

A collaborative framework for brain-computer interfaces

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Recent brain-computer interface (BCI) studies have demonstrated the feasibility of using electroencephalogram (EEG) to enhance human performance. For example, event-related potentials (ERP) could be used to accelerate visual target detection using a rapid serial visual presentation paradigm. However, in some environments where real-time operation is critical, current BCIs would fail to make a rapid and accurate prediction of behavior based on single-trial EEG. Under this circumstance, assessing collaborative event-related EEG activities from multiple subjects might provide a potential solution. This study designs and implements a collaborative BCI, in which brain activities from a group of subjects are recorded, synchronized, and fused to better understand and predict the behavior of individuals and groups.

The advantages of collaborative BCIs were demonstrated through a visual target detection task, in which subjects were instructed to reach for a visual target (appeared to the left or right side of central fixation) on a touch screen with the right hand 700ms after the onset of a centered arrow cue. 128-channel EEG data were recorded from 20 healthy subjects on different days with the same 400 target sequences. EEG data prior to actual movement were used to predict the upcoming direction of movements.

Independent Component Analysis (ICA) was employed to remove EEG artifacts including eye and muscle activities. Contralateral negativity with respect to the direction of movement, which might reflect the processing of movement planning, was found in the posterior parietal cortex (PPC) during 180-350ms after the cue onset. The intercepted ERPs from two bilateral PPC electrodes were used as features to a linear discriminant analysis (LDA) based classifier to predict the movement direction. For each subject, single-trial EEG classification was performed separately using a standard machine learning scheme. For collaborative classification, an ensemble classifier was implemented by summing weighted outputs from each subject-specific classifier. A 10x10-fold cross validation was used to estimate the classification performance.

The classification rate was enhanced substantially from $69.1 \pm 5.8\%$ to $86.9 \pm 3.8\%$, $94.7 \pm 2.1\%$, $97.9 \pm 1.0\%$, and $99.0 \pm 0.0\%$ as the number of subjects increased from 1 to 5, 10, 15, and 20, respectively. These results strongly suggested that, when group EEG data are available, a collaborative BCI can effectively fuse single-trial EEG across subjects to improve the overall BCI performance. Collaborative BCIs might have applications in reducing errors in impulsive decision making of a group in chaotic and data-poor environments.