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# A brain computer interface-based explorer☆

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## HIGHLIGHTS

- We propose a file explorer based on a BCI mouse.
- Common functions of an explorer have been implemented in the BCI system.
- Experimental results prove the feasibility of the system.

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## ABSTRACT

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



## 1. Introduction

As a communication technology for individuals with disabilities, brain computer interfaces (BCIs) can convert electroencephalogram (EEG) into control signals (Wolpaw et al., 2002). The signals used in EEG-based BCIs to date usually include P300 potentials (Farwell and Donchin, 1988), steady-state visual evoked potentials (SSVEP) (Kelly et al., 2005), slow cortical potentials (Schwartz, 2004), and event-related desynchronization/synchronization (ERD/ERS) produced by motor imageries (Pfurtscheller and Lopes, 1999). At present, the applications based on BCI have been developed rapidly, which include virtual typewriter (Birbaumer et al., 1999), cursor control (Fabiani et al., 2004), gaming, robotic arm (Velliste et al., 2008), wheelchair control (Rebsamen et al., 2010, 2007), etc.

Computers are widely used in daily life. For instance, we often store a variety of files in a computer and manipulate them. If patients who suffer from severe motor disabilities can use EEG to access a computer and open, read and close the stored files (such as documents, pictures, music, movies, etc.), they would greatly extend the range of communication, learning and entertainments. However, there has been no a BCI explorer reported in the literatures.

In this paper, we propose a BCI explorer as a novel application. This system allows the user to access a computer and manipulate the stored files with EEG signals. The implementation of our BCI explorer include the following three aspects. The first is to realize a BCI mouse. In our previous studies (Long et al., 2012; Li et al., 2010), we implemented a hybrid BCI incorporating P300 and motor imagery for cursor control. Using this system, the user can move the cursor from an arbitrary initial position to an arbitrary target position, and further select a target of interest or reject an unintended target. This BCI mouse has been successfully applied to a BCI browser for internet surfing (Yu et al., 2012). The second is to realize a speller for inputting the path. In this study, we use a P300 speller, which is similar to those in existing studies, e.g., (Lenhardt et al., 2008). The last is to design an appropriate explorer. Based on the BCI mouse and the P300 speller, we implement a simple BCI explorer

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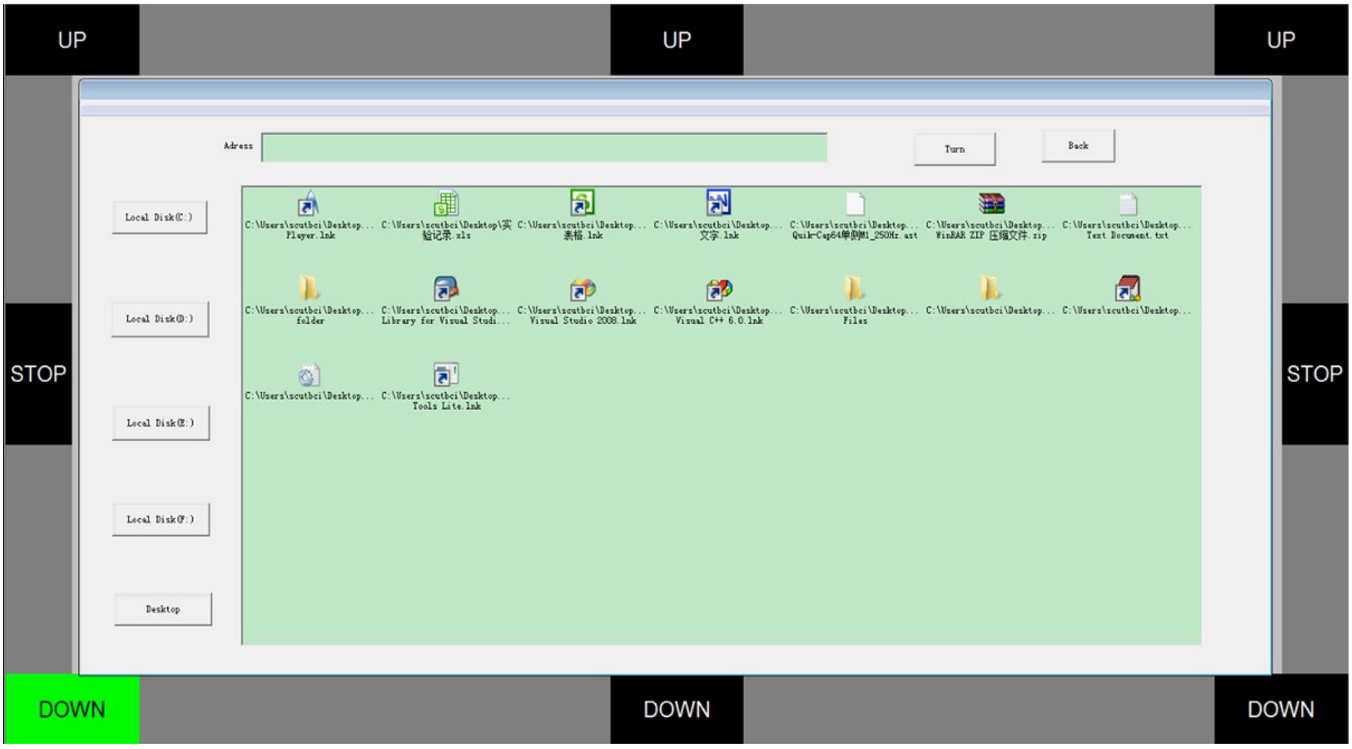


