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Explorer Based On Brain Computer Interface

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***Abstract*—In recent years, various applications which apply the hybrid brain computer interfaces (BCIs) have been studied. In this paper, we present a hybrid BCI system to operate the explorer with P300 and motor imagery, which is mainly composed of a BCI mouse, a BCI speller and an explorer. Through this system, the user can access to his computer and manipulate (open, close, copy, paste, delete) files such as documents, pictures, music, movies and so on. The system has been tested with 5 subjects, and the experimental results show that the explorer can be successfully operated according to subjects' intention with only a small number of mistakes.**

Keywords—Brain computer interface (BCI), BCI mouse, BCI speller, explorer

I. INTRODUCTION

As a communication technology for individuals with disabilities, brain computer interface (BCI) can convert electroencephalogram (EEG) into control signals [1]. The main source of the EEG is the brain electrical activity recorded from electrodes placed onto the scalp .The signals used in noninvasive BCI studies to date usually include P300 potentials [2], steady-state visual evoked potentials (SSVEP) [3], slow cortical potentials [4], and event-related desynchronization/ synchronization (ERD/ERS) produced by motor imageries [5].At present applications based on BCI have been developed rapidly, there are virtual typewriter [6], cursor control [7], gaming, robotic arm [8], wheelchair control [9, 10], etc.

Computers as a work and entertainment tool are really widely used in daily life. People are often store a variety of files on the computer. If patients who suffer from motor disabilities can use EEG to access to my computer and can open, scan and close files (such as documents, pictures, music, movies, etc), these patients will greatly extend the range of communication, learning and entertainment. Perhaps because this system involves many aspects of knowledge in BCI, at present no BCI explorer has yet been reported in the literatures. In this paper, we propose a BCI explorer as a novel application. This system allows direct control of a computer by thought. It's very convenient for users to access to my computer and manipulate files with EEG signal.

The implementation of explorer based on the BCI is faced with many problems. The first question is how to realize a BCI mouse. In our previous studies [11, 12], we presented a hybrid BCI incorporating P300 and motor imagery for BCI mouse. When we use the BCI mouse, the user can move the cursor from an arbitrary initial position to an arbitrary target position, while the user also can click or not click on the target of interest (termed a target selection or rejection). This BCI mouse has been successfully applied to a BCI browser for Internet surfing [13]. The second question is how to realize a speller, which is used to input the path. In this system we use a simple prototype P300 speller with 50 buttons and it is also achieved in previous studies [14]. The last question is how to design an appropriate explorer. In this paper, we implement a simple BCI explorer based on our BCI mouse. Using this system, the subject can finish Windows Explorer's basic functions. the subject can access to my computer and manipulate (open, close, copy, paste, delete) files such as documents, pictures, music, movies and so on. To evaluate our system, 5 subjects are requested to do a series of operations in the BCI explorer. The results of the online experiment show the explorer can be successfully manipulate files according to subjects' intention with only a small number of mistakes.

The remainder of this paper is organized as follows. The implement method including the system paradigm, BCI mouse, BCI speller is presented in Section II. The experimental results and discussions are presented in Section III. Further discussions on the system are involved in section IV. Finally, Section V concludes the paper. Section IV finally concludes the paper.

II. METHODOLOGY

A. System Paradigm

The graphical user interface (GUI) of BCI explorer is shown in Fig. 2. There are eight buttons on the margins of GUI, including three "UP" buttons, three "DOWN" buttons and two "STOP" buttons. These buttons flash in a random order to elicit P300 potentials for the control of the vertical movement of the mouse. During the process of mouse control, one of buttons temporarily changes the color from black to bright green at 120ms intervals, and the stimulus remains bright green for 100ms. In this system, we control mouse movement by combining two brain signals: P300 and motor imagery, which control the vertical and the horizontal movement of the mouse separately [11]. The user devotes his attention to the button towards which the mouse should move, if the subject wants to move the mouse up (down), then he or she should focus on one of the three "UP" ("DOWN") buttons. If the user wants to move the mouse towards right (left) side, the subject could imagine movement of the right (left) hand. Finally, if the user does not want to move the mouse, then the subject should focus on one of the two "STOP" without motor imagery. Although the user with the brain wave can control the mouse movement freely, we also need to simulate the mouse to

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click. The target selection or rejection is implemented using a hybrid feature composed of the motor imagery and P300 features. When the mouse reaches the target which can be clicked and is interesting, the user can select it by focusing on one of the flashing button “STOP” in the explorer GUI and making no motor imagery. Conversely, the user can reject it by continuing motor imagery and ignoring all buttons. For example, when the mouse moves to “Local Disk(C:)” (target area) in this system, user needs to make a decision to click it (target selection) or ignore it (target rejection). The “Local Disk (C:)” is clicked by paying attention to the “STOP” button without any motor imagery, and then the explorer will refresh to list all the folders and files on the local disk (C:) of the computer, otherwise, mouse keeps on moving. Fig. 1 illustrates the flowchart of the system.

