# RECOGNITION OF EEG PATTERNS RELATED TO EVOKED POTENTIALS BY INTERMITTENT PHOTO-STIMULATION

Mauricio Kugler [1],
Ivana Naomi Mukai [1],
Heitor Silvério Lopes [1,2],
Valfredo Pilla Júnior [1,2]

[1] Bioinformatics Laboratory / CPGEI & [2] Electronics Department,
Federal Center for Technological Education of Paraná – CEFET-PR
Av. 7 de setembro, 3165
80230-901 – Curitiba (PR) – BRAZIL

**Abstract** - A prosthetic keyboard for a Brain Computer Interface (BCI) is a device that uses patterns of the electroencephalographic (EEG) signal evoked by specific visual stimuli to recognize symbols or commands. When the user looks to a stimulus, an associated pattern on the EEG signal will be evoked. The objective of this project is to develop a system for signal conditioning and acquisition, as well as for further identification of different patterns. The system uses a LED matrix as the source of visual stimuli and an appropriate data acquisition system, which were used with ten volunteers in different tasks. Acquired data was analyzed offline in both, time and frequency domains with the mean FFTs and spectrogram, using the MATLAB platform. In eight out of ten volunteers the system succeeded to identify relevant patterns. The analysis of the spectrogram showed that it is possible to identify two, four and up to eight different patterns. These results encourage further development towards a functional prosthetic keyboard.

**Keywords**: EEG, evoked potentials, BCI, photo-stimulation, signal processing

## 1. INTRODUCTION

Nowadays, life quality is an issue of the highest importance. Within this scope, accessibility and communicability is a special concern for handicapped people. Specifically for those people who has only the movement of the eyes to communicate with the world, it is imperative the development of special devices that uses this characteristic as the interaction way.

Those devices are known as BCI (Brain-Computer Interface) systems [1]. Along the last years many approaches to functional BCI's have been proposed. The direct monitoring of the ocular globe position is the most direct way to detect a subject's intention to communicate. Notwithstanding, this method lacks accuracy and requires heavy computational resources. In this work, another technique is described, based on the use of the electroencephalographic signal acquired in the occipital region of the scalp (over the visual cortex). This method gives good accuracy and allows a wide range of possible symbols, besides being robust and practical to the user.

The final objective of the work is the implementation of a prosthetic keyboard, attached to a computer that allows communication between the user and the world. A prosthetic keyboard is a stimulus generator, in which different stimuli are related to different keys that represents commands or symbols. The user looks to the symbol (key) that he/she wants to activate, and the symbol stimulus will generate an evoked potential in the EEG. Once the signal is acquired and digitally processed, it can be (hopefully) recognized as the symbol or command required.

## 2. METHODOLOGY

Basically, four generic modules compose a BCI system: stimulation, acquisition and preprocessing, pattern recognition and control [2]. In this work, a data acquisition protocol was used for the first three procedures:

- Stimulation: generation of visual stimuli presented to the volunteer's eyes, synchronized with the acquisition;
- Acquisition and preprocessing: acquisition of the EEG on the subject's scalp using surface electrodes, digitalization and recording of signals in a predefined format;
- Analysis: offline signal processing to find patterns related to the stimulation.

### 2.1. STIMULATION

The stimulation consists in generating visual stimuli that produces specific electric signals in the visual cortex of the brain, related to that stimulation. In this project, an intermittent photo-stimulation was used, inspired by the work described by Sutter [3]. In our implementation, the main parameter to be varied is the frequency of intermittence. Two 8x8 LED arrays were built, each one divided into four quadrants that can be activated individually by software.

### 2.2. DATA ACQUISITION AND PREPROCESSING

The data acquisition system used was composed by a signal amplifier and filter, a 10 bits, 16 channel data acquisition digital board model AT-MIO-16E-10 (National Instruments), and a Windows-based synchronization and management acquisition software, developed in C language. Electrodes on the subject's scalp were positioned according to the 10-20 system recommended by the EEG International Federation [4]. The EEG leads were positioned in the occipital region of the scalp: the first over O2 and the second in the central line, between O1 and O2. The amplifier had a gain of 100000 and was band-limited in 8 to 18Hz. In order to increase the signal to noise ratio the row signal was averaged along 20 acquisitions.

### 2.3. ANALYSIS

After acquiring data, the analysis was done offline using digital processing techniques using a software developed in the MATLAB platform. The objective of this process is the identification of patterns in the raw EEG, in the frequency domain. The analysis methods adopted were: spectral analysis using the average of FFT (Fast Fourier Transform) module, in order to verify the frequencies present in the signal; and the spectrogram, to verify the distribution of the frequency peaks along time.

