Controlling Virtual Environments by Thoughts
Kontrolle Virtueller Welten mit Gedanken

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ABSTRACT
A brain-computer interface is a new device that picks up brain activity to control a device. This work shows the fascinating usage of a BCI in a Virtual Environment for navigation.
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1. INTRODUCTION

A brain-computer interface (BCI) is a new communication channel between the human brain and a computer. BCIs have been developed during the last years for people with severe disabilities to improve their quality of life [Wolpaw 1991, Pfurtscheller 1998]. Applications of BCI systems comprise the restoration of movements, communication and environmental control. However, recently BCI applications have been also used in different research areas e.g. in the field of virtual reality [Pfurtscheller 2006].

A BCI uses either slow cortical potentials, evoked potentials or oscillatory components for the control. It is well known from the literature that during a specific movement an event-related desynchronization (ERD) at a specific brain location occurs and that after the movement an event-related synchronization (ERS) occurs. The same effect can be found if only the imagination of a movement is performed.

Fig. 1. Left column – ERD during a right hand movement imagination over C3, Right column – ERD during a left hand movement imagination over C4. The amplitude attenuation (ERD) in the alpha band (10-12 Hz) is indicated in dark.

The imagination of a foot movement causes an ERD over electrode position Cz of the international 10/20 system, a right hand movement imagination causes an ERD contralateral over C3 and a left hand imagination over C4 (see Figure 1). Therefore the electrodes are assembled exactly over these positions in order to pick up the activity.

2. EXPERIMENT AND RESULTS

For the BCI experiments 2 bipolar EEG derivations where mounted on the subject's head (electrode positions C3 and Cz). The electrodes were connected to a portable amplifier and digitization unit (g.MOBIlab, g.tec medical engineering GmbH, Austria). The g.MOBIlab samples the data with 16 Bit and 256 Hz. Then the data is sent to the Pocket PC (see Figure 2). The Pocket PC was used to control the experimental paradigm for the BCI training of the subject. During the paradigm arrows pointing downwards or to the right side of the screen were presented. The subject had to imagine a foot movement and a right hand movement depending on the direction of the arrows. This was repeated 160 times.

Fig. 2. Components of the BCI system. EEG cap with electrode positions according to the international 10/20 system; EEG amplifier and acquisition unit consisting of g.MOBIlab and the Pocket PC; connector boxes to plug in the EEG electrodes.

Then the EEG data was analyzed in order to distinguish the 2 different imaginations. Therefore the bandpower in the alpha band (10-12 Hz) and in the beta band (16-24 Hz) was calculated of each channel. Then a linear discriminant analysis (LDA) was used to distinguish the right hand movement from the foot movement imagination. This yields to a subject specific weight vector which can be used for the on-line experiments to control a cursor on the screen or to control a VR system [Guger 2001].

After the initial training with cursor control three subjects all with classification accuracy above 80 % were participating in an experiment in a highly-immersive CAVE like, virtual reality (VR) system (see Figure 3). The CAVE system (TRIMENSION ReaCTor) has 3 back projected screens which are 3 m by 2.2 m in size. The floor is projected by a projector mounted in the ceiling. The 3D effect is produced with shutter glasses.

Fig. 3. CAVE system which creates a 3D Virtual World.

We have used a virtual street populated by 16 avatars and shops on both sides of the street. The BCI output signal was transmitted to the VR system in order to navigate in the VE. The goal was to reach the end of the street. The subject was instructed by an acoustic cue to imagine a foot movement (double beep) or a right hand movement (single beep). If the foot movement was classified correctly the subject was moving forward, otherwise the subject was remaining on the same position (see Figure 4). If a right hand movement was correctly detected the subject was also remaining on the same position otherwise as a punishment the subject was moving backwards. Therefore only with a 100 % BCI classification accuracy the subject was able to reach the end of the street.

		subject imagined	
		foot movement	right hand movement
cue class	foot movement	forward	stop
	right hand movement	backward	stop

Fig. 4. Task to explore the virtual world

The accuracy was determined as achieved cumulative mileage and measured how far the subject could move. S1 had a performance of 63.6 %, S2 of 78.9 % and S3 of 85.4 %.

Figure 5 shows the ERD/ERS calculated during the training phase (top) and during the experiments in the CAVE (bottom). In the training phase mainly an ERD in the alpha and beta band is responsible for the classification accuracy while in the CAVE experiments mainly an ERS in the alpha and beta band is used for the control. The figure demonstrates the brain plasticity which is depending on the training stage but also on the way how the feedback is created and on the motivation of the subjects participating in the study.

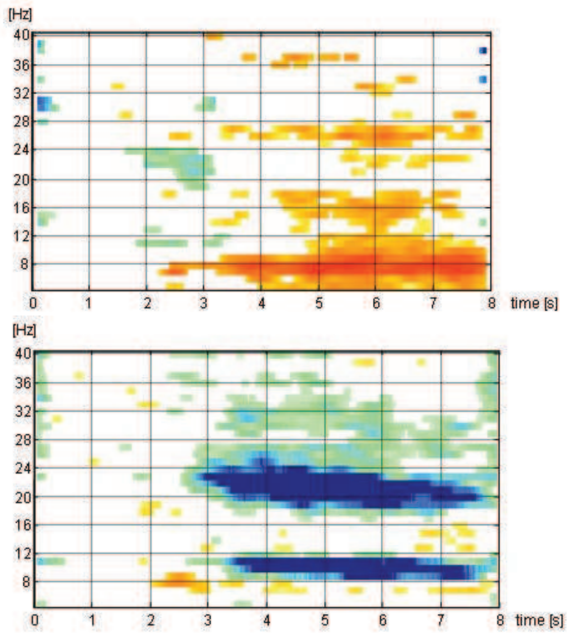

Fig. 5. ERD/ERS time curves during the training phase with the cursor (top) and the experiment in the cave (bottom).

3. DISCUSSION

The work showed that motor imagery can be used as input signal for a BCI system to control a VE in a highly immersive CAVE system. Subjects reported about an exciting experience of moving forward and backward just by the imagination of different types of movements.

Furthermore the study showed the importance of periodic updates of the subject specific weight vector. After the training phase the weight vector is trained on specific ERD/ERD patterns for a specific feedback scenario which might differ completely from the next experiments performed. Such updates are dependent on the training stage of the subject, the way of feedback, motivation and electrode positions.

4. ACKNOWLEDGEMENTS

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