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Error Analysis of the Region-Based P300 BCI

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Abstract. Recently, there have been several attempts to improve the P300-based brain computer interface (BCI) paradigm by going beyond the matrix-based or row/column P300 design introduced around 25 years ago. Region-based paradigm was introduced as an efficient paradigm for eliciting P300 in 2008. In this paradigm, characters are presented in seven regions on the screen and regions are flashed randomly in two levels. In this region-based paradigm 49 characters, numbers and signs are presented. The efficiency and acceptability evaluating parameters such as information transfer rate, accuracy and adjacency error showed improvement by implementing region-based paradigm in several other publications. In this paper, an analysis is performed on the accuracy of each region for the data collected from 10 subjects.

Keywords: EEG, BCI, P300, Paradign Design, Region-based P300

1. Introduction

In P300 BCI systems, spelling based on the paradigm introduced by Farwell and Donchin [Farwell and Donchin, 1988] has been one of the most discussed and used paradigms. In this Row/Column (RC) paradigm, a 6 by 6 matrix of characters and symbols was presented for spelling application, in the way that the rows and columns were flashed randomly based on an oddball paradigm. P300 BCI has also been used in other applications such as virtual environment, smart home, and wheelchair control [Su et al., 2011; Edlinger et al., 2011; Rebsamen et al., 2008]. In an error analysis done in [Fazel-Rezai, 2007], it was shown that there is human error in generating false P300 due to adjacency of character in the matrix-based paradigm. Therefore, a region-based (RB) paradigm was introduced [Fazel-Rezai and Abhari, 2008; Fazel-Rezai and Abhari, 2009]. Several other paradigms (e.g., [Townsend et al., 2010]) have also been investigated to improve the performance of the P300 BCI in which the paradigm is not based on row/column flashing. In our other papers, RC and RB paradigms are compared and adjacency problem of RC paradigm is discussed [Fazel-Rezai, 2007; Gavett et al., 2012], however in this paper the objective is to investigate the adjacency problem in RB paradigm.

2. Material and Methods

The idea of RB paradigm [Fazel-Rezai and Abhari, 2008] is to have flashes of several regions instead of rows and columns. In the first level (level 1) of the paradigm 49 characters, numbers and signs are presented in seven regions. In each region, 7 characters are located. Regions are flashed randomly and as one region is selected, the paradigm goes to the second level (level 2). In the level 2, the 7 character of the selected region are placed in the region with the same pattern. The placement of the regions is shown in Fig. 1. Similar to the Farwell and Donchin paradigm, the user is instructed to attend a specific character in one of the 7 groups while each group of 7 characters randomly flashes. After several flashes of each group the desired group is identified. In the second level, individual characters of the selected group are distributed into the 7 regions. Similarly to the first level, different regions are flashed while the subject attends to one region (i.e., character). The desired character is selected by identifying one of the 7 regions. In this paper, we performed an analysis to determine if there is any difference in error of each region and if there is any adjacency similar to what was reported in row/column paradigm [Fazel-Rezai, 2007]. For this purpose the experiment was done for 10 normal subjects (2 females) ranging in age from 19-29. Subjects were explained the procedure, asked to read and sign the consent form obtained from the Institutional Review Board (IRB) from the University of North Dakota (UND). Subjects were seated in front of a computer screen, and were told to relax and avoid any unnecessary movements during testing. Products of Guger Technologies (g.tec) were used, including g.GAMMAbox and g.USBamp for recording and g.BSanalysis for classification. MATLAB and Simulink were used for the paradigms on the computer. Eight channels, FZ, CZ, PZ, OZ, P3, P4, PO7, and PO8, based on 10-20 system

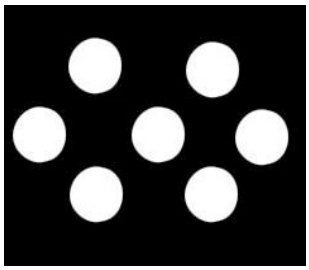

Figure 1. *Regions.*

were utilized for signal recording. An electrode at the FPZ location was considered as a ground channel and one electrode on the right mastoid was considered as a reference. Subjects had calibration and training with spelling two words 'WATER' and 'LUCAS'. The training repeated three times base on linear discriminant analysis (LDA) classifier. After training, the word 'PEBBLE!' appeared on top of the screen and subjects' task was to copy spelling all characters. Each character was flashed six times. After the character was selected, it was shown under the intended character. After finishing the first word, subjects copy spelled 'MX85+Z&'. The characters of the words were selected in the way that all regions would be selected four times. The time required for spelling each character was 21 seconds. Subjects filled out two questionnaires for evaluation of their fatigue level, mood, and feelings.