The explorer is embedded in the center area. The system can finish some Windows Explorer's basic functions with BCI mouse and BCI speller as below:

1) The user can click local disk (C, D, E, F) and desktop directly into the path, and corresponding folders and files will be shown (as shown in Fig. 2).

2) The user can click folders to go into the folder. If the user wants to go into a path which contains many folders, the user is able to search for specified path through address bar. The address bar is used for path editing (as shown in Fig. 4). Once the user completes path spelling, he or she needs to click “Turn” button. If the user wants to back to parent directory, then he or she can click “Back” button.

3) The user clicks specified file in the list control, it will display a pop-up menu for selection (as shown in Fig. 3), so that the user can manipulate (open, copy, paste, delete) files.

4) When specified file is opened, the user can click red “close” button to close the file. Besides, if the user opens text file, he or she can page up and page down to browse document.

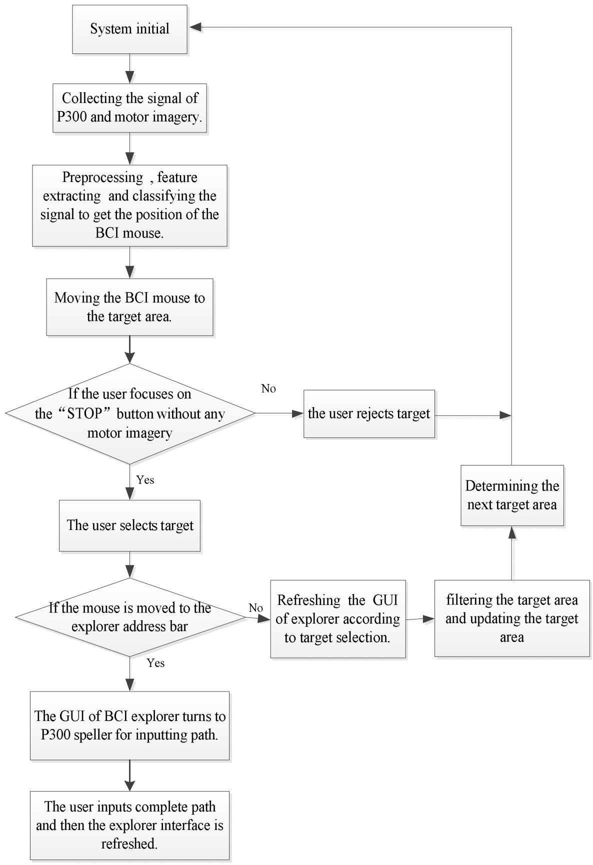

Fig. 1. System flowchart of explorer based on BCI

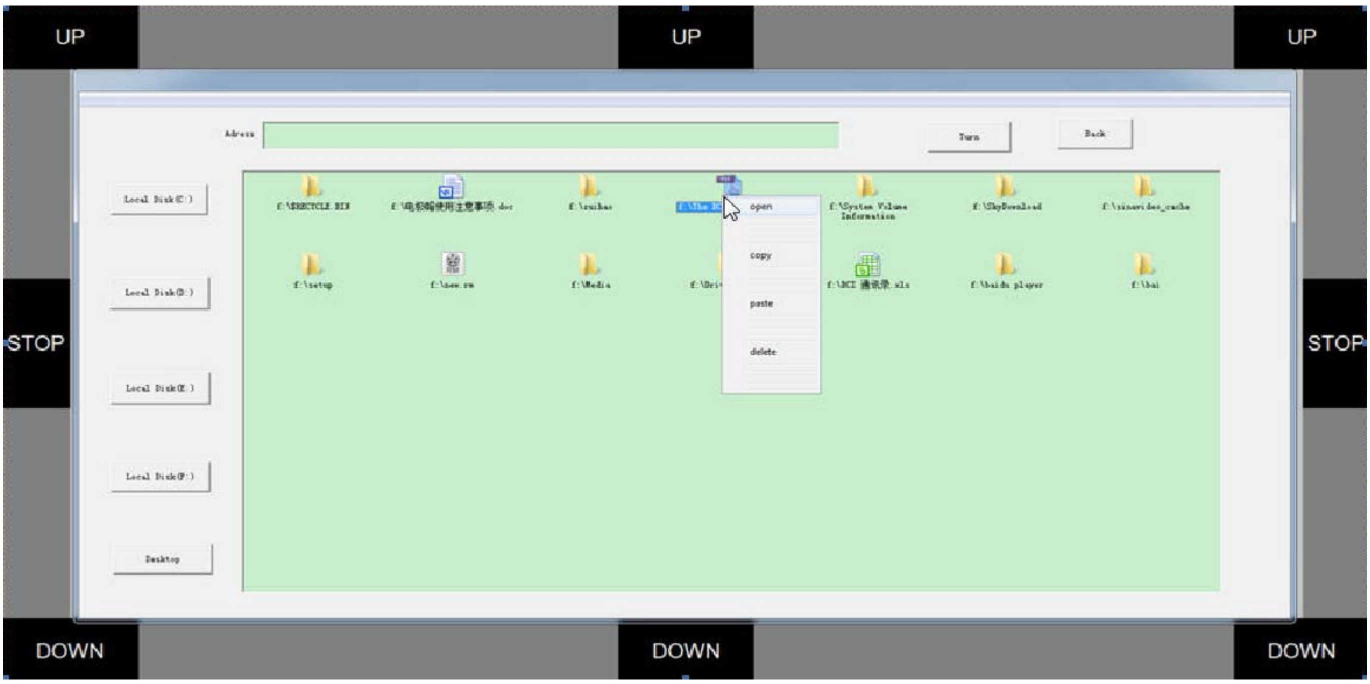

Fig. 2. The interface of the explorer with pop-up menu. Once user clicks file, it will display a pop-up menu for selection.

B. BCI Mouse

1) Mouse movement control: During the process of mouse control, the mouse's position is updated every 200ms according to the results of the P300 and motor imagery detections. The algorithm of the P300 detection and the motor imagery see [11].

2) Target selection or rejection: The user can select target by focusing on one of the “STOP” buttons in the explorer GUI and making no motor imagery. Conversely, the user can reject target by continuing motor imagery and ignoring all buttons. We now need to distinguish two classes, the one is motor imagery without P300 (target rejection), the other is P300 without motor imagery (target selection). The algorithm for detecting P300 is similar to that used in the mouse