VisualMind Framework for Brain-Computer Interface development

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INTRODUCTION

Any mental thought or movement planning and execution are accomplished by specific neuronal activity which is reflected on biopotentials recorded on scalp by means of electroencephalography. At present several systems, called Brain-Computer Interface (BCI), were created capable to differentiate temporal-spatial patterns of scalp biopotentials and to translate them to commands for controlling a computer and other electromechanical devices, e.g. mobile robots.

Such interface can be used in clinics by people with poor or lost neuromuscular control and by healthy person. For example, BCI user will be able to direct cursor to particular area on computer monitor, type messages or browse the Internet.

![Figure 1. Schematic view of BCI system components](image)

Classical definition of BCI was formulated by Wolpaw (2002): “A BCI is a communication system in which messages or commands that an individual sends to the external world do not pass through the brain’s normal output pathways of peripheral nerves and muscles.”

Despite of the fact that BCI-system reliable provides only one dimensional control and, as a result, only binary decision tree it allowed to develop the impressive range of applications:
• Text typing;
• Internet browsing;
• Games (teletennis and Pacman);
• Prosthesis or robot control.

BCI systems can be classified by several criteria:

• Invasive (or implantable) and non-invasive;
• Synchronous and asynchronous;
• Universal or individual classificatory parameters setup;
• Offline and online operation;
• Type of used potentials.

VISUALMIND FRAMEWORK

The most of contemporary EEG registration and analysis systems can’t be used for BCI realization. Some of them lack the real time analysis; others lack flexibility of signal processing routines. That leads us to decision to create universal VisualMind framework which is organized as a set of independent program modules incapsulating different EEG processing algorithms and 2D/3D visualization. At design step, a framework user can select various analysis and visualization methods and then create the overall processing pipeline by inter connecting their inputs and output in a way of Simulink. During execution phase the framework will process the incoming EEG data fed to the pipeline.

For framework development we have selected .NET environment and C# programming language. That allowed us to develop quickly the distributed application which supports graph creation, their storage in XML format, data exchange through TCP/IP protocol, virtual scene and objects creation and control via Direct3D technology, registration equipment control.
Figure 2: VisualMind framework main window during execution

This system was used for experiments with various BCI approaches as well as a standard EEG application. BCI application based on P300 cognitive component of evoked potentials is presented below.

To register P300 component an oddball stimulation paradigm is used. During such experiments two types of stimuli are used – frequent non-target and non-frequent target. Their proportion is typically set as 80 and 20%. Subject should count every appearance of target stimuli. Target stimulus is also referred as a relevant stimulus. After presentation of such stimulus a small positive deflection at 300 ms after stimuli onset will appear. It is called P300 component, lasts 300-400 ms and has amplitude 5-15 μV. Maximum amplitude is registered under Pz electrode. The smaller probability or percentage of target stimuli appearance, the bigger P300 amplitude is observed. Several averages is required to extract the component from background EEG activity which usually has amplitude 50-100 μV.

Based on this neurophysiological facts we have built several BCI modules to enter text in real time. It’s stimulation window is shown below:
32 letters of Russian alphabet together with additional symbols and commands were presented on screen in front of subject as a virtual keyboard. Subject should fix his/her attention on the symbols to be entered. Stimulation is done as a repetitive intensification of rows and columns in random order. As a row or column are flashed randomly the probability that intensity of the letter selected by subject will change is equal 16.7%. Probability for non-target stimuli is equal 83.3%. That ratio is optimal for recording the P300 component.

Usually only 15 averages were used to detect P300 component. After letter is identified, it appears at upper string of stimulation window. Using that module our subjects were able to enter short words and names. It takes around 90 seconds to enter a single letter, if interstimulus interval is set as 1000 msec.

Our current work on P300 BCI is related to built better classifier and to shorten interstimulus interval down to 125 msec. In that case single letter will be entered in 12-15 seconds. Other development is directed to usage icons instead of letters. The system is intended for disabled person communication with hospital staff.
LITERATURE

1. Allison B. P3 or not P3: Toward a Better P300 BCI. PhD Thesis. 2004; UCSD


