Brain-computer Interface Based on Visual Evoked Potentials to Command Autonomous Robotic Wheelchair

Sandra Mara Torres Müller¹,∗ Wanderley Cardoso Celeste¹
Teodiano Freire Bastos-Filho² Mário Sarcinelli-Filho²
Received 31 Mar 2010; Accepted 8 Oct 2010; doi: 10.5405/jmbe.765

Presenter: Ching-Kai Huang
Adviser: Dr. Shih-Chung Chen
Outline

- Background
- Introduction
- Objective
- Materials and Methods
- Results & Discussion
- Conclusions
- Progress report
- Future Works
- References
Background

Four lobes of Cerebral cortex:

- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital lobe

Keywords: Cerebral cortex, Frontal lobe, Parietal lobe, Temporal lobe, Occipital lobe
E.E.G (electroencephalogram): An EEG records the electrical activity of the brain.

EEG features:
- Voltage range: 0.5 ~ 100 μV
- Frequency measure range: 0.5 ~ 100 Hz

The brain wave may be divided into four basic waves:
- α rhythm
- β rhythm
- θ rhythm
- δ rhythm

http://www.fibromyalgiasyndrome.co.uk/images/19161.jpg
The frequency and voltage range of four basic waves:

- **β (Beta)**
  - 14~30 Hz; 5 ~ 20μV;

- **α (Alpha)**
  - 8~14 Hz; 30~50μV;

- **θ (Theta)**
  - 3.5~7 Hz; < 30μV;

- **δ (Delta)**
  - 3.5 Hz; 100 ~ 200μV
Introduction

- **Brain-Computer Interface (BCI)**
  Several different features of scalp recorded EEG signals are being used as control signals.
Introduction

**Event Related Potential (ERP)** is voltage fluctuations that are associated in time with some physical or mental occurrence.

**Components of Event Related Potentials include:**

- μ and β Rhythm
- P300 Evoked Potential
- Steady-State Visual Evoked Potential
- Slow Cortical Potential
Introduction

◆ Steady State Visual Evoked Potential (SSVEP)
  • These signals are natural responses for visual stimulations at specific frequencies.
  • Separate frequencies were used for each arrows. (6 Hz and 10 Hz)
Objective

The goal of this research was to design a control system to allow a robotic wheelchair to move from one place to another, reaching a position and orientation defined by its user through a BCI based on visual evoked potentials.
Upon such choice, the control system onboard the wheelchair generates reference paths with low risk of collision, connecting the current position to the chosen one. Therefore, a system to allow people with severe motor dysfunction to have the quality of their lives improved is the proposal of the work.
Material and Methods

Figure 1. Block diagram of the system structure.
Material and Methods

- Frequency domain analysis.
- Looking at a 17-in LCD display at a distance of 0.7m.
Material and Methods

◆ System Setup

Sample rate: 600 Hz

Filter:
Passband: 1Hz-100 Hz

Recording Channels:
P7, PO7, PO5, PO3, POz, PO4, PO6, PO8, P8, O1, O2, Oz

Reference:
Left ear lobe

Notch Filter:
60 Hz
Material and Methods

First and second experiments:

Seven healthy volunteers, 6 male and one female, aged between 25 and 43, participated in the first and second experiments.
Material and Methods

First and second experiments:

- At the preprocessing step, digital low-pass FIR filtering using a Hamming window with order 128 was performed, with decimation to 128 Hz and passband of 2 to 64 Hz.

- Each successive epoch overlapped the preceding one by 75%, or 96 samples, as suggested in [7].

- Estimation of the PSD in the range of 4-30 Hz was performed to extract the EEG features.

- A separate power spectrum was computed for each EEG channel, using the pwelch function of the Matlab® Signal Processing Toolbox, at intervals of 10 s.

PSD: Power Spectral Density (功率譜密度)
Material and Methods

◆ Third experiment:

- Six healthy male volunteers, aged between 21 and 32, called Vol1 to Vol6, participated in this experiment.

- Each one was asked to watch a stripe at the center of the LCD display, and two minutes of raw EEG were recorded.

- In the first trial, the volunteer was asked to watch the screen without stimulus, which was called the rest state.

- After, the frequencies that the stripe presented at each trial were: 5.0, 5.6, 6.0, 6.4, 6.9, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0 and 20.0 Hz.
Material and Methods

◆ Third experiment:

➢ At the preprocessing step, digital low-pass filtering with a 5th-order elliptic filter with bandpass up to 60 Hz is performed. Also, a spatial filter based on the Common Average Reference (CAR) method was implemented.

➢ Spectral $F$-test (SFT)
Results & Discussion

◆ Results of the first and second experiments:
   ➢ Frequency: 5.0, 5.625, 6.4 and 6.9Hz. [7]

◆ The results show a rate of 92% of correct classification.

The maximum vector for each stimulus frequency (at the same plot) for the channel O2.
The stimuli are black-and-white checkerboards, like stripes, flickering at different frequencies.
Results & Discussion

- the maximum of the power spectrum follows the stimulus frequency. The difference between the maximum value and the stimulus frequency may be due to some interference such as noise or background activity.

- Thus, it is necessary to enhance the frequency response to eliminate these components; that was implemented using the statistic test characterized in the third experiment.

Power spectrum for intervals of 10 s for the second experiment, channel O2.
Results & Discussion

- Results of the third experiment:

![Stimulus signal spectrum](image1.png)

![Rest signal spectrum](image2.png)
As a first result, we have developed a visual feedback composed of four LEDs, which indicate the stripe identified by the BCI.
Conclusions

First, it is possible to identify the stimulus frequency using an approach in the frequency domain, which was shown in the first experiment.

Moreover, it is possible to identify a specific stimulus frequency in an environment with simultaneous stripes with a rate of 92% of correct classification, as shown in the second experiment.
Conclusions

To eliminate the induced one, a statistic test was used, which presented good results, as shown in the third experiment.
Future works

- Papers review
- Comparison of different analytical methods.
References


References


Thanks for your attention.