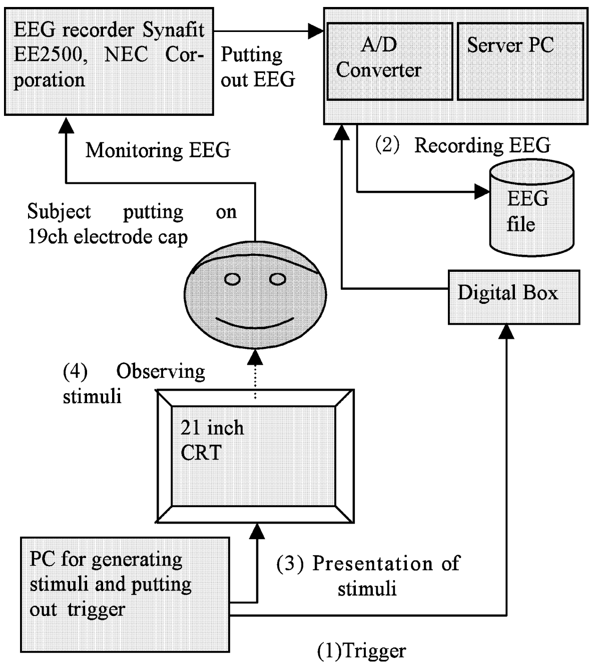

Fig.2 Experimental apparatus

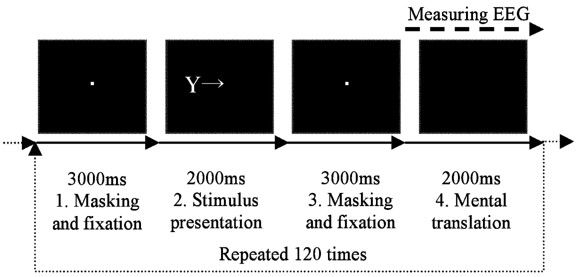

Fig.3 Timing chart of the present experiment

Table 1 Relationship between localized source and its latency after PrCG (Subject MM)

Stimulus	left MFG	right IFG	right AnG	left AnG	Broca's area
↑	307	486	490	549	613
↓	296	473	494	527	607
←	313	475	497	531	623
→	311	454	480	537	613

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 forth periods of 2000 ms (Fig.3).

From the experimental instructions, subjects were forced to translate a direction mentally by the arrow which was displayed just before on the center of CRT screen. So we measured brain activities during translation of direction.

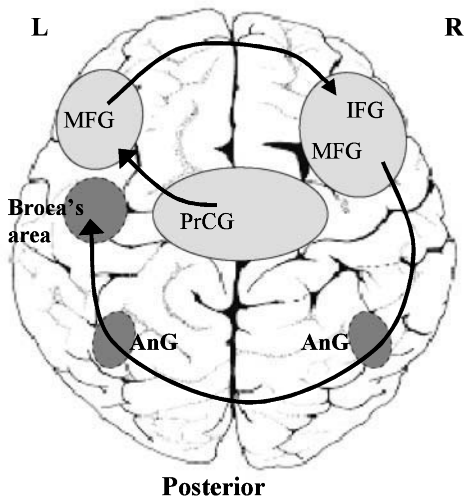

Fig.4 Spatiotemporal pathways after PrCG in the case of mental translation

2.3. Analysis by equivalent current dipole source localization

We have measured EEGs of each visual stimulus. In order to effectively execute the ECDL method, both data were summed and averaged according to the type of directions and the subjects in order to get event-related potentials (ERPs). Summing these ERPs of the directional types respectively, then the ECDL method was applied to each ERP by each subject. Because the number of the recording electrodes was 19, three ECDs at most were estimated by use of the PC-based ECDL analysis software "SynaCenter [4]" (NEC Corporation). The goodness of fit (GOF) of ECDL was more than 99.8%.

2.4. Result of ECDL method

Same as the preceding research, the ventral pathway that relates shape recognition and the dorsal pathway that relates movement recognition were estimated before ECDs were localized to the precentral gyrus (PrCG). After PrCG, process of the Kanji (Chinese character currently used in Japanese) is mainly through the left hemisphere; the left middle temporal gyrus (MTG) called the Wernicke's area and the left angular gyrus (AnG). And that of symbol is mainly through the right hemisphere; the right inferior frontal gyrus (IFG) and the right middle frontal gyrus (MFG), they are so-called the working memory for spatial recognition, in the preceding research [6]. However, in the case of mental translation, pathways are both the same. Especially reactions on the Broca's area, that is a part of the language area, were found also in the mental translation of arrow cases (Table 1, Fig. 4). Subjects are supposed to read symbols silently.

