A General Framework for Implementing a Multi-Subject Brain-Computer Interface

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Abstract. Recently, multi-brain computing has attracted growing attention in the fields of cognitive neuroscience and neural engineering. The potential of using a multi-subject brain computer interface (BCI) to improve individual human performance has been proposed and demonstrated in offline studies. However, little is known about the feasibility and practicality to implement such a system. This study proposes a general centralized system framework for implementing an online multi-subject BCI and demonstrates a collaborative BCI for group decision making using the proposed framework. The online test results suggest that the proposed framework can greatly satisfy the technical requirements of an online multi-subject BCI.

Keywords: Multi-brain computing, brain-computer interface (BCI), online BCI, collaborative BCI, decision making

1. Introduction

Two heads are better than one, known as collective intelligence, the mechanism and neural basis of which has recently attracted growing attention of researchers in psychology and neuroscience [Bahrami et al., 2010; Eckstein et al., 2011]. The collective intelligence has also been introduced to the neural engineering field. For example, the potential of using a brain computer interface (BCI) based on multi-brain computing, named collaborative BCI, to improve human performance has been explored by recent studies [Wang et al., 2011; Eckstein et al., 2011]. However, although the theoretical aspects of a multi-subject BCI have been proposed in these studies, a general system framework for developing and implementing an online system has not been well established. Therefore, it is of great importance to provide a general system framework of an online multi-subject BCI to researchers. To this end, this study proposes a centralized system framework of an online multi-subject BCI and demonstrates a collaborative BCI for improving group decision making.

2. Material and Methods

The system framework consists of four major modules: (1) an EEG recording module (comprising multiple EEG amplifiers and data recording computers), (2) a stimulus and feedback presentation module (including multiple LCD monitors, one in front of each subject), (3) a data-analysis module (implementing group EEG data analysis on a server computer), and (4) a control module (performing stimulus generation, feedback generation and synchronization control). Fig. 1 shows a schematic overview of the proposed system. In the system, the EEG data from a group of subjects are recorded with multiple EEG amplifiers synchronized by trigger signals from the computer server. A Media-Key multimedia teaching system delivers visual cues to multiple LCD monitors simultaneously. EEG data from each of the subjects are sent to the server via TCP/IP for real-time group data analysis. Visual feedbacks are presented on the screens to all subjects.

This study used the proposed framework to implement a collaborative BCI for Go/NoGo decision making. During the experiment, a series of images including face images (Go tasks) and car images (NoGo tasks) were presented to the subjects. Seven groups of people (three subjects in each group) participated in the experiment. A 16-channel EEG amplifier was used for collecting data from each subject. A two-layer support vector machine (SVM) classifier was applied to predict the Go/NoGo decision with the first and second levels for individual and group classification, respectively. The experiment comprised a training session used to train the classifiers and a testing session used to evaluate the performance of the system. Each session comprised 120 trials.

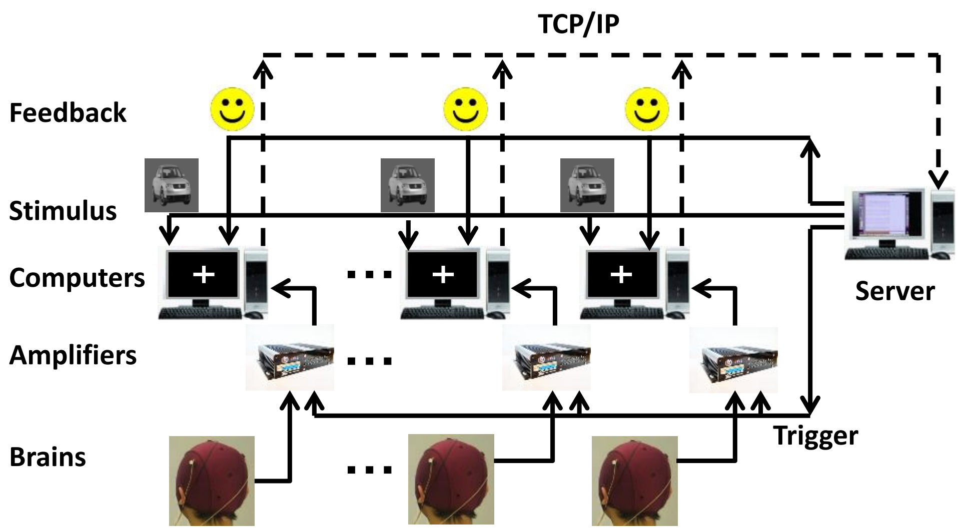

Figure 1. *System framework for an online multi-subject BCI.*

3. Results

Consistent with offline analysis, the online test showed that the collaborative classification significantly improved the performance of the individual classification. Using the EEG data within 300 ms after the stimulus onset, which was about 90 ms earlier than the mean behavioral response time (RT) (393 ± 69 ms), the mean accuracy of the collaborative classification was 82.4 ± 6.1% across all groups. It was 11.6% higher than the average individual accuracy (70.9 ± 6.2%, $p < 10^{-4}$) and 7.6% higher than the best individual accuracy (74.7 ± 4.8%, $p < 10^{-3}$). The results suggest that the proposed framework can greatly satisfy the technical requirements of an online multi-subject BCI.

4. Conclusion

This study demonstrates a general framework for implementing the multi-subject brain-computer interaction. In addition to BCI applications, the proposed framework might have potential for EEG-based group brain imaging of social processes and behavior.

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References

Bahrami B, Rees G, Frith CD, Olsen K, Roepstorff A, Latham PE. Optimally interacting minds. *Science*, 329(5995):1081-1085, 2010.

Eckstein MP, Das K, Pham BT, Peterson MF, Abbey CK, Sy JL, Giesbrecht B. Neural decoding of collective wisdom with multi-brain computing. *Neuroimage*, 59(1):94-108, 2011.

Wang Y, Jung T-P. A collaborative brain-computer interface for improving human performance. *PLoS ONE*, 6(5):e20422, 2011.