A Simple Approach to EEG-based Control

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Abstract

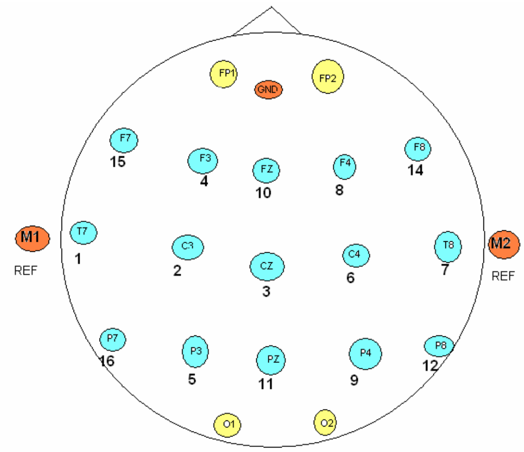
Based on event-related desynchronization of the premotor cortex when imagining movement, we implemented a simple system for EEG based control. By training one subject, we identified the μ-band and simply compared the power of each hemisphere to control a game. The response was slow and often inaccurate, but the chance of desired output in 3 seconds was 61%.

Introduction

An electroencephalogram-based brain-computer interface (EEG-based BCI) provides a communication channel between the human brain and a computer. Different brain signals can be used as input to a BCI: evoked potentials, slow cortical potentials (SCP), or oscillatory EEG components. Patients who suffer from severe motor impairments (e.g., late stage of amyotrophic lateral sclerosis) could use such a BCI system as an alternative communication channel through thoughts, whereby such an interaction between brain and computer must be realized in real-time. Possible applications of an EEG-based BCI are moving a cursor by mental control which allows the patient to select letters or words, and to control a functional electrical stimulation device for patients with spinal cord lesions. These applications can be controlled by at least one binary output signal of the BCI which is obtained by classification of EEG patterns during imagination of left and right hand movements. The use of oscillatory EEG components as input signals for a BCI requires online analysis of EEG signals with the extraction of reliable parameters. It was shown recently that unilateral hand movement imagery results in a contralateral event-related desynchronization (ERD) close to primary motor areas and, in certain cases, in conjunction with an ipsilateral event-related synchronization (ERS) of sensorimotor rhythms. A minimum of EEG channels is therefore assembled close to primary hand areas (electrode positions C3 and C4 according to the international 10-20 system) as an array of electrodes overlying motor and somatosensory areas. A recent paper based on discrimination of the EEG recorded during preparation for movement gives strong evidence that by the use of multiple EEG channels and common spatial filters, the classification accuracy of single-trial EEG can be increased. [1]