3. EEG DISCREMINATION BY MULTIVARIATE ANALYSIS

3.1. Sampling point of EEGs for multivariate analysis

By use of single trial EEG data, that were measured in the experiment with symbols (arrow: ↑, ↓, ←, →), we attempted the discriminant analysis; one method of the multivariate analysis. For the use of real time application, it is natural to use small number of the EEG channels and/or sampling data. Some of the authors have investigated to minimize a number of EEG channels and a number of sampling data [7]. They investigated the minimal sampling number to obtain complete discriminant ratio (100%) for the same subjects by three channels. However, the sampling interval was 50ms between the latency 400ms and 900ms.

From the result of the preceding research, the pathway goes to the right frontal area at the latency after 400ms. We sampled EEGs from latency of 400ms to 900ms at 25ms interval; therefore number of sampling point is twenty one. Electrodes that lies near to the right frontal area are F4 (No.4), C4 (No. 6) and F8 (No.12) (Fig.5 and Fig.6) in the International 10-20 system, we chose these three channels among 19 channels (Fig.7). Although the EEGs are time series data, we regarded these as vectors in sixty three, twenty one by three, dimensional space.

3.2. Discrimination method and results

We gather each single trial EEGs data to play as learning data (Fig.8). For each type of mental translation, a number of experiments were thirty. Each data has one criterion variable and 63 explanatory variates. Because explanatory variates consist of three channels × 21 sampling data. So the learning data are 120 with 63 variates. And each criterion variable has four types index (upper, lower, right and left).

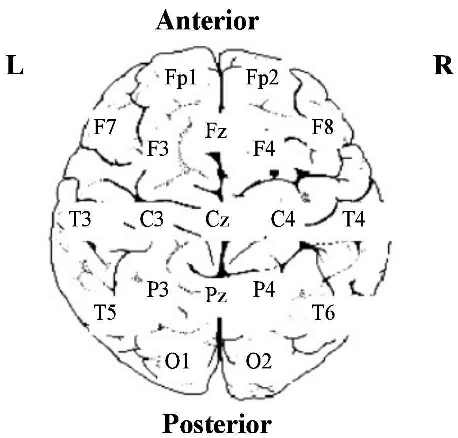

Fig.5 Positions of electrode in International 10-20 system

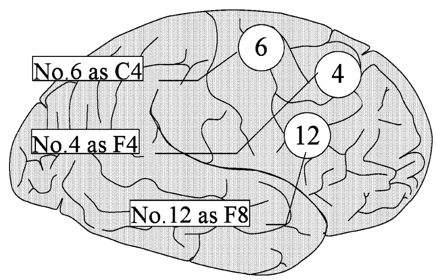

Fig.6 Chosen electrodes on right side lateral view

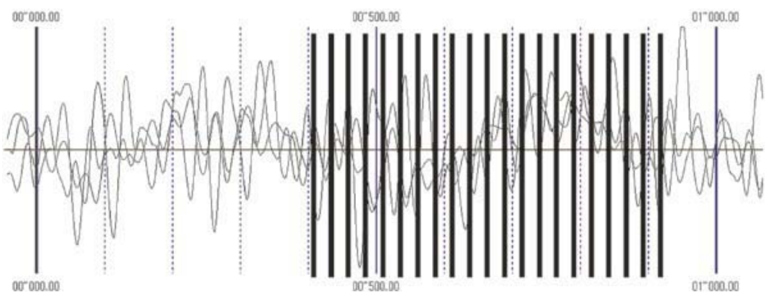

Fig.7 Three chosen channels of EEG and their sampling points; Bold lines denote sampling points

