DETECTION OF SIGNAL P300 IN THE PROCESSING OF EEG DATA

Radoslava Avdzhieva

Department of “Theoretical Electrical Engineering”, Technical University - Sofia, bul.“Sv. Kliment Ohridski” No.8, Postal Code (ZIP) 1000, Sofia, Bulgaria
phone: +359 893 690 826; e-mail: r_avdzhieva@tu-sofia.bg

Abstract. *The Electroencephalogram (EEG) is a powerful instrument to collect vast quantities of data about human brain activity. A typical EEG experiment can produce a data matrix related to the human neuronal activity every millisecond. The lie detector is the most common method used by law enforcement agencies to detect fraud. Detection of signal P300 is a step towards the development of safer methods. Test data using EEG controlled experiment by neuroheadset “Emotiv EPOC”. It has developed an automated system to extract information about features of EEG signals to detect signal type P300, which is implemented in MATLAB. In the presence of P300 signal to determine whether the studied object is associated with a specific event or problem. In this paper, an experiment is presented to the detection of signal P300.*

Keywords: *detection, EEG signals, signal type P300, MATLAB*

1. INTRODUCTION

This thesis proposes a P300-based BCI system using a inexpensive commercial neuroheadset “Emotiv EPOC”. The research work studies and reviews the literature for the state-of-the-art of P300 wave evoking and detection approaches and algorithms. This research uses these algorithms and approaches to develop the proposed BCI system. Finally, this thesis describes results from tests of the reliability and performance of the proposed system in simple control applications.

To clarify the ability of such sensors, first, the P300 brain wave has to be guaranteed to exist among signals that are acquired from the human brain using these sensors. That requires efficient visual paradigms that keep the user engaged and attended for such a purpose. Second, adequate data processing and classification algorithms have to be used to efficiently detect the P300 wave among these noisy signals.

The main objective of the study in this thesis is to develop an affordable P300-based BCI system that uses an Emotiv Epoc headset to control different computer based processes. Then, the next goal is to review specific P300-based BCI data processing and classification algorithms, test, and compare them using well-known benchmark P300 datasets from the BCI.

2. EEG DATA PROPERTIES

Electroencephalography (EEG) is the recording of electrical activity of the human brain. EEG refers to the recording of the brain’s instant electrical activity for short periods of time as recorded from multiple electrodes placed on the scalp. That is, the type of neural oscillations that can be observed in EEG signals. [1]

The International so-called 10-20 system is usually employed to record the spontaneous EEG. Odd numbers indicate electrodes located on the left side of the head. Even numbers indicate electrodes located on the right side of the head. Capital letters are used to reference each cortical zone, namely frontal (F), central (C), parietal (P), temporal (T), and occipital (O). Fp and A letters stand for frontal pole and auricular. The designation 10-20 comes from the percentage ratio of the inter-electrode distance with respect to the nasion-inion distance [2].

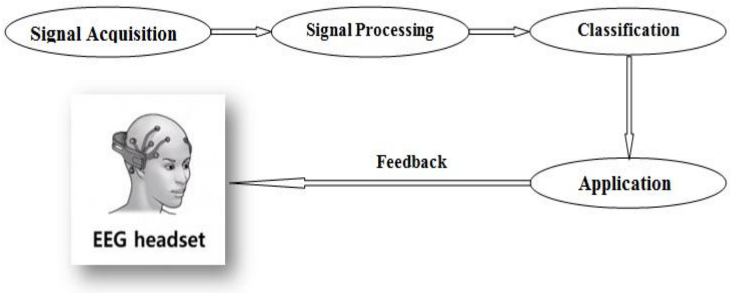

Fig. 1. General block diagram of a BCI system

On figure 1 is presented general block diagram of a BCI system. A subject performs a specific cognitive task or concentrates on a specific stimulus. Brain signals are acquired and then processed with signal processing and classification algorithms. The outcome of the classification is fed into an application. The application generates feedback to inform the subject about the outcome of classification.

As a result, it is difficult to use only the EEG to infer the activity of small brain regions, let alone the activity of single brain neurons [3].