Experimental Setup

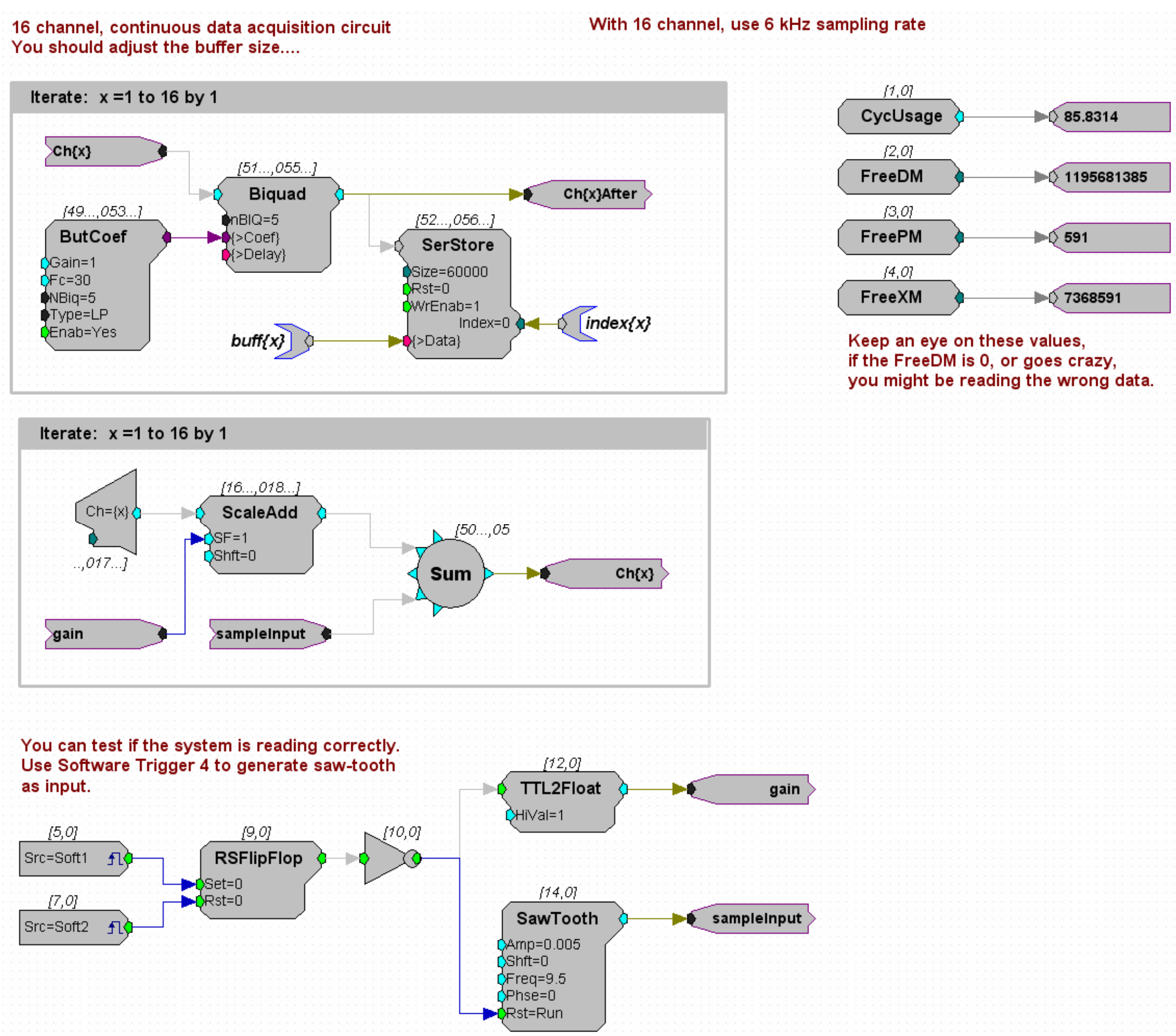
Electrode Positioning

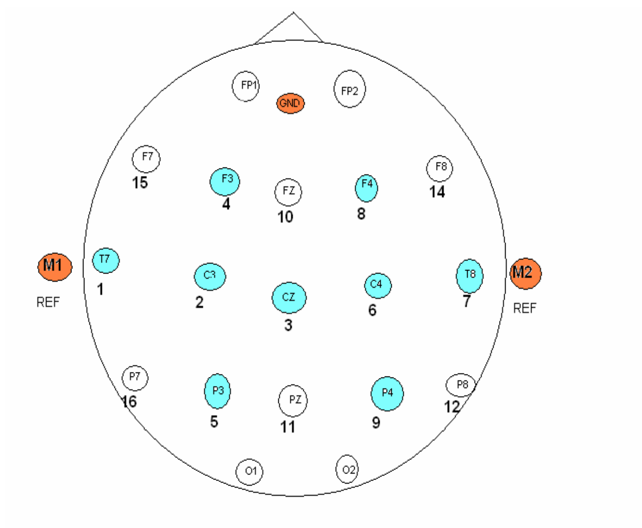


Initially the electrodes were placed on the scalp of the subject according to the standard 10-20 system. The exact electrode connections are shown in the adjacent figure. In all 15 electrodes were used, one ground electrode, and M1, M2 were the reference electrodes to stabilize the ground.

Tucker-Davis System

The following circuit is used for recording with 6kHz sampling rate using TDT Medusa system. All input from 16 channel passes through 30Hz low pass filter. The circuit is designed to produce test signal to check consistency of the system.





Surface Laplacian

To reduce noise and better separate the signal from the C3 and C4, we performed surface laplacian using the surrounding 4 electrodes. The signal from C3 and C4 are multiplied by 4 and substracted by all surrounding signals to approximate the surface laplacian [2][3]. The resulting configuration of electrods are 9 of the initial configuration, shown in the right figure.

Finding the µ-band

In order to find the µ-band, we measured power spectrum of the subject. We assumed three states: resting, actually moving left hand, and right hand. Due to the nature of electrodes, the slightest motion of the subject's body generates a huge artifact in the EEG recording. Thus we used a very small movement of the middle finger in a stable pose. The most difficult part is to put the subject into a complete resting state. We asked the subject to be in a comfortable pose with all muscles relaxed. We observed that meditation method that concentrates on the breathing is also harmful for finding the µ-band. After the subject is in a complete resting state, we recorded 30 seconds of each state and calculated the power spectrum of both C3 and C4 (Figure 1). The µ-band for the subject was around 13 Hz and we used 12-14 Hz through the experiments.