### 2.3.1. FFTs Averaging

In a session, $m$ different stimulation frequencies are used (for instance $m$ = 2, 4 or 8). The stimulation sequence is repeated $n$ times (for instance, $n$ = 20). The $n$-fold averaged input signal is acquired in a 512 samples/sec rate. Within segments of the same stimulation frequencies, the 1024-point FFT is computed using 1 sec. non-overlapping windows (0.5Hz of resolution). The final graphics is build using the computed FFTs of segments of the same stimulation frequency.

Figure 1 shows the block diagram of the FFT averaging for a four stimuli session with $n$ signals.

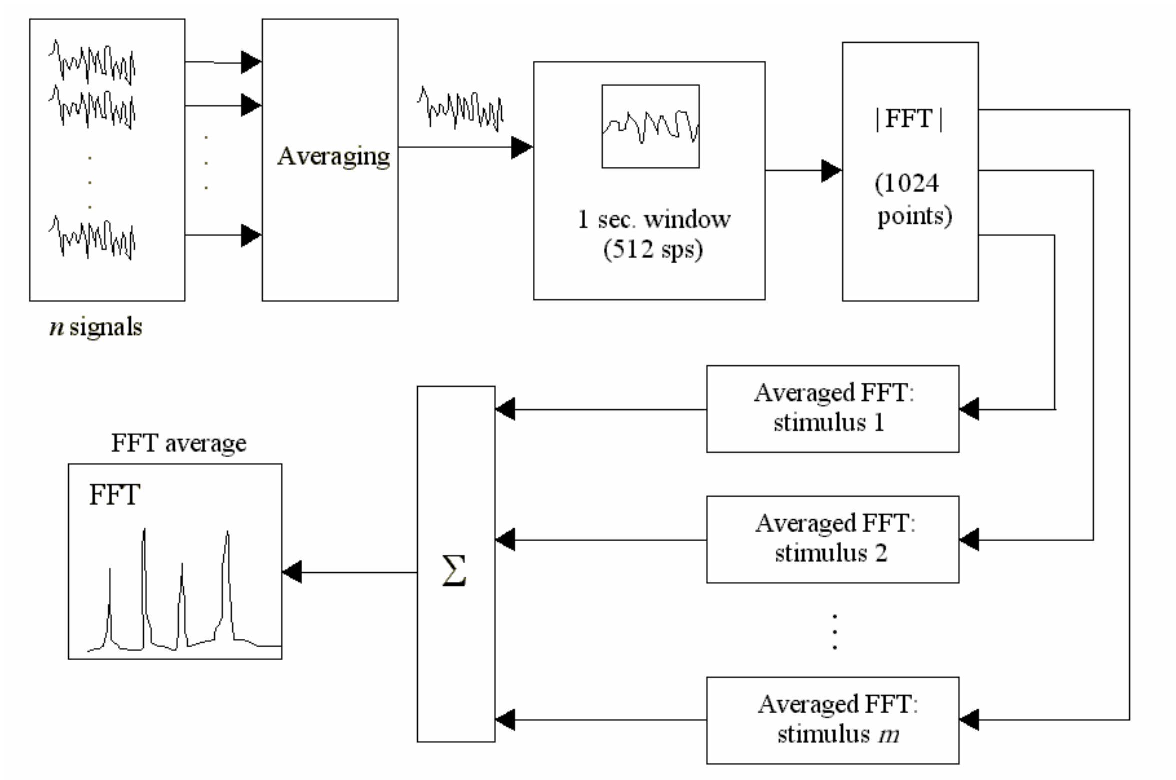


Figure 1 - Block diagram of the FFT average computation

### 2.3.2. Spectrogram

To compute the spectrogram, a 2:1 decimator is necessary so as to reduce the sample rate, and thus, the processing time. The spectrogram is calculated using the FFT module with 256 points in a rectangular window of 1 sec. (1 Hz resolution). Every 0.125 sec., the window advances 32 new samples, discarding the last 32 ones, and a new FFT is calculated. The spectrogram is shown in a 3D graph, where the axes x, y and z are, respectively, frequency, time and amplitude (of the FFT). Figure 2 shows in detail the block diagram of the spectrogram computation.

