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A Hybrid Brain Computer Interface Based on Audiovisual Stimuli P300

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Abstract

Brain Computer Interface (BCI) aims to translate the brain signals, reflecting the neural activities of brain evoked by external stimuli or mental tasks, into the corresponding commands, which thus provides a direct communication between human brain and machine. P300 based BCI has demonstrated to be one of the most reliable and subject independent paradigm. However, the existing P300 based BCI only uses single modality, i.e., visual stimuli evoked potential. In this paper, to further improve the reliability of BCI system, we develop a hybrid BCI by using auditory and visual stimulus simultaneously. Experimental results demonstrate that the event-related potentials evoked by hybrid stimulus are significantly different with single visual evoked potentials, and our hybrid BCI shows more reliable performance than the traditional P300 BCI system.

Keywords: Brain Computer Interface (BCI), Electroencephalography (EEG), Linear discriminant analysis (LDA).

1. Introduction

BCI provides a direct way of communication between brain and outer devices. BCI captures signals reflecting neural activities of the brain under the condition of external stimuli or mental tasks and directly translate these signals into corresponding commands. The basic configuration of BCI is shown in Fig. 1. Because of such characteristics, BCI is attracting attention for physically handicapped people, such as patients with amyotrophic lateral sclerosis and elderly [1]. In the past decades, BCI has been achieved a significant progress in research and application, such as, psychophysiology of P300 [2], auditory oddball ERP [3], checkerboard paradigm [4], BCI mouse [5], BCI wheelchair [6], motor imagery [7], robotics [8], etc.

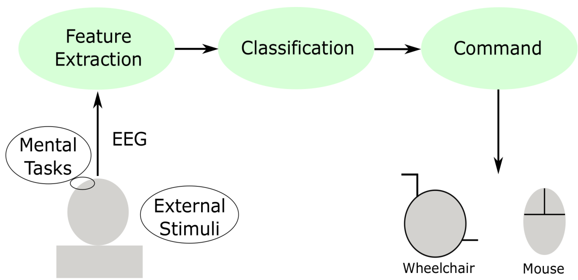

Fig. 1: Basic configuration of BCI

For SSVEP based BCI, LED or liquid crystal display (LCD) are used as a flicker stimulus (from 3 to 70 Hz). When the test subject is looking at the flicker stimulus, the brain signals show significant synchronization with the same frequency of the stimulus [9]. Though SSVEP based BCI is almost effective for anyone [10], the flick stimulus can cause visual fatigue. ERP (event related potential) is the change in potential of brain waves evoked by mental task and cognition [11]. P300 is a kind of ERP which appears 300 ms after the presentation of stimulation (visual, tactile, auditory, olfactory, taste,

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etc.). Motor imagery (MI) based BCI is an interface that users can input commands by imagining the movement of a certain body part [12]. Compare with P300 and SSVEP based BCI, the advantage of MI based BCI is that the stimulus is unnecessary. However, it not effective for anyone.

In the previous studies, the EEG based BCI system usually uses a single type of external stimuli, such as auditory [13] or visual [14] stimuli. By using the single external stimulus, people are easy to be influenced by outside noise and this can affect significantly the experiment results. A comparison of visual stimulus and audiovisual stimulus is given [15]. In this study, we developed a hybrid BCI system based on P300 evoked by auditory and visual stimuli simultaneously. These two type of stimulus can evoke the essentially different ERP with visual evoked ERP. We conduct experiments and show that the enhanced P300 appears under the hybrid stimulus. The experiment results show that P300 evoked by hybrid stimuli provide us a more reliable BCI system with a higher performance than single stimulus.

2. Experiment and Method

2.1. Participants

Four male volunteers aged 20-26 years participated in the experiments. All the participants are healthy and normal vision and hearing. The participants sit in a chair in a quiet room and 30 cm away from an LCD monitor (14 inch, 1920*1080, 60 Hz refresh rate).

2.2. Equipments

We use the g.Tec EEG system (a 32-channel EEG cap (11 electrodes), and a g.USBamp amplifier). The location of the electrodes is selected at Fz, Cp5, Cz, Cp6, Pz, PO7, Oz and PO8. The system is 10-20 international system. The ground electrode is placed on the forehead (Fpz) and the reference electrodes are placed on the left earlobe (A1) and right earlobe (A2). All the electrode locations are shown in Fig. 2.