The subjects are four students; however,

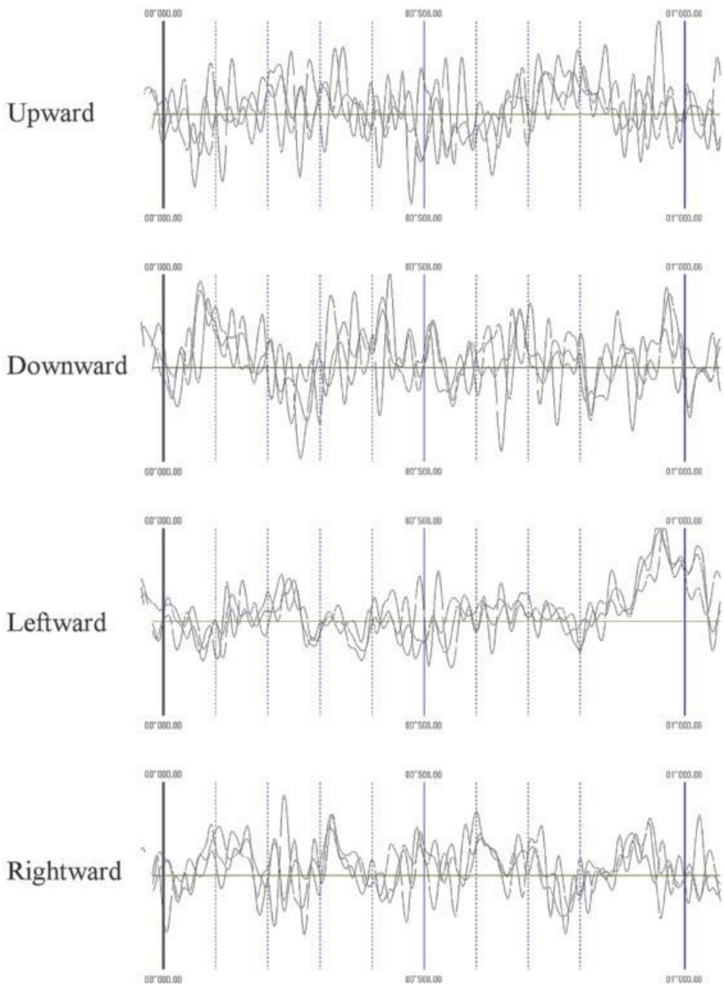

Fig.8 Examples of single trial EEGs (upward, downward, leftward and rightward)

three of them were taken data twice in other day, so the total number of the experiment was seven. We denote each experiment as HY1, MY1, MY2, MM1, MM2, SI1 and SI2. We tried to discriminate the four types by 120 samples using the discriminant analysis. As a result, the mean discriminant ratio was 85.35%. (Table 2 and Table 3)

4. CONTROLL OF MICRO ROBOT E-PUCK

From the results above, we attempt to control a micro-robot e-puck using stored EEG data. By way of USB output from PC, the result of discrimination is transformed into a USB I/O terminal (DIO-0808LY-USB, CONTEC Co., Ltd.) connected to an infrared remote control unit (CT-90165, Toshiba Corporation) (Fig.9) by lines. The output of discrimination '↑', '↓', '←' and '→' corresponded to 'forward', 'stop', 'rotate counter-clockwise' and 'rotate clockwise', respectively. Each output controlled infrared signal was transformed to the micro-robot e-puck directly (Fig.10). The present system is a prototype, so EEG data used were stored on PC, they were analyzed by the discriminant analysis, and discriminant coefficients were also stored.

By an output as a result from the discriminant analysis of a single trial EEG data in the stored EEG file, the e-puck moved within 1.5 seconds according to results of discrimination. Each single trial EEG data was measured during two seconds for 19 channels. Therefore, reaction time of the system would be improved when only three channels EEG are measured and discriminated directly.

Table 2 Example of result of the discriminant analysis for symbol imaging in best case (Experiment HY1): Discriminant ratio 95.83%)

Obs./Pred.	↑	↓	←	→	Total
↑	29	0	1	0	30
↓	0	29	0	1	30
←	0	0	29	1	30
→	1	1	0	28	30
Total	32	29	27	32	120

Table 3 Example of result of the discriminant analysis for symbol imaging in worst case (Experiment SI1): Discriminant ratio 80.83%)

Obs./Pred.	↑	↓	←	→	Total
↑	25	1	1	3	30
↓	4	22	2	2	30
←	1	3	24	2	30
→	2	2	0	26	30
Total	32	28	27	33	120

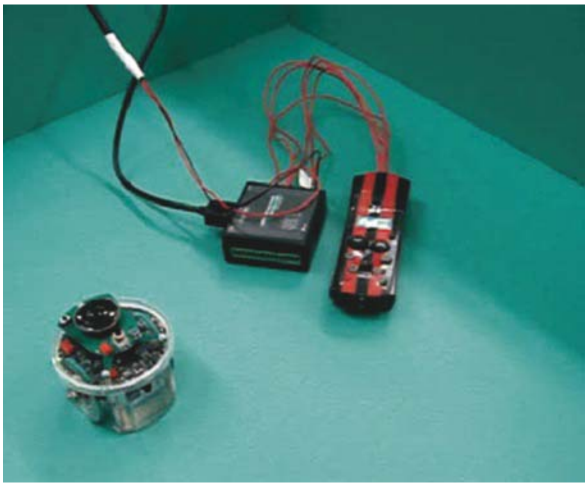

Fig.9 Infrared rays' remote control device and micro robot e-puck

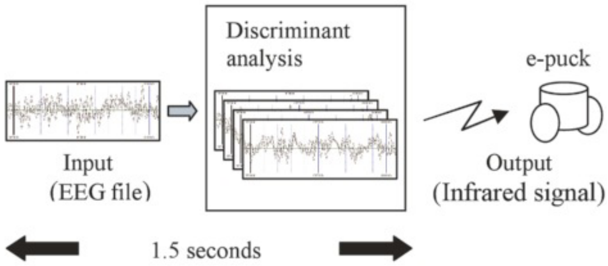

Fig.10 Scheme of control of e-puck

5. ACKNOWLEDGEMENT

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