2.1. Data acquisition

In BCI application, working with raw data is essential. Proper data is needed to apply some filtering process and converting raw data into the digital form. Digitized data is used in applications after it is classified.

Applications in this thesis are used both offline and online data acquired from Emotiv Headset. Offline data is recorded in edf file format and used in MATLAB to work with. Online data is used with the application that is written for real time control.

2.2. Feature selection

Feature selection is the first step of the classification. Classification of the data set is impossible in some cases. Feature selection is important because it provides a transformation to different space where data can be classified.

EEG signals are complex signals seem like noise, so gathering information from the time domain is hard. In time domain data seems irrelevant, but it is possible to gather information from that data.

Different spaces give different eigenvectors of this space and different conditions can be shown by the linear combination of these eigenvectors. Transforming data to other spaces obtain different features. Using different spaces guarantee that two different features are not linearly dependent.

Time domain is the main space of the EEG data collected as shown in figure 2 Frequency is also used as a feature space as shown in figure 3 Various transforms can be possible for gathering information on different spaces.

EEG data in time domain is separated in distinct interval parts. These intervals are called Window Length which is also a parameter for classification. Window Lengths should be power of two because FFT (Fast Fourier Transform) transform is faster if the time series length is power of two.

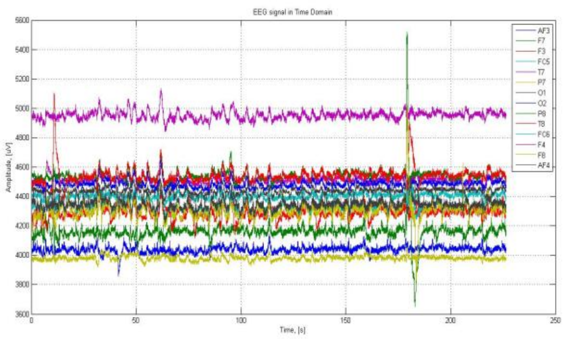

Fig. 2. EEG Signals for every channel separately in Time Domain

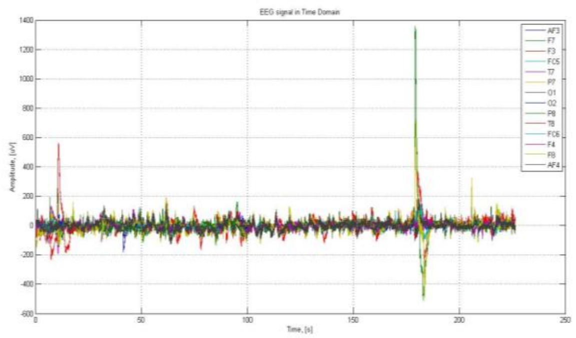

Fig. 3 Average EEG Signals for every channel in Time Domain

3. SIGNAL TYPE P300

The accurate detection of deception or lying is a challenge to experts in many scientific branches. [4]

Signal type P300 is a positive peak in the EEG, observed approximately 300 ms after the stimulus presentation. A typical pattern of P300 response can be seen in figure 4. [5]

The P300 wave is an event-related potential (ERP) which can be recorded via EEG. [6] Discovery of the P300 event-related potential (ERP) stimulated the use of human brain recording methods to evaluate brainwaves and thinks. The P300 component is measured by assessing its amplitude. Amplitude (μV) usually is defined as the difference between the mean baseline voltage and the largest positive peak of the ERP waveform within a time window.

Signal type P300 human scalp distribution is characterized as the amplitude change over the midline electrodes (Fz, Cz, Pz) that increases from the frontal to parietal electrode sites for target influences. [7]

The detection of P300 waves remains a very challenging problem for both the machine learning and neuroscience communities. [6]

4. HARDWARE USED TO DETECTION

Based on the latest developments in neuro-technology, one Swiss based company called “Emotiv” developed a cheap new interface for human interaction with the computer wirelessly.