The EEG signals are amplified and digitized by g.USBamp amplifier with a 256-Hz sampling frequency rate. EEG signals are processed by a bandpass filter between 0.5-30 Hz and a notch filter 50 Hz to remove the AC artifacts. All the processes are controlled by Simulink/Matlab (Mathworks Inc., USA).

2.3. Auditory stimuli experiment

In the auditory stimuli experiment, the image shown in Fig. 3 is displayed on the LCD monitor. Number 1 to number 8 represents 8 different targets, characters under the numbers represented the

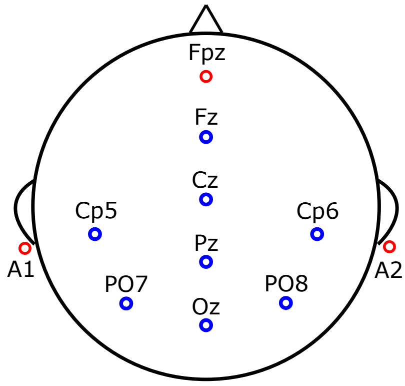

Fig. 2: The location of electrodes

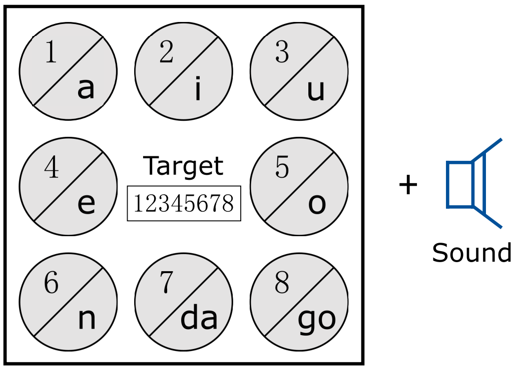

Fig. 3: Auditory stimuli based experiment

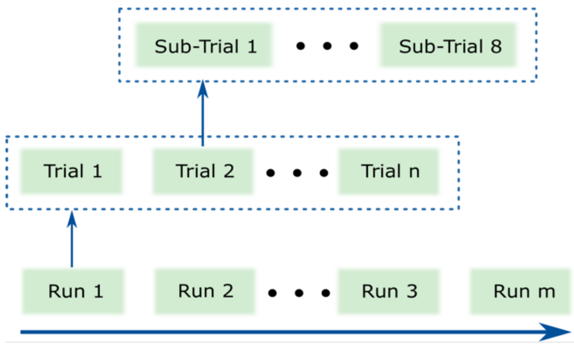

Fig. 4: Experiment process

corresponding sounds for each number. The target number sequence is displayed in the center target box.

Experiment contains a training phase and an online test phase. In the training phase, 8 different targets are set as 8 runs, and each run consists of 5 trials. Every trial has 8 sub-trials, shown in Fig. 4 (m = 8, n = 5). At the beginning of each trial, there is a one second stop for the subject to see the target number, then 5 trails will perform. In every trial, 8 auditory stimuli (sub-trial) randomly play the 8 sounds for once, the auditory stimulus presentation

