 DOI:10.3217/978-3-85125-260-6-27

Rapid Prototyping for hBCI Users With Cerebral Palsy

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Abstract. A rapid prototyping system is described that allows efficient development of hybrid Brain-computer interfaces (hBCIs) for users with Cerebral palsy (CP). The system is based upon an expansion of the TOBI framework and is demonstrated to allow rapid construction of a Steady state visual evoked potential (SSVEP) based hBCI system.

Keywords: Cerebral palsy, EEG, rapid prototyping system, hBCI, multi-modal signal acquisition

1. Introduction

Cerebral palsy (CP) is an umbrella term for a range of differing motor and other disabilities caused by damage to the fetal or infant brain. Individuals with CP can experience a range of difficulties relating to motor control, coordination, posture and other difficulties such as speech impairments or cognitive difficulties [Iosa et al., 2012].

Hybrid Brain-computer interfaces (hBCIs) base control on a combination of neural and other physiological signals and have been proposed as assistive devices for individuals with CP [Daly et al., 2012]. An optimal assistive device should simultaneously address various aspects of daily life and offer many user-specified applications (i.e. health monitoring, communication etc.). Usabilitiy should also be optimised via a user-centered interface requiring both monitoring of and adaptation to user states. In addition, because individuals with CP will not only have specific application needs but also a unique set of hBCI-utilisable capabilities, the device should be flexible and readily customisable. Therefore, a system is required which is capable of simultaneously recording, processing, and storing multiple signal types in an environment which allows quick prototyping and testing of customised hBCIs.

Therefore, a rapid prototyping environment is developed based upon open standards for data transmission defined in the TOBI framework [Müller-Putz et al., 2011]. Key aspects are multi-modal signal acquisition, standardised data transmission protocols, support for rapid development and integration of new modules, and data storage mechanisms.

The system may be constructed in a modular fashion and distributed over multiple devices. In the envisioned setup the system is distributed over a central server (laptop) and tablet computers to minimise the complexity of the user-facing components. Support is provided for simultaneous acquisition and processing of physiological signals including EEG, EMG, EDR, ECG, breathing, accelerometers for monitoring limb movement, and blood oxygenation levels. This allows hBCIs to be constructed for control, emotion, and health monitoring.

2. Material and Methods

The system is described and its efficacy demonstrated by constructing an SSVEP hBCI and health monitoring system.

2.1. Rapid prototyping system

The rapid prototyping system is comprised of five sections; signal acquisition, pre-processing, processing, visualisation, and control. Communication is via TOBI interface A (TiA), D (TiD), and C (TiC) [Breitwieser et al., 2012].

The system consists of a computer and one or more tablets. The first handles signal acquisition, pre-processing, and processing. The latter realises visualisation and control. The tablet mainly serves the end-users with applications specifically tailored according to their needs. Additionally, the tablets may be used to provide residual voluntary control by end-users or, if present, caregivers, (e.g. keyboard, microphone). Fig. 1 illustrates the system.

The first module (based on the SignalServer [Breitwieser et al., 2012]) handles signal acquisition and synchronisation. This is extended to handle specific devices applicable to users with CP to provide continuous monitoring of health status and generate alarms upon abnormal values. Additionally, EDR and ECG are recorded for emotional state detection. The acquisition system is chest-worn with ECG sensors, sensors for breathing frequency, a triaxial accelerometer to quantify physical activity and detect falls, and temperature and blood oxygenation sensors. Data is then transmitted to the pre-processing and processing blocks. The final blocks handle visualisation and control.

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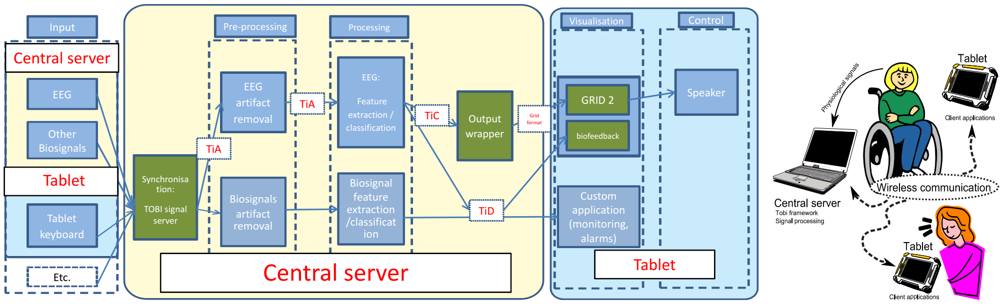

(a) System modules and data flow (b) System overview

Figure 1: Figure 1a, data flow through the system. Data originates in the devices and moves through the blocks. Figure 1b, the system structure, signal acquisition, and processing are in the central server and feedback and visualisation are in the tablets.

2.2. Demonstration

To demonstrate the efficacy of the rapid prototyping environment it is used to build an SSVEP hBCI, with integrated health monitoring, for CP users. Three modules are created. The first attempts to clean the EEG of artifacts [Daly et al., 2013], the second to classify via Canonical correlation analysis (CCA), and the third presents the BCI application and feeds back the classification results. The system is tested with 3 healthy users (all male ages 29–30, two right handed).

Regarding the health monitoring, separate acquisition devices are used to acquire non-EEG biosignals from the user (Heart Rate Variability (HRV), Respiration Rate (RR), temperature values). Artifactual segments are removed and signals are processed in order to highlight variations with respect to baseline values. Processed data and events are sent to the remote user interface (caregiver's tablet) for monitoring purposes and to raise alarms.

3. Results

The rapid prototyping system is successfully used to construct an SSVEP hBCI integrating a health monitoring system. The demonstration system evokes clear SSVEP responses. The hBCI is also observed to operate efficiently and allow acquisition, cleaning, classification, and storage of physiological signals. Additionally, the rapid prototyping system has also been used to develop motor imagery and SSVEP BCIs for users with CP (see [Daly et al., 2012]).

4. Discussion

The rapid prototyping environment is demonstrated to allow efficient construction of hBCIs. Modules may be constructed for all steps of the hBCI pipeline. The use of open standards means the system is compatible with a range of hardware acquisition devices and may be efficiently integrated with any other modules adhering to the same standards.

On-going inter-institutional research will seek to use this rapid prototyping environment to develop hBCI devices to provide help with the assistive living, health monitoring, and emotional state detection needs of individuals with CP.

Acknowledgments

This work was supported by the FP7 Framework EU Research Project ABC (No. 287774). This paper only reflects the authors views and funding agencies are not liable for any use that may be made of the information contained herein.

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