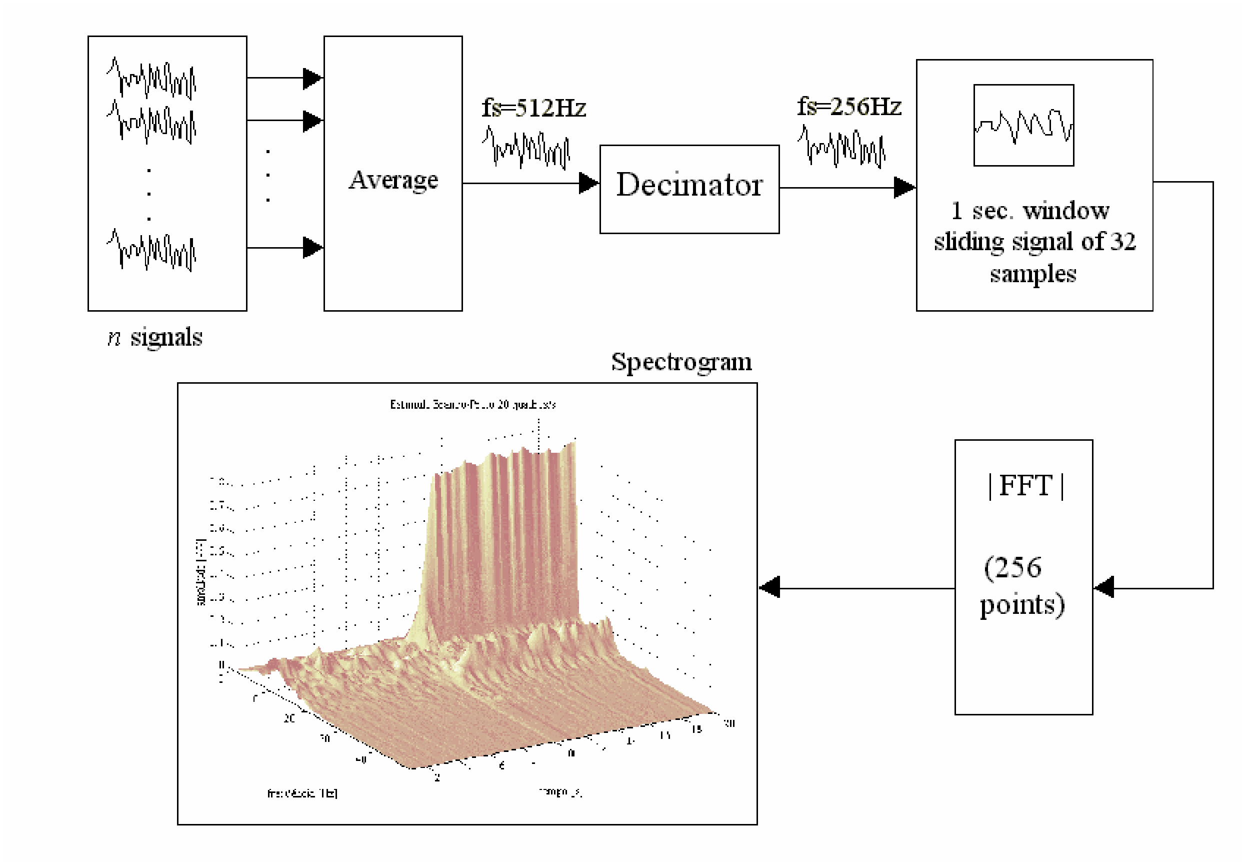


Figure 2 - Block diagram of the spectrogram computation

## 3. RESULTS

Signals from ten volunteers were collected in several acquisition sessions, in which different stimuli were used. The stimulation/acquisition sessions consisted in stimulation with 2, 4 and 8 different frequencies simultaneously generated to the volunteer sight. The volunteer, quiet and relaxed, had only to observe each visual stimulus (in different frequencies) for a given time, in a given order, synchronized by the software.

Figures 3 to 8 show the results for a specific volunteer. Figures 3 and 4 show, respectively, the average FFTs and the spectrogram with two sets of peaks, in 11Hz and 15Hz. Each peak has 4 sec. and the whole acquisition section is then 16 sec. Two other smaller peaks can be observed in 20Hz, which are harmonics of the first stimulating frequency. Figures 5 and 6 show results for four different simultaneous frequencies in 10Hz, 12Hz, 14Hz and 16Hz. Figures 7 and 8 show results for eight different stimulating frequencies: 9Hz, 11Hz, 13Hz, 15Hz, 10Hz, 12Hz, 14 Hz and 16Hz.