The “Emotiv EPOC” device (Fig. 5) has 16 sensors which come into contact with the scalp of the head and using the conventional technology - electroencephalography, by detecting electric signals from the surface of the scalp and making them appear on the screen. [8]

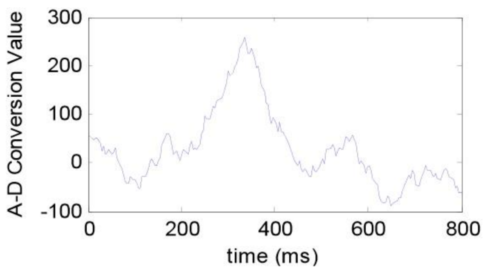

Fig. 4. A typical signal type P300

Fig. 5. Emotiv EPOC neuroheadset

The “Emotiv EPOC” is an EEG neuroheadset which supplies 14 channels EEG data and 2 gyros for 2 dimensional controls. The advantage is that it is wireless cable free solution with long autonomous operation time. The “Emotiv EPOC” sends EEG data to computer with USB receiver via Bluetooth interface.

The academic version of the “Emotiv” software can access the raw data which is decrypted using Control Panel and can save the extracted data. The “Research Edition SDK” includes a research headset: a 14 channel (plus CMS/DRL references, P3/P4 locations). The channel names based on the International 10-20 locations are: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 (shown in Fig. 6). Other specifications are listed below (Table. 1). [1]

Table 1. “Emotiv EPOC” Specifications:

Number of channels	**14 (plus CMS/DRL references)**
Channel names (International 10-20 locations)	AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2
Sampling method	Sequential sampling, Single ADC
Sampling rate	~ 128 Hz (2048 Hz internal)
Resolution	16 bits (14 effective) 1 LSB = 1.95 uV
Bandwidth	0.2 – 45 Hz; digital notch filters at 40 Hz and 60 Hz
Dynamic range (input referred)	256 mV (pp)
Coupling mode	AC coupled
Connectivity	Proprietary wireless, 2.4 GHz band
Battery type	Li-poly
Battery life	12 hours
Impedance measurement	Real-time contact quality using patented system

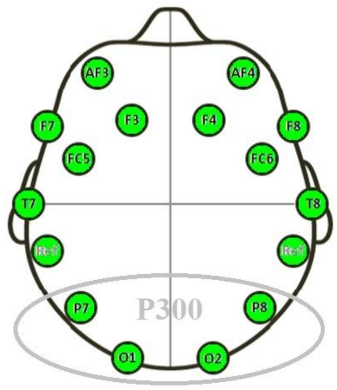

Fig. 6. Emotiv EPOC’s Sensors Layout

5. DETECTION OF P300 RHYTHM

5.1. Detection

Detection is mostly used in P300 type evoked potential applications. Detection of the stimulus is important to understand the function of the focused responses then these responses can be classified more accurately. Activity patterns usually stimulate the upper cortex of the brain where a good quality of the EEG signals can be measured.

5.2. Classification

EEG signals are complex signals because of its nature. That makes working with EEG data harder. Classifying the data of EEG signal requires some techniques to determine differences between signals. Classification can be done on different domains such as frequency or time. Methods using classification and feature extraction differ from problems characteristic. Classification is implemented on the windowed data to extract the eigen values of signals for selected feature. After determination of the eigenvalues and preparation of the data set are completed, the packet of data and eigenvalues is sent to the classifier. Several classifiers are used for classification of EEG data. Classifiers are run for each data packet recorded for certain window length.

6. EEG SIGNAL PROCESSING AND RESULTS IN MATLAB

The display screen “Emotiv EPOC” during an experiment is shown in figures from 7 to 11. At the time of recording the research subject is asked a series of test questions. Recording is stopped when questions stopped and the final result is obtained.

7. CONCLUSIONS

This paper presented an experiment on P300 detection based on brain wavelet analysis in MATLAB using the “Emotiv EPOC” neuroheadset. The results presented in this paper are part of a project with the ultimate goal of designing and developing “Lie Detector”. The proposed method is suitable for integration into a brain-computer interface and information control for external devices with BCI applications. It has presented part of offline classification system for P300 based brain computer interface. This is classification system and it can improve.