movement, but we now distinguish between motor imagery (left hand or right hand motor imagery) and idle state. According to the theory of CSP [14], $\overline{W}$ is a transformation matrix, which is composed by the first and last three columns of CSP spatial filter W. Usually the last three entries are larger than values of the first three entries in the right-hand class in W, values of the last three entries are smaller than values of the first three entries in the left-hand class. When there is no motor imagery, these values have not significant difference, so we can reverse the feature vector of right-hand, then the feature vectors of left-hand and right-hand motor imagery become one class. After the feature vectors of P300 and motor imagery are extracted respectively, the hybrid feature is composed of the P300 feature and motor imagery feature. Finally, we feed the hybrid feature vectors into an SVM algorithm to perform the classification.

C. BCI speller

If there are a lot of folders in the BCI explorer and the mouse operation is complicated, the user can use address bar directly into a specified path. When the mouse is moved to the explorer address bar and clicked, it will appear a simple prototype P300 speller (see Fig.4) for inputting path [14]. The stimulus interval is 30ms and each character is intensified for 100ms. These characters flash in a random order to elicit P300 potentials. The algorithm used for detecting P300 event-related potential is similar to that used in the mouse's vertical movement control. In this BCI speller, The subject only needs to focus on the flashing button which he or she wants to input. Through the 50 buttons we can input different characters, numbers and punctuations. In addition, there are many control buttons{“Ctrl/Shift” (Ctrl+Shift), “SPACE”, “PgUp” (Page Up), “PgDn” (Page Down), “DEL” (Delete)} except “OK” and “BACK”, which imitate those in the keyboard of a computer. The “BACK” button clears all of the input characters. If the user inputs complete path, the “OK” button returns to the explorer interface.