**Fig. 1.** GUI of the BCI explorer.

in this study. Using this system, the subjects can perform Windows Explorer's basic functions (e.g., access a fold in the computer, open, close, copy, paste, and delete a file in this fold). Five subjects participated the experiment and performed a series of operations using the BCI explorer. The experimental results demonstrated the effectiveness of our system.

The remainder of this paper is organized as follows. The system paradigm, BCI mouse, BCI speller and explorer are presented in Section 2. The experimental results are shown in Section 3. Further discussions are involved in Section 4. Finally, Section 5 concludes the paper.

## 2. Methodology

### 2.1. System paradigm

The graphical user interface (GUI) of the BCI explorer is illustrated in Fig. 1. The explorer is embedded in the center area of the screen (working area). There are eight buttons on the margins of GUI, including three "UP" buttons, three "DOWN" buttons, and two "STOP" buttons. These buttons alternatively flash in a random order to elicit P300 potentials. Specifically, during the process of mouse control, each button flashes by changing the color from black to bright green at an interval of 120 ms, and remaining in bright green for 100 ms. In this system, we control the vertical and the horizontal movements of the mouse using P300 and motor imagery, respectively (Long et al., 2012). If the user wants to move the mouse up (down), then he or she should focus on one of the three "UP" ("DOWN") buttons. Meanwhile, if the user wants to move the mouse towards right (left) side, the subject could imagine the movement of his/her right (left) hand. Finally, if the user does not want to move the mouse, he should ignore the three "UP" and the three "DOWN" buttons, while not to perform any motor imagery. Once the mouse hits to a target, it will stop at the target area for 2 s and the user needs to select or reject the target. The target selection or rejection is implemented using a hybrid feature of motor imagery and P300 (Long et al., 2012). Specifically, the user can select it by focusing on one of the flashing button "STOP" in the explorer GUI and not performing motor imagery. Conversely, the user can reject it by continuing motor imagery and ignoring all buttons. For example, when the mouse reaches "Local Disk (C:)" (target area) in the GUI, the user can click/select the "Local Disk (C:)". In this case, the explorer will refresh to list all the folders and files of the local disk (C:) of the computer. If the user rejects the "Local Disk (C:)", there is no change of the GUI and the mouse will continue to move after 2 s.

Fig. 2 illustrates the flowchart of the system. Specifically, in the system, we implement the following Windows Explorer's basic functions.

(1) The user can click a local disk (C, D, E, and F) and desktop directly into the path, and the folders and files contained in the disk will be shown (see Fig. 1).
(2) The user can click a folder to open it. If the user wants to go into a path which contains many folders, the user is able to search for the specified path through an address bar, which is used for path editing (as shown in Fig. 3). Once the user completes path spelling, he or she needs to click the "Turn" button to reach it. If the user wants to go back to parent directory, then he or she can click the "Back" button.
(3) The user can click/select a specified file in the list. A pop-up menu will appear for selection (as shown in Fig. 5), and the user can manipulate (open, copy, paste, and delete) the file.
(4) When a specified file is opened, the user can click the "close" button to close the file. Moreover, if the user opens a text file, he or she can read the contents, page up and page down to browse the document (as shown in Fig. 4).