

ERD/ERS BCI training on the basis of a labyrinth application

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Abstract. In this work we present the training protocol with a brain-computer interface (BCI) system, which is able to detect event-related (de)synchronization (ERD/ERS) patterns during the imagination of feet, right and left hand movement. For feedback training we utilized a miniature robot e-puck. The task was to move the robot through a maze by using three mental states corresponding to the commands turn right, turn left and move forward. After three training sessions the subject was able to navigate the miniature robot e-puck out of the labyrinth with an accuracy of 68%.

Keywords: Brain-computer interface (BCI), event-related (de)synchronization (ERD/ERS), feedback training

1. Introduction

Motor imagery is a mental task that has been intensely studied in context of BCI [Pfurtscheller et al., 1997]. Two distinct operating modes: cued (synchronous) and self-paced (asynchronous) modes are possible. The main focus of this work is to establish an asynchronous BCI system, because of its more natural and possibly faster interfacing [Millan et al., 2009]. The subject can deliver a mental command at any moment without waiting for external cues.

2. Methods

2.1. Experimental setup

One healthy subject (29 years old, female, right-handed) participated in this experiment. An EEG amplifier Porti32 (Twente Medical Systems International, Netherlands) was used for experiments. The EEG signals were acquired using 15 electrodes over the motor cortex with a sampling rate of 256 Hz.

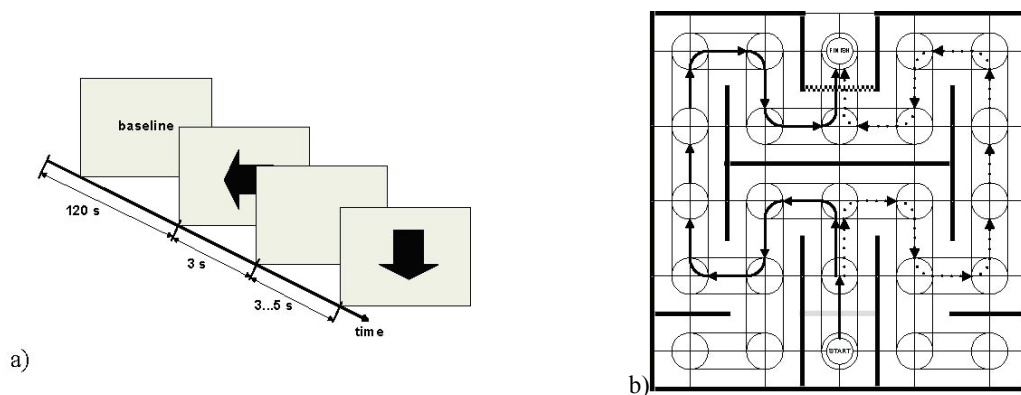


Figure 1: Calibration session (a): each trial started with the presentation of a visual cue (arrow) for 3 s, while the subject had to imagine left/right hand movement (left/right arrow) and feet movement (down arrow). Feedback session (b): top view of the labyrinth, two optimal trajectories are shown.

The experiment consists of two phases. First a calibration phase, in which we set up classifiers based on EEG potentials recorded during repeatedly user's imagination of feet, left and right hand movement (see Figure 1a). This session consisted of 150 trials (50 for each class). Afterwards, in the online feedback phase, subject used the motor imagery to navigate the miniature robot e-puck [Mondada et al., 2009] out of the labyrinth (see Figure 1b). At the beginning of the experiment, the robot is located at the *start* position. With "move forward" command the robot can be navigated to the next position in the labyrinth. With the commands "turn left" and "turn right" the robot can be rotated by 90 degrees to the left and to the right. A run starts with a single "move forward" command and ends when the robot has reached the *finish* position. Imagination of feet movement corresponds to "move forward", left and right hand imagery to "turn left" and "turn right", respectively. If the robot was facing a wall, and a "move forward" command was classified, the command was counted as incorrect, but the robot did not move forward.

2.2. ERD/ERS Trainer

BCI training is usually done by feedback training, where the output of the signal processing module of the BCI is translated into a representation that shows how successful the subject was in modulating the desired brain pattern. The feedback representation can have various forms; most often visual feedback is used, but auditory and tactile feedback have been suggested as well. The training protocol and the feedback representation have to be carefully designed to support learning. In this work, we used visual feedback in a real application and the main goal was to keep the attention of the user and to improve the motivation. The signal processing used in this study is based on an Autoregressive Model, Multiclass Common Spatial Pattern and Mutual Information; the calibration function and function detecting the imagery of movement in an asynchronous way was designed and implemented by co-authors from the University of Warsaw.

3. Results

Initially, the subject trained without feedback for about 6 weeks (two sessions per week). These training sessions consisted of 150 trials, similar as the calibration session, and lasted about 20 minutes. Next, the subject started the training with feedback. Each training session with feedback also required a calibration session with 150 trials to set up the classifier. In total, three feedback sessions were performed on different days. Only after the third session, the subject was able to navigate the miniature robot e-puck out of the maze with information transfer rate ($N=3$) of 1.67 bit/min. During this session, 53 commands were needed to reach the final position, 36 of these were correct (68% accuracy). Two possible optimal trajectories of movement are drawn with color arrows in Figure 1b, the subject selected trajectory on the left side. The subject reported more difficulties to keep the resting state than the imaginations.

4. Discussion and Conclusions

The results showed that advanced signal processing methods together with feedback training makes possible to successfully complete a very difficult task (navigate a robot out of the labyrinth) by using three independent control signals derived alone from ongoing EEG signals.

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