Decision by majority by thinking

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Abstract --- This paper describes a technique for decision by majority by applying brain signal analyses. The ElectroEncephaloGram (EEG) of twenty-four volunteers were recorded with the serial presentations of Computer-Generated (CG) images of human emotional faces. We focused on the Event-Related Potential (ERP) P300 signals and the amplitude was investigated varying the ratio of collaborative P300 occurrences in the group. The supervised machine learning technique was used to perform the decision by majority and the estimation performance value could be almost 80%. This novel concept would be applicable to the decision by majority for Computer-Supported Cooperative Work (CSCW) such as Virtual Reality (VR) interactions only by means of thinking.

Keywords: Decision by majority, Collaborative EEG, ERP P300, CSCW

1 INTRODUCTION

The Brain-Computer Interface (BCI) by applying EEG measurements has been extensively studied [1,2]. This novel interface enables people to operate computers only by means of brain activities. However, the performance of the BCI is not perfect, since the EEG signals elicited in human brain are difficult to be classified or decoded, in particular, with the single-trial analyses.

It has been remarked that the EEG recordings with multiple subjects lead to the improved classification performances. This novel concept is referred to as collaborative EEG and is state-of-the-art. Then, the thoughts of all subjects are coincided and synchronized, and with perfectly collaborative EEG signals, the high classification rates are expected even with single-trial (short-time) EEG signals. Wang and Jung proposed a collaborative paradigm to improve BCI performance by integrating ERPs from multiple subjects [3]. In their movement-planning EEG experiment, there were nine conditions, differing by three movement types and three movement conditions. As a result, by increasing the number of subject to 20, the classification performance of 2-class – reaching left vs reaching right was 95%. Furthermore, Poli et al. performed shapes matching experiment – whether the shapes etc. were the same or different [4]. The response time data and ERPs data of subjects were used for classification. As a result, when the number of subjects was increasing to 10, the classification performance was more than 96%.

The situations of the collaborative thinking are considered as frequent. For example, the CSCW can be seen everywhere in our ordinary lives, and the CSCW based on the brain signals has been studied in recent years [3,4]. The neural approach of CSCW is one of the attractive topics in the information engineering and social neuroscience. Furthermore, the EEG-based decision by majority leads to a new direction of VR interactions.

In this paper, we address the situation in which the perfectly collaborative thinking is NOT realized in the group. Here, the perfectly collaborative thinking means that the simple decision makings of all subjects are coincide and same. We investigate the P300 amplitudes by varying the ratio of the majority (the ratio of the P300 occurrences in the group) and focus on the performance of the decision by majority.

2 EXPERIMENTAL

This experiment was approved by ethics committee in Toyama Prefectural University. In this experiment, twenty-four healthy adults (the students in Toyama Prefectural University, 22 males and 2 females, mean age 23 years, range 21-33 years) participated. Each subject was wearing an EEG cap and was seated on the standard chair at 3.5m apart from a 150-inch screen (Fig.1). The vertical visual angle and horizontal visual angle of stimuli images were 13° and 8°, respectively. The EEG signals of four subjects (1 group) were simultaneously measured by using g.USBamp (EEG measuring instrument, Guger Technology), and the measurement was repeated until the datasets of twenty-four subjects (totally 6 groups) were collected.

The CG images of human faces were prepared and there were 4 types of emotional facial expressions (non-emotional, angry, fear, and smile) of male and
female, respectively. Each emotional facial image was randomly and serially presented with a duration time of 1s (Fig.2).

All subjects were instructed to pay attention only to the smile faces (target stimuli). They were also instructed to ignore the other emotional faces (standard stimuli). It was expected that the P300 signals appeared only during target stimuli presentation. For each group, there were totally 10 sessions of EEG recordings for 3 minutes. And totally, there were 100 target and 300 standard stimuli for each subject.

EEG and ElectroOculoGram (EOG) signals were recorded with a sampling rate of 512Hz. We selected a bandpass filter between 0.1 and 200Hz. Four EEG electrodes were placed at Fz, Cz, Pz, and Oz in the extended international 10-20 system. To monitor eye blinks and vertical eye movements, we recorded the vertical EOG (VEOG).

3 SIGNAL PROCESSING

After the re-referencing, the bandpass filter was applied to extract the frequency components of P300 signals between 0.1 and 10Hz. And the baseline processing was followed. The artifacts from eye blinks and vertical eye movements were removed by using Independent Component Analysis (ICA). We used FastICA algorithm [5].

The target and standard EEG signals for 1s after the stimulus onsets were extracted to obtain each subject’s P300 and non-P300 averaged waveforms. In particular, we varied the ratio of the collaborative P300 occurrences in twenty-four subjects. The details will be explained in the following paragraph.

The collaborative EEG signals were classified to investigate the performance of the decision by majority. To construct the feature vectors, we applied temporal Principal Component Analysis (temporal PCA). Furthermore, the classification was achieved based on the supervised machine learning technique. We prepared the collaborative EEG datasets from twenty-four subjects. We denoted them G1, G2, ..., G6, respectively. In each group, there were 4 subjects and they were in collaborative thinking. If no group paid attention to the visual stimuli images, which means all groups ignored the stimuli images, the label for the dataset was set to 0/6. Furthermore, if the group G1 and G2 were in target condition and the others were in standard condition, the label was set to 2/6. In these ways, there were possibly seven labels (0/6, 1/6, 2/6, 3/6, 4/6, 5/6, and 6/6). The label 0/6 and 6/6 denote the perfect collaborative thinking, and the label 1/6, 2/6, ..., 5/6 means the non-perfect collaborative thinking.