Designing the Controller

We took the simplest approach to compare the activity of C3 and C4 of the subject, since it was even visually evident that we could do that. However, since the power of C3 and C4 is not balanced, we deployed a normalization method. Based on the basal activity in resting state, we calibrated the power of C3 and C4 so that they have equal average power. After calibration we simply choose threshold for resting and left/right movement. The following pseudocode explains details.

```
If (C3+C4 < low-threshold) ➔ Both hands
else if (C3+C4 > high-threshold) ➔ Resting state
else if (C3 > C4) ➔ Left hand
else if (C3+C4 < middle-threshold) ➔ Both hands
else ➔ Right hand
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Thus we had 4 choices of action including the resting state. We translated each action to the Quake action: left (right) hand movement to left (right) and backwards movement of the character, and both hand movement to fire and forward movement of the character.

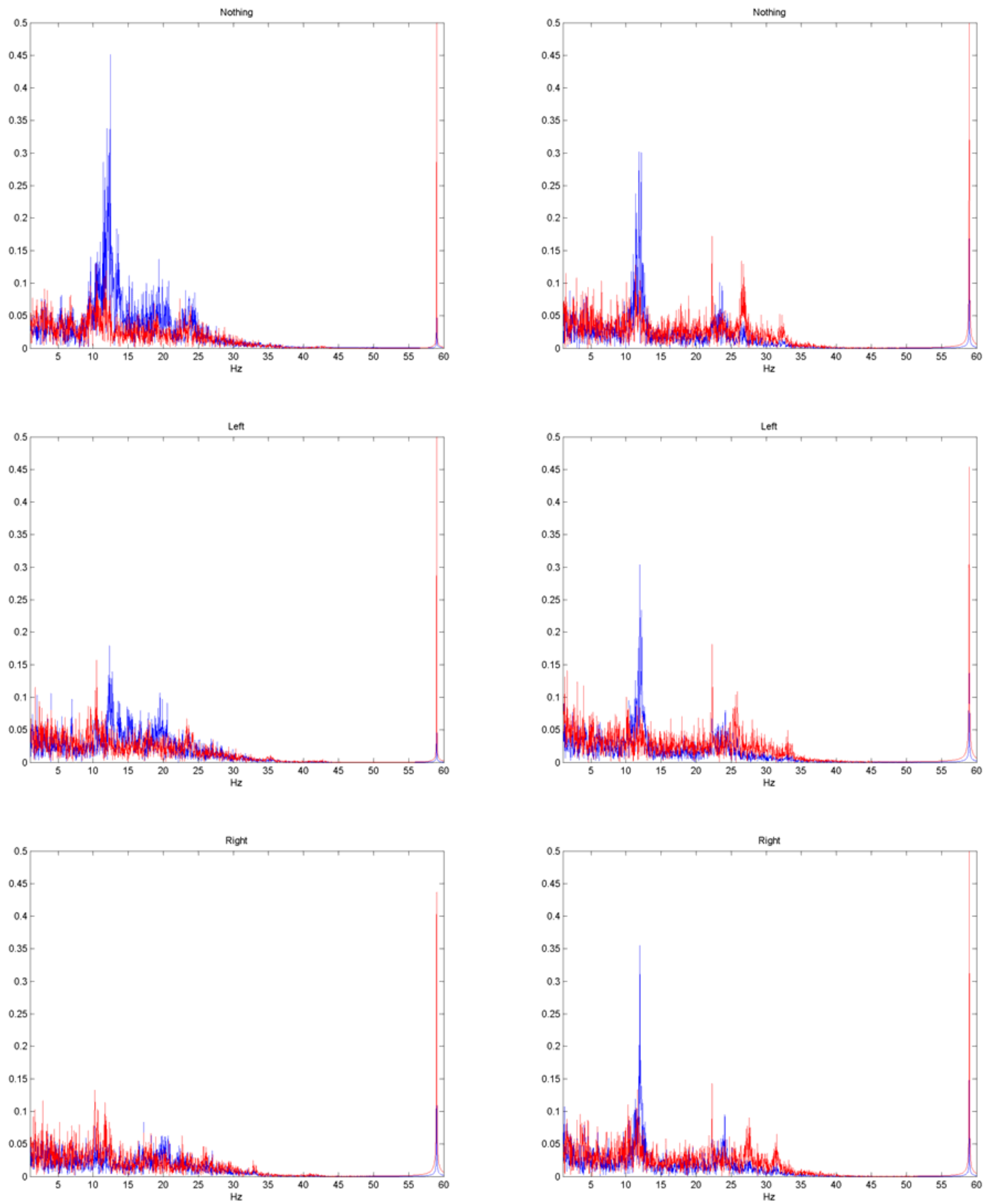
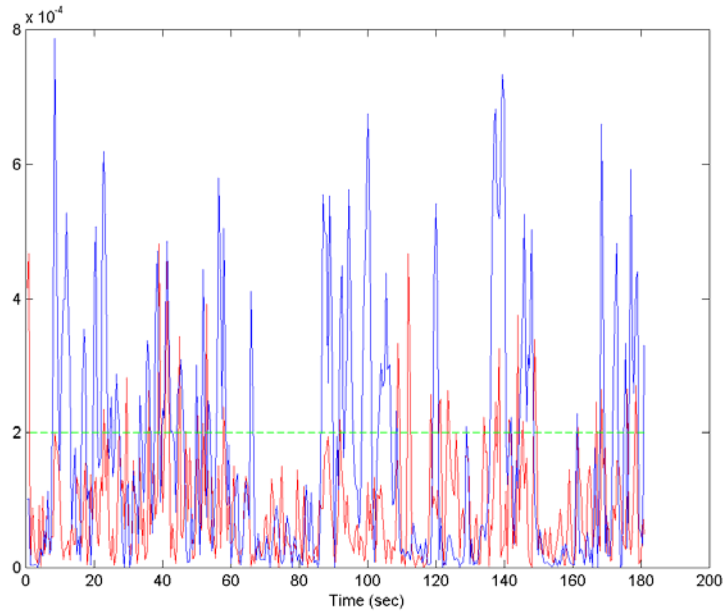


Figure 1: Power spectrum of EEG recording. The peak around 60 Hz are noise. The left three graphs are from actual movements and the right three are from imagery. Top is resting state, Middle left hand, and bottom right hand. Blue is C4 and red is C3. Note the peak around 13 Hz.

Results

We measured the performance of the method by giving a series of orders to the subject while he is controlling the game with imagery movements. Since the response of the subject was rather slow, we treated the result to be correct, if he could do it in 2-3 seconds. The total result was 61.0% (Left 14/28 = 50 %, Right 12/15=80%, Ahead 10/16=62.5%). The recorded time series of µ -band for C3 and C4 is shown in the next figure.