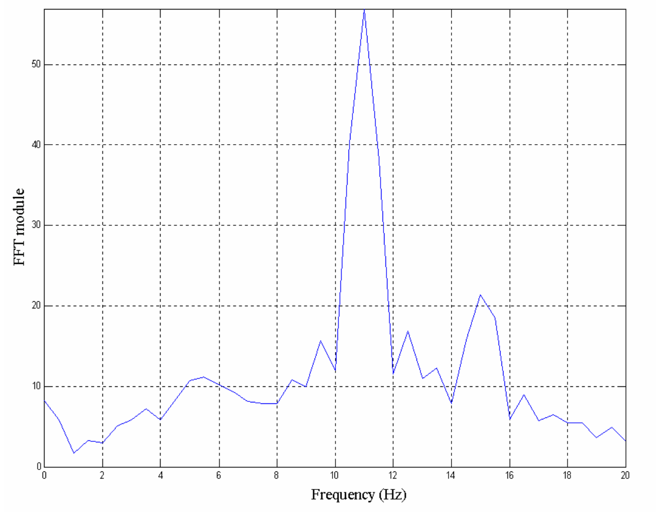


Figure 3 – FFT average for volunteer 1 - Session 1 with stimuli in 11Hz and 15Hz

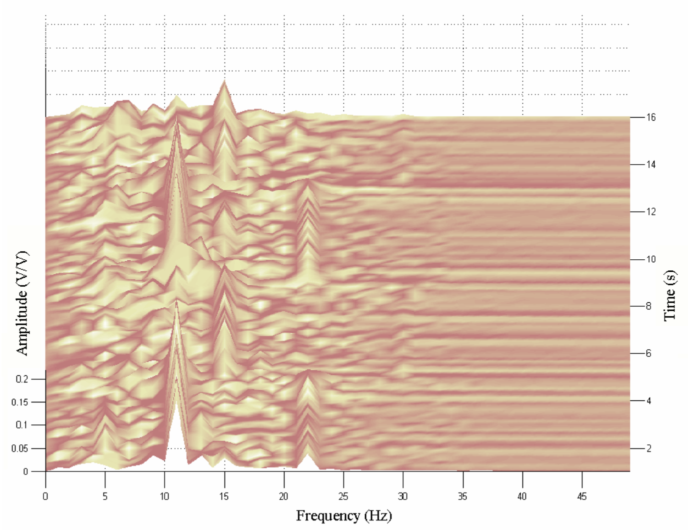


Figure 4 - Spectrogram for volunteer 1 - Session 1 with stimuli in 11Hz and 15Hz

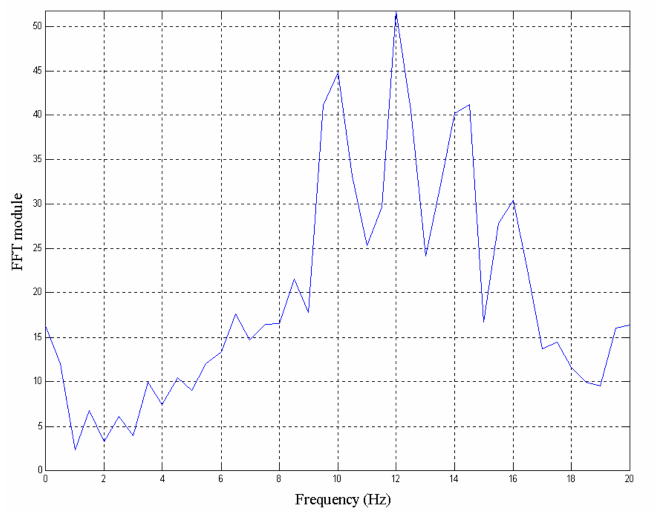


Figure 5 – FFT average for volunteer 1 - Session 2 with stimuli in 10Hz, 12Hz, 14Hz and 16Hz

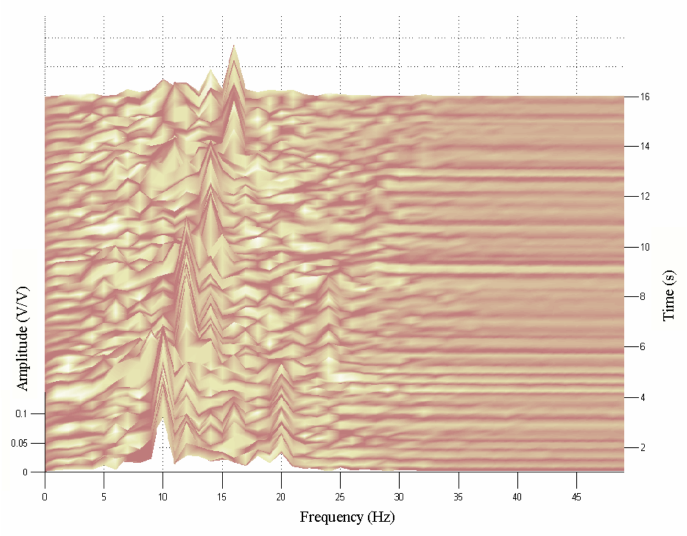


Figure 6 - Spectrogram for volunteer 1 - Session 2 with stimuli in 10Hz, 12Hz, 14Hz and 16Hz

