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BCI-based Operation of Off-the-Shelf Software Applications: Towards a General-Purpose Application Control Framework

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Abstract. Applications for (hybrid) brain-computer interfaces ((h)BCIs) are usually custom-made and adapted to compensate for the low information transfer rates achieved by such devices. Users are consequently not enabled to operate off-the-shelf software applications. Here, we introduce a general-purpose application control framework that allows (i) flexible and easy mapping of (h)BCI outputs to keyboard and mouse inputs and (ii) creating customized graphical user interfaces (GUI) and overlay elements for providing essential visual feedback. We demonstrate the validity of the framework by interfacing the popular puzzle-platform video game Portal2 (Valve Corporation) and a hBCI consisting of 3-class SSVEP and 7-class electromyogram-based (EMG) hand movement detection.

Keywords: EEG, Hybrid BCI, SSVEP, EMG hand detection, off-the-shelf applications, universal control

1. Introduction

Off-the-shelf software applications are typically designed for use with standard physical human-computer interaction (HCI) devices such as keyboard and mouse. Assistive technologies including Brain-Computer Interfaces (BCIs) and hybrid BCIs (hBCI) [Pfurtscheller et al., 2010] usually extract data from user at considerably lower information-transfer rates and provide fewer control signals. Hence, (h)BCI users cannot benefit from the large number of available off-the-shelf applications. To solve this issue, we started developing methods for mapping BCI output signals into keyboard and mouse input (KB&M) for applications, e.g. for the game World of Warcraft (Blizzard, Inc.) [Scherer et al., 2012]. In this paper, we introduce our general-purpose application control (GPAC) framework. The GPAC allows (i) mapping of BCI outputs to KB&M inputs and (ii) creating custom user interfaces (UIs) that can be overlaid to applications and provide essential BCI feedback or stimuli for BCIs that are based on visual evoked potentials (VEPs).

2. Material and Methods

2.1. General-Purpose Application Control (GPAC) Framework

The GPAC converts information (e.g. classification result) received over TCP/IP from the (h)BCI into a set of predefined actions (Fig. 1(a)). These actions can either simulate KB&M inputs or modify customized graphical user interface (GUI) elements. An application running as a window in focus receives the KB&M inputs and triggers mapped in-app actions. KB&M inputs include keyboard key press and release, mouse button press and release, and relative mouse cursor movements. Individual KB&M inputs can be linked by macros, which can be used to trigger more complex in-app actions. The IEE allows customizing the UIs of applications by placing basic interface elements such as textured icons, mono-color or checkerboard icons and progress bars for dwell timers anywhere on the screen. Each of these elements can be decorated with animations or defined as steady-state VEP flicker with predefined frequencies. XML configuration files allow rapid and easy definition of finite-state machines for graphical user interface (UI) layouts (masks) and KB&M macro sets for individual applications.

2.2. The Portal2 game and basic requirements for gameplay

Players have the task of solving a series of puzzles by teleporting the player's character and simple objects by placing a set of portals. Objects include a cube that can be used to trigger switches and redirect laser beams (Fig. 1(b)). Meaningful interaction with the game requires (i) self-paced (h)BCI operation (on-demand access) and

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(ii) the ability to select between ten different control commands: seven for navigating the player's character and three for selecting special actions.

2.3. hBCI and mapping of in-app actions

We selected a hBCI consisting of a 7-class EMG-based hand movement detection system and 3-class SSVEP-BCI. Not focusing on flickering stimuli and not performing predefined hand movements should not generate hBCI output and thus allow self-paced control. SSVEP detection was based on canonical correlation analysis, Fisher's linear discriminant analysis and dwell timers (1 s). Hand movement detection involved movement on-set detection, followed by time domain-based feature extraction and support vector machine classification. EEG was recorded from 13 occipital sites; EMG from 16 monopolar electrodes placed on the users forearm.

The hand movements hand closed, hand open, wrist flexion, wrist extension, radial deviation, ulnar deviation and thumb extension were mapped to the in-game commands walk forward, walk backward, turn left, turn right, look up, look down and jump forward, respectively. The 3 SSVEP stimuli were mapped to the commands place orange portal, place blue portal and activate the cube. Fig. 1(b) illustrates the adapted GUI.

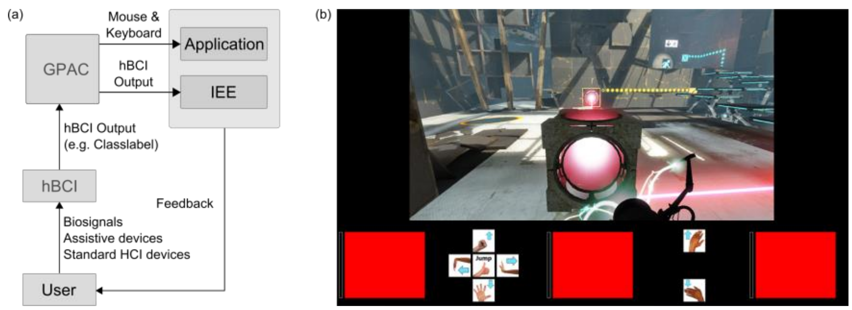

Figure 1. *(a) Scheme of the general-purpose application control framework. (b) Screenshot of the custom GUI. Ten basic interface elements are located in the lower part of the screen. The seven small icons show the mapping of hand movement to in-app navigation commands. After hand movement detection the arrow in the related icon changes from color blue to green. The three large plain-colored icons flicker at different frequencies and are used to elicit SSVEPs. Whenever corresponding SSVEPs are detected, an animated dwell timer bar is shown on the left side of the SSVEP icon and on completion the whole icon is framed by a green border indicating a selection.*

2.3. Experimental paradigm

Two able-bodied individuals (S1 and S2) participated in this study. Firstly, users were familiarized with Portal2 by playing level 2.1 and 2.2 by standard HCI inputs. Secondly, to get a reference performance, users were asked to play the levels by mouse only (all commands mapped on mouse buttons/wheel). Finally, after SSVEP-BCI and EMG hand detection calibration was performed, users were asked to replay the levels by hBCI.

3. Results

The time required to successfully finish levels 2.1 and 2.2, respectively, by hBCI (mouse) was 75 s (32 s) and 280 s (54 s) for S1, and 116 s (33 s) and 210 s (66 s) for S2. To test for false positive detections, 60 s of data was recorded and subjects were asked not to activate hBCI control. S1 triggered no FP selection; S2 triggered 1 FP. Hand movement classification accuracies of over 96% were computed for both users from the EMG calibration data.

A video of the experiment is available at http://www.youtube.com/watch?v=ZUsY3YsyiAw.

4. Discussion

The presented GPAC allows controlling off-the-shelf software applications by non-standard HCI devices. The IEE is a valuable extension that allows customizing interfaces and providing visual feedback for hBCI user.

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