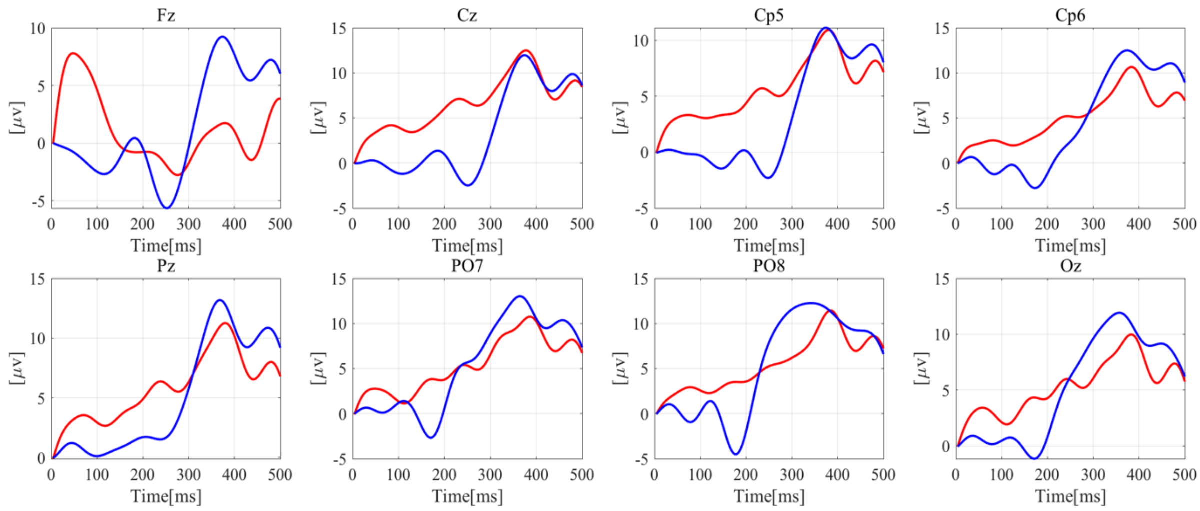

Fig. 6: P300 component

duration is 150 ms and inter stimulus interval (ISI) is 100 ms. Participants are instructed to perceive the target sound and silently count how many times the target sound has happened.

In each sub-trial, a 500-ms data segment of EEG after baseline corrected by 100-ms pre-stimulus interval is extracted. The training phase includes 320 data segments consist of 40 targets and 280 non-targets. Then the 320 data segments are used to train a linear discriminant analysis (LDA) classifier which is applied to the online test.

In the online test phase, we perform 30 target numbers (30 runs, m = 30), and each run consists of 2 trails (n = 2). In each sub-trail, a data segment is extracted, and use the classifier to calculate the posterior probability for the target class. Then, the stimulus number with the maximal posterior probability is considered as the target number.

2.4. Audiovisual stimuli experiment

In the audiovisual stimuli experiment, when the auditory stimulus is happening, at the related number's location, a face image appears, as shown in Fig. 5. The image stays for 150 ms and then disappears for 100 ms. Participants are instructed to focus on the location of the target number and to silently count how many times the target (sound and image) has happened.

3. Experiment Results

The results of the P300 component in each channel are shown in Fig. 6. The red curve represents the average of the target P300 component by auditory stimuli and the blue curve represents the average of the target P300 component by audiovisual stimuli. From these results, we can see the target P300

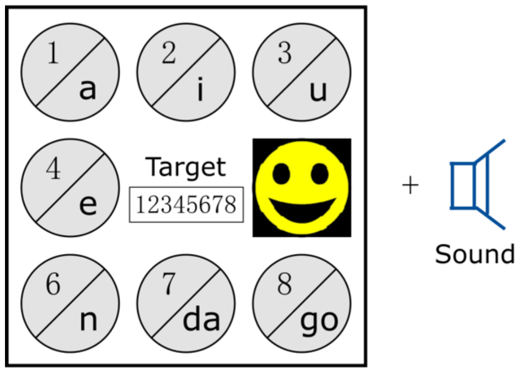

Fig. 5: Audiovisual stimuli experiment

component by audiovisual stimuli is more enhanced than the target P300 component by auditory stimuli.

We conduct the experiment 4 times with 4 participants. The accuracy of classification results is shown in Fig. 7, from this result, we can see for each subject the classification accuracy of audiovisual stimuli is higher than the classification accuracy of auditory stimuli. The average value of the results for 4 participants is shown in Fig. 8. As can be seen from the results in Fig. 7 and 8, the accuracy of audiovisual stimuli is higher than the accuracy auditory stimuli.

4. Conclusions

In this paper, we developed a hybrid BCI system based on P300 evoked by auditory and visual stimuli simultaneously, From the results, we can see the target P300 component by audiovisual stimuli is more obvious than the target P300 component by auditory stimuli, and the classification accuracy of audiovisual stimuli is higher than the classification accuracy of auditory stimuli. Future works will focus