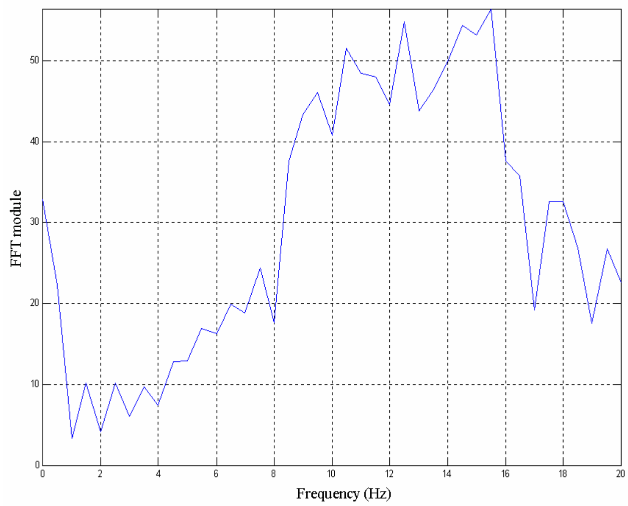


Figure 7 - FFT average for volunteer 1 - Session 3 with stimuli in 9Hz, 11Hz, 13Hz, 15Hz, 10Hz, 12Hz, 14Hz and 16Hz

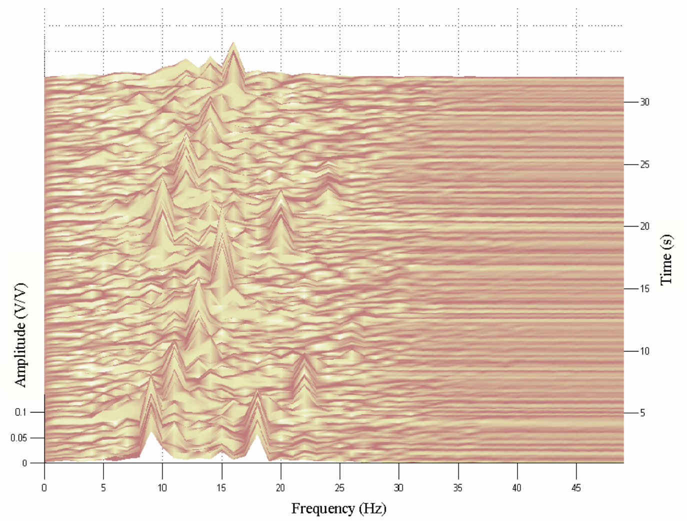


Figure 8 - Spectrogram for volunteer 1 - Session 3 with stimuli of in 9Hz, 11Hz, 13Hz, 15Hz, 10Hz, 12Hz, 14Hz and 16Hz

## 4. CONCLUSIONS

The methodology proposed here for stimulation, signal acquisition, signal processing and analysis was suitable and efficient for the purpose of discriminating different patterns evoked in the EEG, related to visual stimuli. The accuracy in detecting very close frequencies in the evoked response, present in most volunteers, indicates the possibility of a further development, in which a larger number of symbols could be identified. Some subjects reported visual fatigue after 30 or more minutes of a continuous session. Probably, this is due to the low frequencies used in the experiments, suggesting that higher frequencies should be tested in the future. This may not represent a serious drawback of the method.

Results encourage the development of a full BCI system to be implemented as a prosthetic keyboard for seriously handicapped people.

## 5. REFERENCES


[1] Pfurtscheller, G., Kalcher, J., Neuper, C., Flotzinger, D., Pregenzer, M., On-line EEG classification during externally paced hand movements using a neural network-based classifier. *Electroencephalography and Clinical Neurophysiology*, 99(5): 416-425, 1996.

[2] Pilla Junior, V., Lopes, H.S., Detection of movement-related desynchronization of the EEG using neural networks. *Proceedings of World Congress on Medical Physics and Biomedical Engineerin*g, Chicago, USA, [CD-ROM], 2000.

[3] Sutter, E. E., The brain response interface: communication through visually induced electrical responses. *Journal of Microcomputer Application*s, 15: 31-45, 1992.

[4] Clark Jr, J., The origin of biopotentials. In: Webster, J. G. (ED.) *Medical Instrumentation Application and Desig*n. John Wiley & Sons, 121-182, 1998.