In the analyses on the decision by majority, we want to discriminate whether the ratio of the P300 occurrence in a collaborative EEG data is more than half or not. And thus we set the new Label 1 to the EEG datasets with the previous label 0/6, 1/6, and 2/6, which correspond to the non-P300 and moderate P300 occurrences. And we set the new Label 2 to the EEG datasets with the previous label 3/6, 4/6, 5/6, and 6/6, which correspond to P300 occurrences. With these new Label 1 and 2, we performed two-class classification for the decision by majority. In this study, multiple discriminant analysis was used to classify. The classification rate was derived by using leave-one-out cross-validation (LOOCV) technique.
4 RESULTS

In Fig.3, the seven waveforms correspond to the seven labels mentioned before. The P300 amplitudes were systematically varied according to the varying labels or the ratio of the collaborative P300 occurrences. The larger the ratio was, the larger the averaged P300 amplitudes were. The P300 signals were clearly seen with the label around 6/6, when all the subjects paid attention to the target stimuli images. On the other hand, the amplitude is minimum with the label 0/6, when all the subjects ignored the standard stimuli images.

Figure 4 shows the classification results of the decision by majority. The performance was measured by F-measure values. We derived the relation between the F-measure and the number of the principal component in the temporal PCA. The number of principal component more than about 4 led to high performances. The maximum F-measure could be 79.8%.

5 DISCUSSIONS

In this study, the classification performance of the decision by majority was about 80%. It is noticed that the performance value was derived by using the single-trial ERP datasets. Therefore, we concluded from this result that the non-perfect collaborative thinking would be applicable to perform the EEG-based CSCW. In order to obtain a perfect classification performance, the other methods of the feature construction and the classification will be tried in the future. For example, we could use the Spatial-Temporal PCA (STPCA) to extract the EEG features, and then use the Support Vector Machines (SVM) algorithm for the classification.

So far, the EEG-based interfacing with multiple subjects has been considered to require that the thoughts of all subjects are coincided and synchronized. If not so, the average P300 signal amplitude is not large enough and rather reduced than expected, and then the classification performance will be lower. However, the non-perfect collaborative thinking is leading to the concept to estimate the ratio of P300 occurrences in a group. We confirmed that the P300 amplitudes were varied according to the ratio of the P300 occurrences. The variation was remarkably systematic and therefore it was expected that the ratio estimations were possible. In fact, the supervised machine learning technique revealed that we could estimate whether the ratio of the P300 occurrences is more than half, which means we achieved the decision by majority. To achieve the EEG-based decision by majority, we averaged single-trial EEG data from all subjects. In usual, the decision by majority is performed by questionnaire. Our novel technique enables the decision only by means of thinking.

The concept of the decision by majority based on EEG signals is applicable to a variety of fields. For example, the BCI system has been developed with VR technology [6]. The immersive virtual environment and augmented reality based interfacing were studied in recent years [7,8]. However, the BCI system with VR technology was studied with the single subject so far. The collaborative BCI system enables to realize the VR interfaces by using the decision by majority with multiple subjects. Then, the collaborative brain signals are reflected in the VR systems and the new CSCW will be realized. In those systems, a higher classification performance will be obtained.

Our research will go on to develop the concept of the collaborative EEG signals by investigating a variety of EEG activities. The motor imagery tasks provide the event-related synchronization and desynchronization, which require the frequency analyses. In the previous studies, with the motor imagery, we could control the
cursor movement in the two-dimensional space under the single subject condition [9]. This type of EEG signals is in our research scope with the concept of the decision by majority.

Furthermore, the collaborative brain signals will lead to a new marketing research. Neuro-marketing is an approach for reading the consumer’s mind based on the human brain activities [10]. In recent years, it was wildly studied. The usual neuro-marketing system might extract the preference information from the single consumer. The brain signals from the massively multiple consumers were necessary to be investigated for the neuro-marketing in the future. In this study, we measured the P300 signals. It could be used for detecting the attention which the subject paid. However, it is difficult for extracting the subject’s preference information, such as Like or Dislike. In recent works, the Late Positive Potential (LPP) was studied [11]. It is an ERP that elicited by emotional stimuli images. With the LPP’s amplitudes, the emotional information could be detected, such as neutral, positive, and negative. The collaborative LPP signals will be investigated in our research.

Finally, the increasing of the number of subjects is to be studied, since the larger number of subjects will reduce the artifacts, and the classification performance will be remarkably improved. However, it requires the portable and wearable EEG devices. The quick attachment of the EEG electrodes would be also one of the important factors in the collaborative EEG recordings.

6 CONCLUSIONS

In this study, we measured the ERP P300 with twenty-four subjects by using the CG images of the emotional facial expression. The analysis of the decision by majority based on the collaborative EEG signals was performed. In order to achieve our purpose, we averaged single-trial EEG data from all subjects. In our results, the decision by majority could be realized with about 80% in the ERP classification. Therefore, our novel technique could be applicable to the decision by majority for CSCW such as VR interactions only by means of thinking. In addition, this concept is also applicable to a variety of fields, such as neuro-marketing.

REFERENCES


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