EEG-based navigation of immersing virtual environment using common spatial patterns

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ABSTRACT

In this paper, the technology of non-invasive brain-computer interfacing (BCI) in immersing virtual environment was focused for navigation with no subject training. The common spatial patterns were for the first time applied to EEG-based BCI system in CAVE with five-screen configuration. The interfacing system was based on two brain states of left and right hand phantom movements. It was suggested that the navigation could be demonstrated with no subject training in immersing virtual environment.

CR Categories and Subject Descriptors: H.1.2 [User/Machine Systems]: Human information processing; H.5.2 [User interfaces]: Input devices and strategies

Additional Keywords: Brain-computer interface (BCI), Motor imagery, Electroencephalogram (EEG), Subject training, Common spatial patterns (CSP), Virtual reality (VR), CAVE

1 INTRODUCTION

The virtual reality is a technology which enables the user to have an interaction with a computer-generated environment, that is, the virtual environment. The technology can provide a method to test in advance the procedures which might be applied in reality.

In recent, a new technique of human-computer interfacing has been studied in immersing virtual environment [1, 2]. This interfacing technology is called as non-invasive brain computer interface (BCI). Such approach can provide the user with one of the communication channels which can send commands to the external devices only by human brain activities [3]. One of the most effective BCI systems is based on motor imagery. This type of system has been extensively studied [5] and becoming one of the research paradigms also in immersing virtual environment [1, 2, 6]. Nevertheless, there is still a problem of subject training. The motor imagery-based BCI system has often imposed the subject the extensive training for long span.

The purpose of this paper is to provide a BCI system with no subject training in immersing virtual environment, applying the spatial filters. Recently, the common spatial patterns (CSP) have been studied in the context of motor imagery-based BCI system [7], aiming no or little subject training [5]. The CSP algorithm is found to be very useful in calculating spatial filters to detect ERD effects. However, this algorithm has not been applied and evaluated in immersing virtual environment.

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2 MOTOR IMAGERY AND BCI

The mu rhythm of somatosensory cortices was found owing to the recent development of computer-based analyses on EEG activities. Movement and even phantom movement are accompanied by a suppression of mu and beta rhythms. This suppression has been known as event-related de-synchronization (ERD). After the movements or when inactive, the idling rhythm increase call as event-related synchronization (ERS) occurs, as in the case of visual alpha rhythm during eye close in relax. It is a strong motivation for EEG-based brain computer interfacing that the ERD/ERS can occur even without actual movements [4]. The phantom movement or motor imagery can cause the modulation of the EEG oscillations.

The subject training is one of the problems on the BCI system based on motor imagery. Blankertz et al have investigated the BCI system with motor imagery tasks with no or little subject training (the Berlin BCI) [5]. The algorithm was based on the common spatial patterns (CSP) and is useful to extract subject-specific, discriminative spatial filters. It was reported that with CSP algorithm the correct rate of 88.4 % was achieved in two-class classification [5].

Note that the novel works on motor imagery and the BCI system based on it are reviewed in the Ref. [3].

3 SIGNAL PROCESSING

In the preprocessing procedures after the data acquisition the EEG signals were bandpass filtered between 8 and 30 Hz. In the feature extraction procedure, the algorithm of common spatial patterns (CSP) was applied. See Ref. [7] for details. The support vector machine (SVM) with linear kernel was chosen in performing the classification. To test the discrimination performance, 10 x 10-folded cross validation was applied. We investigate two-class classification using CSP algorithm.

4 EXPERIMENTAL

4.1 Immersing virtual environment

By using the immersive projection technology (IPT), the user can feel high degree of immersion. Thus, the immersing virtual environment is expected to be one of the suitable methods to evaluate a BCI system in advance before the implementation into the real world, extracting a variety of problems in use.

The experiments with our BCI system were performed in immersing virtual environment called as ‘CABIN’ [8] constructed at Intelligent Modeling Laboratory in Tokyo University.

4.2 Experimental protocols

Three healthy volunteers ‘s1’, ‘s2’ and ‘s3’ participated in the experiments as subjects. There were two types of experiments with and without visual feedback. With visual feedback, the classification results of the discrimination of brain activities, that is, the control commands ('L' or 'R' corresponding to the left or right hand motor imagery, respectively.) were transmitted to the workstation of CABIN. One measurement run consisted of 20 trials. The 20 trials randomly included 10 trials of left hand motor imagery task and residual 10 trials of right hand. A visual cue was used to announce the start time of the imagery tasks at t = 0 sec. The cue was presented in the centre of the front screen for 3.5 seconds by a virtual object superposed on the virtual panorama, which presented the task the user should perform. The user had been instructed to make a motor imagery during the presentation of the cue. At t = 3.5 sec, the cue vanished and the user stopped imaging for a randomly selected time period (range 2.5 to 3.5 seconds).

For experiments without visual feedback, any online control was not performed. The measurement run was repeated 10 times for each subject. In the experiment with visual feedback, the virtual scene was moved toward left or right direction after the cue vanished, according to the classification results of the BCI system. There were several runs of the experiments with visual feedback. Fig.1 shows the appearance of experimental environment.

Fig.1 A subject and a visual cue in immersing virtual environment

5 Results and discussions

Table 1 shows the classification performance with and without visual feedback. It was found that the CSP algorithm was effective for the BCI system in immersing virtual environment based on motor imageries. With and without visual feedback, the average classification performance was 78.9 and 79.7 %, respectively. Note that the advantage of the present study is in no subject training.

The common spatial patterns during phantom hand movement were investigated to have the dominant component of EEG activities in specific electrodes. Fig. 2(a) shows the three significant components of patterns, projecting the 16-channel electrode montage onto a rectangle map. In phantom left finger tapping, the left side of the hemisphere contributes to the significant spatial patterns, while in right finger tapping the right side does. This can be successfully expressed by the ERD in motor imagery. Note that similar results have been obtained for other two subjects.

Fig. 2(b) shows r^2 topography for subject s3. The r^2 value is the proportion of the variance of the signal feature that is accounted for by the user's intent. Actually, for all subjects the spatial patterns of r^2 did not have localized patterns. In Ref. [9], it was reported that the localized patterns could be observed for well trained subjects. Thus, our results would promote the BCI study with no subject training in immersing virtual environment.

Subject	s1	s2	s3	Average
Without visual feedback	78.0	81.6	77.0	78.9
With visual feedback	78.0	78.1	83.0	79.7

Table.1 Classification performance (percent correct) with and without visual feedback

The effect of the immersing virtual environment on the BCI performance is ambiguous in the present stage. It was reported that characteristics in the CAVE condition is a dominant ERS pattern which was permanently present. In contrast to the CAVE condition, such characteristics are less pronounced ERS pattern in the head-mounted display condition [1].

(a)

(b)

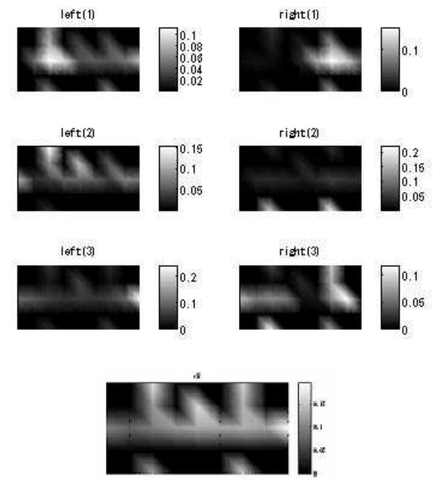

Fig.2 (a) An example of common spatial patterns during motor imagery tasks (Left and right hand) (b) The r^2 topography

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