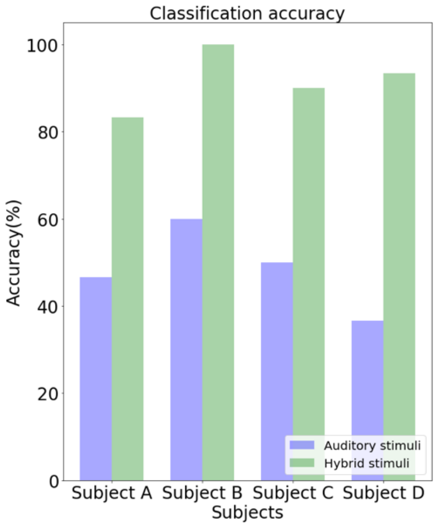

Fig. 7: Classification accuracy

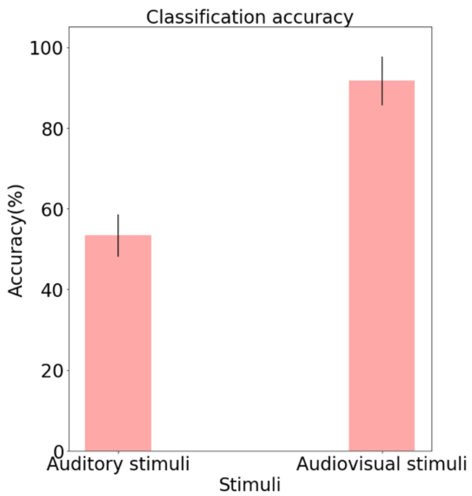

Fig. 8: Average classification accuracy

on different stimulus and improve the accuracy of classification.

Acknowledgements

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References

[1] J.R. Wolpaw, N. Birbaumer, D.J. McFarland, G. Pfurtscheller, and T.M. Vaughan, "Brain-computer interfaces for communication and control," *Clinical Neurophysiology*, pp. 767-791, June 2002.

[2] W.S. Pritchard, "Psychophysiology of P300," *Psychological Bulletin*, pp. 506-540, May 1981.

[3] A. Furdea, S. Halder, D.J. Krusienski, D. Bross, F. Nijboer, N. Birbaumer, and A. Kubler, "An auditory oddball (P300) spelling system for brain computer interfaces," *Psychophysiology*, pp. 617-625, May 2009.

[4] G. Townsend, B.K. LaPallo, C.B. Boulay, D.J. Krusienski, G.E. Frye, C.K. Hauser, N.E. Schwartz, T.M. Vaughan, J.R. Wolpaw, and E.W. Sellers, "A novel P300-based brain-computer interface stimulus presentation paradigm: Moving beyond rows and columns," *Clinical Neurophysiology*, pp. 1109-1120, March 2010.

[5] T. Yu, Y. Li, J. Long, and Z. Gu, "Surfing the internet with a BCI mouse," *Journal of Neural Engineering*, pp. 036012, June 2012.

[6] C. Tom, L. Robert, M. Guillaume, and A.K. Abdul, "Driving a BCI wheelchair: A patient case study," *Proceedings of TOBI Workshop lll: Bringing BCIs to End-Users: Facing the Challenge*, pp. 59-60, March 2012.

[7] H. Petar, S.E. Teodoro, N. Christa, and M.P. Gernot, "Combined motor imagery and SSVEP based BCI control of a 2 DoF artificial upper limb," *Medical & Biological Engineering & Computing*, pp. 567-577, May 2011.

[8] Y. Chae, J. Jeong, and S. Jo, "Toward brain-actuated humanoid robots: Asynchronous direct control using an EEG-based BCI," *IEEE Transactions on Robotics*, pp. 1131-1144, October 2012.

[9] D. Regan, "Steady-state evoked potentials," *Journal of the Optical Society of America*, pp. 1475-1489, November 1977.

[10] B. Allison, T. Luth, D. Valbuena, A. Teymourian, I. Volosyak, and A. Graser, "BCI demographics: How many (and what kinds of) people can use an SSVEP BCI?," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, pp. 107-116, April 2010.

[11] S.J. Luck, "*An introduction to the event-related potential technique*," The MIT Press, pp. 7-9, August 2005.

[12] G. Dornhege, J.d.R. Millan, T. Hinterberger, D.J. McFarland, and K.R. Muller, "*Toward brain-computer interfacing,*" The MIT Press, pp. 399-401, July 2007.

[13] M. Schreuder, T. Rost, and M. Tangermann, "Listen, you are writing! Speeding up online spelling with a dynamic auditory BCI," *Frontiers in Neuroscience*, pp. 1-12, October 2011.

[14] Y. Wang, Y.T. Wang. and T.P. Jung, "Visual stimulus design for high-rate SSVEP BCI," *Electronics Letters*, pp. 1057-1058, July 2010.

[15] G. Cui, Q. Zhao, J. Cao, and A. Cichocki, "Hybrid-BCI: Classification of auditory and visual related potentials," *International Conference on SCIS and ISIS*, pp. 297-300, December 2014.

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