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A Motor Imagery Based Asynchronous BCI Speller

B. Xia[1,2], J. Yang[1], C. Cheng[1]
[1]Shanghai Maritime University, China; [2]University of Tuebingen, Germany

Correspondence: B. Xia, Shanghai Maritime University, China. E-mail: binxia@shmtu.edu.cn

Abstract. In this paper, we present a motor imagery based asynchronous BCI speller. The speller paradigm is implemented by combining 2D control strategy and a mental switch in a well designed interface, in which the mental switch and 2D control are both based on a three-class motor imagery system. The experimental results (two subjects participated) demonstrates the satisfactory performance of the proposed speller.

Keywords: Motor Imagery, Asynchronous protocol, BCI speller

1. Introduction

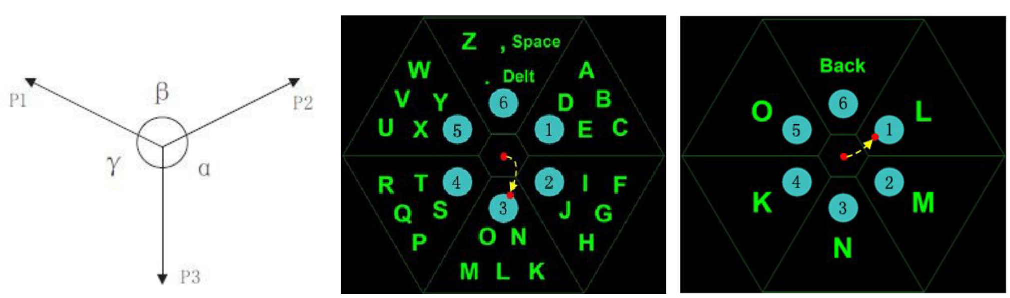
Motor imagery based BCI spellers cannot use full size virtual keyboard on the screen due to their limited commands. Therefore, motor imagery based speller always has a special interface. Depending on the operation protocol, BCI spellers work in synchronous and asynchronous modes, whereas the latter is a natural course of interaction that spells the characters depending on user's intention. In this paper, we developed a motor imagery based asynchronous BCI speller, which combines 2D cursor control strategy and a mental switch in Hex-o-Spell interface [Blankertz et al., 2006].

2. Material and Methods

2.1. 2D control strategy and asynchronous protocol

In a previous study [Xia et al., 2012], we presented a three-class (left hand, right hand and feet) motor imagery based BCI for 2D cursor control. The predicting probabilities (P1, P2, P3), obtained from Support Vector Machine classifier, are projected to three vectors, as shown in Fig. 1(a). P1, P2, and P3 are the probability of the left hand, right hand, and feet imagery respectively. The angle between two vectors is 120 degree and the norm of the vector is equal to the value of the corresponding output probability. To hit the target located in the area between two vectors, the user performs two corresponding motor imagery tasks simultaneously to generate a speed vector, by which the cursor is driven directly to the target.

To work in asynchronous mode, the motor imagery mental switch needs to be opened prior to spell, for which the predicted probability of the motor imagery task should exceed a threshold in a duration $\triangle t$. Considering variation of the user's status, we set three conditions for the mental switch: (1) threshold 0.9 with duration 0.5 s; (2) threshold 0.85 with duration 1.0 s; (3) threshold 0.8 with duration 1.5 s. If the user achieves one of the three conditions, the switch opens.



(a) (b) (c)

Figure 1: *Speller paradigm (a) three-class MI based 2D control, (b) first layer, (c) second layer.*

2.2. Asynchronous spelling paradigm

We designed a novel Hex-o-Spell interface consisting of two-layer structure as shown in Fig. 1(b,c). In the first layer, each block includes five letters (or specific symbols) and a target ball, while in the second layer, there are only one letter and a target ball in each block. At the beginning of experiment, the user opens the mental switch and uses 2d control strategy to move the cursor to hit the ball of the block with target letter in the first layer (Fig. 1b). And then, the paradigm will extend to the second layer (Fig. 1c). Following the movement of the cursor to hit the ball of the target block, the speller outputs a letter and ends the current trial. Then, the system automatically changes to idle state automatically and begins to monitor mental switch.

Table 1: *Average Accuracy, CPM, ITR and Switch type*

Subject	Accuracy (%)	CPM	ITR (bits)	Switch type1 (%)	Switch type2 (%)	Switch type3 (%)
S1	100	11.90	61.54	91	7	1
S2	100	9.74	50.34	97	2	1
Mean	100	10.82	55.94	94	4.5	1.5

3. Experiment

The EEG was measured using a 16 channel g.USBamp system using band-pass filtered between 5 and 30 Hz and sampled at 256 Hz. Electrodes were placed according to the international 10–20 system. Thirteen channels in motor cortex area were selected (FC3 FCz FC4 C5 C3 C1 Cz C2 C4 C6 CP3 CPz CP4), the ground and reference electrodes were fixed on Fz and the right earlobe respectively. Two subjects participated this study, and they both joined previously 2D control experiment [Xia et al., 2012].

In online spelling experiment, each subject spell English word in 3 runs (Run1 WOMEN DESK WATER HAND MEMORY; Run2 ZONE BABY FACE TAXI JUNE; Run3 QUICK VIDEO GOLF HOUR PENCIL). Subject repeated the experiment 3 times. We set the ‘no’error protocol in this experiment that means subject should correct spelling mistake.

4. Results

To evaluate the performance of the proposed speller system, we calculated the accuracy, the characters per minute (CPM), information transfer rate (ITR). As shown in Table.1, the average spelling accuracy is 100 % for two subjects. The average CPM and ITR are 10.82 letters/min and 55.94 bits/min respectively. To evaluate the efficiency of switch, we calculated the percentage of switch type using in online experiment. Two subjects used switch type1 over 90 % that means they can switch from idle state to work state in 0.5 s. Both users rarely use switch type 2 and 3.

5. Discussion

In general, the performance of motor imagery based BCI speller is not good as visual stimuli based speller due to its limited commands. In this work, we developed an asynchronous BCI speller only using three-class motor imagery tasks. Comparing with recently published synchronous speller with average CPM 9.39 [Hwang et al., 2012], our results are satisfactory and comparable.

Acknowledgments

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