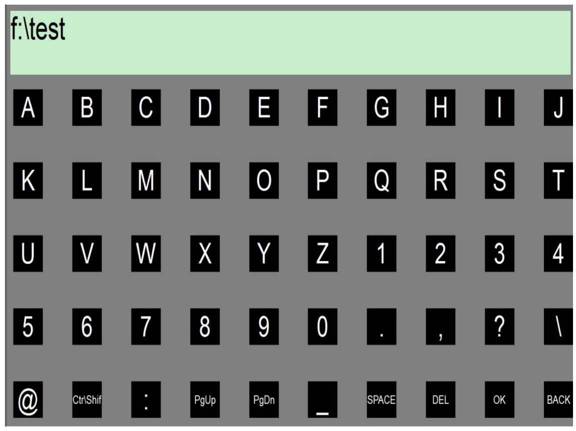

Fig. 3. The P300 speller of BCI explorer

III. Experimental Results

Five subjects, four males and a female, aged from 20 to 28, attended the experiment. The EEG signals were recorded with a SynAmps2 amplifier at a sampling rate of 250Hz. To evaluate our system, each subject was requested to perform the following 6 sequential operations in the BCI explorer as below:

1) The subject first moved mouse to address bar, and input “F:\ test” with the P300 speller.

2) After the subject entered the fold “F:\test”, he or she copied the file “paper.pdf”.

3) The subject moved mouse to “desktop” button and selected it.

4) The subject pasted the file “paper.pdf” to the desktop.

5) The subject opened the file “paper.pdf”.

6) Using the BCI mouse, the subject paged up and paged down to browse the document, and then closed it.

Before our online experiments, three training datasets were collected for each subject to set parameters of the three models as below. For collecting Dataset I, the user attended a P300 training session with the same GUI of the P300 speller (Fig. 4). The P300 training session contained 30 trials. In each trial, the subject was instructed to focus on a button randomly give by the system. The P300 classification model was trained with Dataset I. The Dataset II was collected in a motor imagery training session containing 40 trials. In each trial, the subject was instructed to imagine the movement of the left or the right hand according to the cue (left/right arrow) on the screen. The motor imagery classification model was trained with Dataset II. The Dataset III was collected to establish a classification model for target selection/rejection. There were three types of cues. An upward arrow indicated an operation of selection. In this case, the subject should pay attention to the “STOP” button without any motor imagery. The other two types of cues were the same as those in the motor imagery training session. The left/right arrow indicated that the subject performed left or right hand motor imagery without paying any flashing button. After 40 trials, we trained a classifier for differentiating the two classes: motor imagery without P300 and P300 without motor imagery. Then we used the three models for the online experiment of the explorer.

In the online experiment, the subject were instructed to carry out the above six tasks for four times. Note that the subjects needed to perform at least twelve selections and input seven characters to carry out the six tasks. If an unintended target was selected, the subject could perform some actions to remedy. If an unintended character was inputted, the subject could pay attention to the "DEL" button to delete it. Table 1 shows the average results of the online experiment for four times, including the average number of selection operations, the average number of inputted characters, the average time of text spelling and the average time for performing the six tasks.

TABLE I. THE AVERAGE RESULTS OF THE ONLINE EXPERIMENT FOR FOUR TIMES.

Subject	No. selections	No. characters	Spelling time(s)	Trial time(s)
S1	13	7.5	75	633.24
S2	13.5	9	80.10	811.15
S3	14.5	7.5	69.75	873.55
S4	14	8.5	80.75	1110.06
S5	14.5	8.25	69.52	1020.12
average	13.9	8.15	72.77	889.62

IV. DISCUSSIONS

From Table 1, we can find out that the hybrid BCI with the P300 and motor imagery is functioning properly in our system, and results of all the five subjects are satisfactory. For 6 sequential operations, the subjects must perform at least 12 selections and input 7 characters .The results of the online experiment show subjects can successfully finish experiment at average 13.9 selections and average 8.15 characters within average 889.62s. In a word, subjects can freely move, select an intended target and input text in the explorer with only a small number of mistakes.

Although our experimental results show that this BCI resource manager has realized some simple and basic functions, our system needs to be improved and extended in the future. Firstly, the control time of each trial is not short. The main reason is that detecting P300 and text inputting are time consuming, so improving the speed of the system is our future work. Secondly, we set the speed of the mouse according to the experience in this system, because the speed of the mouse also affects mouse control, we can choose the speed based on a certain principle. Thirdly, we can extend several other functions for the system. Finally, it will be of great interest to verify whether this system works for paralyzed subjects.

V. CONCLUSIONS

This study presents a BCI explorer as a computer application of our hybrid BCI combining motor imagery and P300. Common functions of an explorer, including accessing to disks and folders, opening, closing, copying, pasting and deleting files, have been implemented in this system. Experimental results show that the subjects could perform these simple and basic operations through the BCI explorer. In the future, we need to improve this system especially for paralyzed patients' use.

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