3. Results

The errors in a row/column paradigm were reported in a matrix of numbers where at the center of the matrix all correct spelling and to the left/right and top/bottom of the center errors were displayed [Fazel-Rezai, 2007]. This approach was followed later by several authors [Townsend et al., 2010; Fazel-Rezai and Abhari, 2008], which has advantage that the adjacency problem can be clearly identified in the paradigm. In a similar analogy, the correct detection of target and the errors for a region-based paradigm for 10 subjects are displayed in Fig. 2. The center circle with black background shows the target region and surrounding circles show the error in each region based on the distance from the target region. The difference of error for two words had less than 1% difference. The average accuracy of all 10 subjects for both words was 84.06% and 80.96% for levels 1 and 2, respectively.

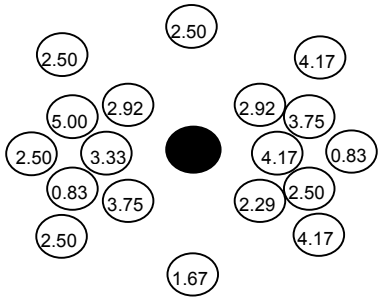

Figure 2. *Region error distribution (%).*

4. Discussion

A similarity with less than 1% difference for two words shows that there is no difference in spelling a word with specific meaning and a collection of characters and symbols. Comparing accuracy obtained for level 1 and level 2 showed no significant difference. The distribution of the errors in Fig. 1 also shows that there is no dominant region with high error. Therefore, compared to the row/column paradigm that its accuracy can be affected by adjacent characters due to false generation of P300, the adjacency did not have any effect of the accuracy in the region based paradigm.

References

Edlinger G, Holzner C, Guger C. A hybrid brain-computer interface for smart home control, *Proceedings of the 14th International Conference on Human-Computer Interaction, Interaction Techniques and Environments*, 417-426, 2011.

Farwell L, Donchin E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. *Electroenceph Clin Neurophysiol,* 70:510-523, 1988.

Fazel-Rezai R. Human error in P300 speller paradigm for brain-computer interface. *29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2516-2519, 2007.

Fazel-Rezai R, Abhari K. A comparison between a matrix-based and a region-based P300 speller paradigms for brain-computer interface. *Conf Proc IEEE ENG Med Biol Soc,*1147-1150, 2008.

Fazel-Rezai R, Abhari K. A region-based P300 speller for brain-computer interface. *Can J Elect Comput Eng*, 34:81-85, 2009.

Gavett S, Wygant Z, Amiri S, Fazel-Rezai R. Reducing Human Error in P300 Speller Paradigm for Brain Computer Interface. *34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* 2869-2872, 2012.

Rebsamen B, Burdet E, Zeng Q, Zhang H, Ang M, Teo C, Guan C, Laugier C. Hybrid P300 and Mu-Beta brain computer interface to operate a brain controlled wheelchair. *Proceedings of the 2nd International Convention on Rehabilitation Engineering and Assistive Tech*, 51-55, 2008.

Su Y, Qi Y, Luo J, Wu B, Yang F, Li Y, Zhuang Y, Zheng X, Chen W. A hybrid brain-computer interface control strategy in a virtual environment. *J Zhejiang Univer Sci C*, 12:351-361, 2011.

Townsend G, LaPallo BK, Boulay CB, Krusienski DJ, Frye GE, Hauser K, Schwartz NE, Vaughan TM, Wolpaw JR, Sellers EW. A novel P300-based brain-computer interface stimulus presentation paradigm: moving beyond rows and columns. *Clin Neurophysiol,* 121:1109-1120, 2010.