

A novel EEG acquisition system for Brain Computer Interfaces

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Abstract. Brain Computer Interface (BCI) systems provide communication and control without movement. These devices use the brain activity as input signal and may be the only possible way of communication for people with severe motor disabilities. But before BCI becomes practical, daily setup and clean up should be enhanced. Improvements to all components of a BCI system will facilitate its reliability, flexibility and usability. In this work, a new lightweight and combined signal acquisition system that can be used for BCIs based on steady-state visual evoked potentials (SSVEP) and event-related (de)synchronization (ERD/ERS) is introduced. The system works in a sequential hybrid approach in which external devices are selected with the help of an eye tracking system and then operated via BCI.

Keywords: Brain Computer Interface (BCI), SSVEP, ERD/ERS, Eye tracking

1. Introduction

Several Brain Computer Interface (BCI) systems have been successfully implemented and demonstrated over the last years. However, BCI technology alone cannot allow patients to interact with assistive devices over long periods of time and without expert assistance [Millán et al., 2010]. The solution to this problem could be the combination of different BCI approaches with other biosignals or external devices such as an eye tracking system. This approach is known in the literature as a hybrid BCI [Pfurtscheller et al., 2010]. The goal of this work is the development of a hybrid BCI that allows faster and more reliable control.

2. Methods and Materials

The proposed system consists of three main components. The signal acquisition integrates a head cap, EEG sensors, and cameras in a single device (see Fig. 1) aiming to reduce preparation times and to improve the comfort of the users over long periods of time. The eye tracking system detects the user's viewing direction to localize objects or external devices of interest in the environment, and the BCI signal processing module detects SSVEP and ERD/ERS patterns to control the selected device.

2.1. Signal Acquisition

The novel EEG acquisition system in combination with an eye tracking system for hybrid operation is presented in Fig. 1. This prototype consists of fixed holders for 22 electrode positions (8 for SSVEP: P_z, PO₃, PO₄, PO₇, PO₈, O_z, O₉, O₁₀; 13 for ERD/ERS: FC₃, FC_z, FC₄, C₅, C₃, C₁, C_z, C₂, C₄, C₆, CP₃, CP_z, CP₄, and AF_z for a ground electrode), and two cameras used for eye tracking. Currently, EEG data are recorded using Ag/Ag-Cl electrodes and conventional electrolytic gel, and then digitized through a Porti32 amplifier. One of the future improvements of the system will be the EEG acquisition using water-based electrodes, which will make both daily setup and clean up much faster, easier and comfortable [Volosyak et al., 2010]. In general, the main advantages of the acquisition system are the reduction of the subject's EEG preparation time, better repeatability of the electrode locations between EEG acquisition sessions, and the combination with eye tracking for hybrid control.



Figure 1. EEG signal acquisition system combined with eye tracking. EEG signals for the SSVEP paradigm are acquired from the visual cortex area and for ERD/ERS from the motor cortex area.

2.2. Eye Tracking System

The eye tracking system is used to detect the user's intentions (searching and selection) based on the viewing direction. If the subject is interested in a specific device in the environment, i.e., a predefined fixation time is reached, then the BCI system is used to interact with the selected device.

2.3. BCI Signal Processing

The signal processing module translates ongoing brain signals from 21 electrodes into device control commands. Eight signals are acquired from the visual cortex to detect SSVEP patterns using adaptive spatial filtering and the signal-to-noise ratio at each stimulation frequency. The remaining electrodes are used to detect ERD/ERS patterns during three types of motor imagery (MI): right hand, left hand, and feet imagery of movement. The algorithm is based on autoregression, multiclass common spatial patterns and mutual information.

3. Results

EEG recording with the full set of 22 EEG ring electrodes was achieved in only 12 minutes. In contrast to approx. 20 minutes with the standard EEG cap. In both cases standard abrasive electrolytic electrode gel was applied between the electrodes and the skin to bring impedances below 5 K Ω . The SSVEP and ERD/ERS signal processing modules were tested independently using different applications. An average accuracy of 97.87% was obtained for 27 subjects in an SSVEP spelling task using five stimulation frequencies (no training was required), whereas 91.3 % accuracy was obtained for one subject after 14 sessions of ERD/ERS training with a virtual labyrinth and three MI classes.

4. Discussion and Conclusions

In this paper, a new EEG signal acquisition system for hybrid Brain-Computer Interfaces in combination with an eye tracking system is introduced. This system facilitates multi-channel EEG signal acquisition and detection of two brain patterns (SSVEP and ERD/ERS) combined with the analysis of the user's viewing direction. Further research will investigate the feasibility of the system for environmental control (open and close the door, control switches for television or music player) including also the high-level control of assistive devices (robotic arm mounted on a wheelchair).

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