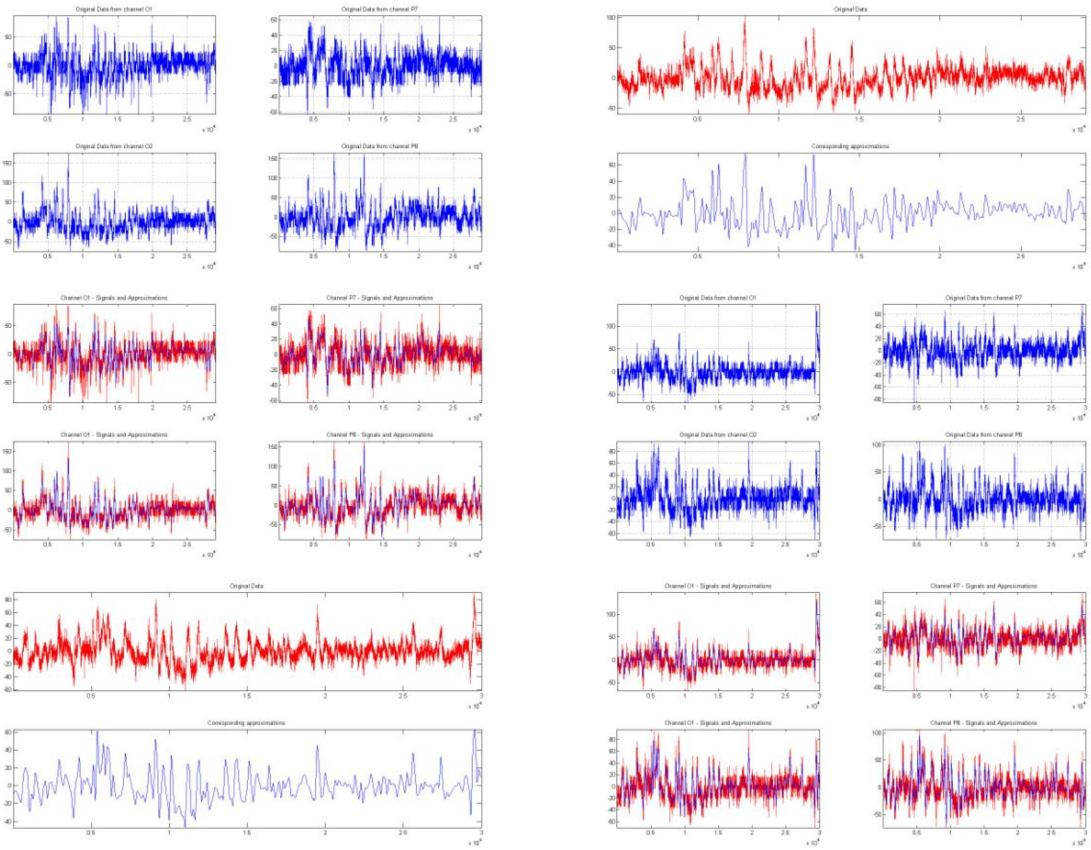

Fig. 7-11 Emotiv EPOC's screen during an experiment – original and approximated signals (in left – when saying LIE // in right – when saying TRUTH)

References

[1] R. Avdzhieva, G. Tsenov and V. Mladenov, "Brainwave Type Detection in MATLAB with EEG signals", Challenges in Higher Education & Research, vol. 11, Heron Press, Sofia, 2013, pp. 123-126

[2] H. Cecotti and A. Graser, "Convolutional Neural Networks for P300 Detection with Application to Brain-Computer Interfaces", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 33, No. 3

[3] J. Polich, "Neuropsychology of P300", The Oxford Handbook of Event-Related Potential Components

[4] T. Lee, H. Liu, L. Tan, C. Chan, S. Mahankali, C. Feng, J. Hou, P. Fox and J. Gao, "Lie Detection by Functional Magnetic Resonance Imaging", pp. 157–164

[5] B. Akinci, "Realization of a cue Based Motor Imagery BCI with its Potential Application to a Wheelchair"

[6] A. Sinha, M. Pavithra, K. Sutharshan and M. Subashini, "A MATLAB Based On-line Polygraph Test Using Galvanic Skin Resistance and Heart Rate Measurement", Australian Journal of Basic and Applied Sciences, 2013, pp. 153-157

[7] T. Fleck, M. Gruener, Br. Halaburka and C. Moskaites, "ME 224 Project: Lie Detector"

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