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Motor Imagery Based BCI Racing: Challenge a Friend with 4 Channel Dry Electrode EEG

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Introduction: Most current BCI applications are realized with EEG systems having a dense net of conductive gel electrodes connected to a non-portable unit. These EEG systems lack mobility and robustness, thus making brain-computer interface applications in daily-life scenarios inconvenient or unfeasible. Recent advancements in terms of miniaturization and wearability have made it possible for measurements to be performed outside the laboratory environment. Here, we investigate a combination of a motor imagery BCI with a relaxation/concentration paradigm to operate remote-controlled cars in a gaming application using IMEC's wearable EEG system with 4 active dry channels. Two players engage in a BCI-controlled racing game, choosing the directions of their cars with motor imagery, while controlling the car's speed by relaxing/concentrating. The application is available as a demonstrator.

Material, Methods and Results: In this work, we facilitate a minimalistic BCI approach that uses two low-power wireless EEG headsets developed at IMEC, which have 4 active dry EEG channels each [1]. EEG headset mounting process requires less than a minute, allowing for easy game setup. The headset comprises 6 reusable silver-silver chloride (Ag/AgCl) electrodes with 12 posts, each 2 mm deep. The 4 active channels are positioned at C_z, C_3, C_4 and P_z of the International 10-20 system, while the reference and patient ground electrodes are positioned at left and right mastoid, respectively. The headsets transfer the acquired data over Bluetooth to a workstation running an in-house developed EEG acquisition and visualization software. BCI commands are actuated through ZenWheels micro cars which are controlled via Bluetooth, implemented in the same software. The data is analyzed in real-time for facilitating

Motor imagery response detection from imagined left and right hand movements by means of pre-trained classifiers. The classification is performed in two steps. Firstly, common spatial filters are applied to extract spatial components that differ maximally for both motor imaginary classes [2]. Secondly, score values from linear discriminant analysis are used to operate the steering axle of the cars. If the score values exceed a predefined threshold, the steering is turned left/right for two seconds and the cars navigate in the direction of the detected motor imagery class.

Relaxation/concentration level detection from the background brain activity. The level is estimated based on the mean spectral power in the theta, alpha, and beta frequency bands over the central and parietal cortex [3]. The relaxation/concentration ranges are calibrated beforehand for each participant.

To prepare the gaming application, we collected the data on two subjects engaged in a motor imagery BCI training sessions. The measurements were performed in a regular office environment, susceptible to external interferences of electrical or physiological nature. Each subject participated in 4 recording sessions distributed over several days. Results from offline analyses shows an average classification accuracy of 92.5% (std=4.5%) for imagined movements between the two participants.

Figure 1. *A picture taken during the BCI racing game. The two opponents wearing the wireless headset are in the upper left corner, the white and orange remote controlled cars are driving on a racetrack on the table.*

Discussion: These findings indicate that despite using a minimalistic approach in uncontrolled environment, we are able to achieve state-of-the-art classification accuracies that can be successfully utilized in gaming applications such as the one presented here.

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