Discussion

We only had a single subject, and the subject was trained by direct visual feedback of the power spectrum for a long time. So it is hard to generalize this result. However, for this single subject, we could observe clear distinction of the power in C3 and C4 as expected from ERD.

Reference

[1] Guger C, Schlögl A, Neuper C, Walterspacher D, Strein T, and Pfurtscheller G. Rapid Prototyping of an EEG-Based Brain–Computer Interface (BCI). IEEE trans. on neural systems and rehabilitation engineering, vol. 9, no. 1, Mar 2001

[2] Tandonnet C, Burle B, Hasbroucq T, and Vidal F. Spatial enhancement of EEG traces by surface Laplacian estimation: comparison between local and global methods. Clin Neurophysiol. 2005 Jan;116(1):18-24.

[3] Thomas Ferree and Ramesh Srinivasan . Theory and Calculation of the Scalp Surface Laplacian. Technical Note. (http://www.egi.com/Technotes/SurfaceLaplacian.pdf)

Appendix: Result Table

Command Given	Movement by the subject	Command Given	Movement by the subject
Right	Right	Right	Right
Left	Right	Right	Ahead
Left	Left	Right	Ahead
Left	Right	Right	Right
Left	Right	Ahead	Ahead
Left	Right	Ahead	Ahead
Left	Right	Ahead	Ahead
Right	Right	Ahead	Ahead
Ahead	Ahead	Left	Left
Ahead	Ahead	Left	Left
Ahead	Ahead	Left	Left
Left	Ahead	Left	Left
Left	Left	Left	Left
Left	Ahead	Right	Right
Left	Ahead	Right	Right
Left	Ahead	Right	Right
Right	Left	Right	Right
Right	Right	Ahead	Ahead
Right	Right	Ahead	-
Right	Right	Ahead	-
Left	Right	Ahead	Right
Left	Left	Ahead	Ahead
Left	Left	Left	Ahead
Ahead	Left	Left	Left
Ahead	Left	Left	Left
Ahead	Ahead	Left	Ahead
Ahead	Left	Left	Left
Left	Left	Left	Left
Left	Ahead		

Left: left and backward

Right: right and backward

Ahead: forward and shoot