Integration of a brain-computer interface into Virtual Environments

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Abstract

Electroencephalogram (EEG)-based brain-computer interface (BCI) systems convert brain activity into control signals and have been initially developed for people with severe disabilities. In the last few years BCI systems were also used in Virtual Environments (VE) for the control of experiments. Specially for the application in VE the BCI system has to satisfy specific demands. The key advantage of a Pocket PC based BCI approach is its small dimension and battery supply. Hence a mobile BCI system can be worn by a human subject during experiments in VE.

1. Introduction

Electroencephalogram (EEG)-based brain-computer interface (BCI) systems have been developed for people with severe disabilities in order to improve their quality of life. A BCI measures brain activity and transforms specific thoughts into control signals. Applications of BCI systems comprise the restoration of movements, communication and environmental control [1]. However, recently BCI systems have been also used in other research areas such as in the field of virtual reality (VR) [2, 3].

Parameters generally used to quantify the performance of BCI systems are the accuracy and speed. Furthermore, a BCI approach should ensure that the users learn to control the system within a few training sessions. The level of control should be stable after an initial learning phase and should improve over time [1, 4, 5].

Different strategies are used for the control of a BCI. The user can e.g. perform a real hand or foot movement or can just imagine the movement. Depending on the strategy it is important to measure the EEG activity exactly over the corresponding brain regions.

Thereafter, feature extraction and classification of EEG data is performed resulting in the control signal. After some training sessions the BCI accuracy enhances to a certain degree, meaning the BCI system and the subject have adapted to each other for a better general system performance [1, 4].

However, for the portable use in Virtual Environment (VE) the BCI system must be as small as possible and easy to use.

2. Mobile system

For portable applications like in VE an embedded solution including the processor and DAQ board without mechanical disks and extra display is required. Size, robustness and usability are major considerations. The hardware must be fully portable and supplied by a battery [5].

Fig. 2. Components of a Pocket PC based BCI system.

For the embedded BCI a standard Pocket PC is used as a portable host. The Pocket PC is connected via a serial cable to an embedded target computer system g.MOBIlab (see Fig. 2). The embedded system consists of a µC operating at 12 MHz to optimize the power consumption. A 16 bit analog to digital converter samples 8 analog channels. Each channel is sampled at 256 Hz. The amplifier module is equipped with 4 EEG type channels, 2 ECG type channels and 2 analog inputs for external sensors. Two digital inputs and 2 digital outputs allow controlling different external devices. Two batteries of type "AA" power the embedded system.

The Pocket PC operating system is Windows Mobile and the BCI system is programmed in eMbedded Visual C++. The integrated Wireless LAN (WLAN) module of the Pocket PC can be used for wireless data transmission. Data are stored on the internal 64 MByte storage or streamed to a Compact Flash card for later analysis. An application programming interface allows accessing the hardware components and data buffers. Hence BCI applications can be adapted to optimally meet user specific needs or novel applications can be developed.

The following paragraphs give one example for a typical BCI experiment based on oscillatory brain activity measured over electrode positions C3 and C4 [6].

3. Training phase

For BCI training two different experimental paradigms are implemented. In order to acquire EEG data in the training phase the first experiment is performed without feedback. Therefore, an arrow pointing to the left or right side of the computer monitor is shown (Fig. 2). Depending on the direction of the arrow the subject has to imagine a specific kind of movement. If the arrow is pointing to the left hand side the subject should imagine a left hand movement, if the arrow is pointing to the right side the subject should imagine a right hand movement.

EEG data for a total of 160 trials (80 right and 80 left hand movement imageries) are acquired. Specific EEG parameters are then extracted from the data and the trials are classified into two classes yielding a subject specific classifier.

4. Application phase

After computing the classifier the application phase can be started. The classifier weights the extracted features calculated from the EEG data in such a way that the thoughts are converted in real-time into bar movements (Fig. 3).

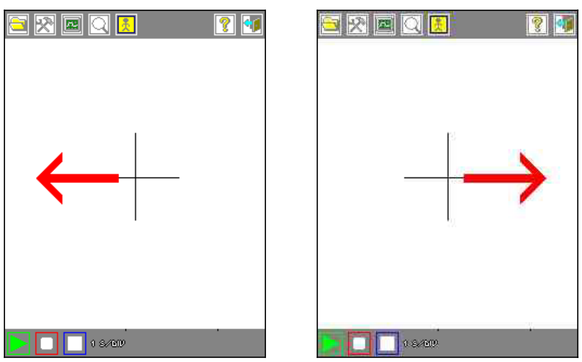

Fig. 2. Training phase displayed on the Pocket PC: Red arrows indicate that the subject should image a left hand (left panel) or right hand (right panel) movement.

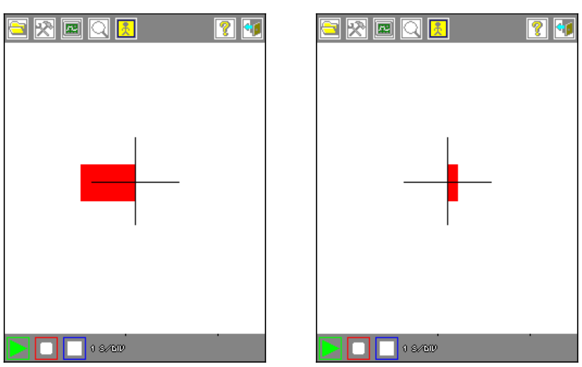

Fig. 3. Application phase displayed on the Pocket PC: The direction of the bar indicates the classification in either the left hand movement class (left panel) or the right hand movement class (right panel).

A classification result of a right hand movement extends the bar to the right side. A classification result of a left hand movement class extends the bar to the left side. This cursor movement was translated into a navigation signal in a CAVE environment. In this way the subject was able to move forward or backward depending on the imagination [2].

5. Discussion

The embedded BCI system with its compact dimension allows the usage of the BCI inside VE and (as Pocket PC CPUs are getting more and more powerful) also for implementing sophisticated applications. The system can be easily worn by the human subject and is fully battery powered. Therefore the subject is more flexible and can move through the virtual world. A big advantage is that the Pocket PC based BCI operates immediately after switching it on without booting of the operating system.

The combination of BCI systems with Virtual Reality allows people to accomplish tasks within a virtual environment simply by having the appropriate 'thoughts'. The purpose of this is to explore completely new paradigms for operating with computers, to give people an experience that is unlike anything possible in real life - thus exploiting the power of virtual reality to deliver entirely new experiences, and finally has obvious practical applications for people with disabilities.

Acknowledgment

This project is funded by the European Union project PRESENCIA, IST-2001-37927 and by the Austrian FFF.

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