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Concept of Software Interface for BCI systems

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Abstract. Brain Computer Interface (BCI) technology is intended to control external system by brain activity. One of main part of such system is software interface, which carries about clear communication between brain and either computer or additional devices connected to computer. This paper is organized as follows. Firstly, current knowledge about human brain is briefly summarized to points out its complexity. Secondly, there is described a concept of BCI system, which is then used to build an architecture of proposed software interface. Finally, there are mentioned disadvantages of sensing technology discovered during sensing part of our research.

Keywords: Electroencephalography, Brain – Computer Interface, Robotics, Human Brain
PACS: 07.05.Tp, 05.45.Pq, 89.20.Ff.

INTRODUCTION

The human brain is regarded as the most complex system in the universe. The modern science is currently attempting to understand the complex interconnection among individual parts of the brain [1]. There are many publications, which deal with a description of the brain. [1, 2, 3]

There are many scientific disciplines which deal with the human brain; for example numerical neuroscience, neuroinformatics, informatics or medicine. Each of them bring theories, which could explain different brain activities. Numerical neuroscience brings mathematical and biophysical models, which are able to model basic processes in neurons and neural networks. The main goal of neuroinformatics is a systematic development of database intended to collect information such as brain morphology, brain parts anatomy and their functional connection, brain electrophysiology, brain states obtained with magnetic resonance and their integration. Further, it seeks to develop tools for modelling, where the aim is the most accurate emulation of brain activity. In informatics, complex networks are highly suitable to model a complex system among which the brain includes. The contribution of medicine is undisputable especially in brain anatomy research.

The brain itself is composed of several parts, without which his activity could not be possible. One of its basic structural parts is a neuron. The neuronal cells are characterized by the fact that electrical activity is carried out in them. These cells communicate with each other by electrical signals. According to the last estimate, there are approximately 10^{11} neurons in the brain. Every one of them is connected with thousands of other neurons. The main source of Electroencephalography (EEG) signal is an electric activity of synapse - dendrites membrane located in the surface layer of the cortex. Each active synapse dispatches electromagnetic pulse to the environment during excitation [4]. Due to the high number of these pulses, it is difficult to locate their source by means of multichannel sensor on the skin. The brain activity consists in enormous amount of electrochemical reactions. Therefore, it is a combination of chemical transformations and electrical processes. Changes in electrochemical activity of individual parts are correlated with sensory perceptions, motor activity, changes of attention, etc. This article deals with the BCI technology, which represents the connection of brain waves with the output device through software interface.

Currently there are many known applications of BCI technology, but not enough at each particular field of study. Signal that is sensed from the brain is the key element in the BCI model; therefore the design of an appropriate algorithm for processing of the signal is the most discussed part of BCI model structure [8].

The aim of this article is to provide possible concept for designing software interface using in BCI systems.

DESCRIPTION OF BRAIN – COMPUTER INTERFACE TECHNOLOGY

BCI system can be divided into three main parts: signal sensing, signal processing and external system control. Each part is described separately in the following chapters.

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The basic principle of a system based on BCI is depicted on Figure 1. Firstly, the brain activity has to be obtained from the subject's brain by equipment based on some of the technologies, which are currently used to sensing the brain activity; for example fMRI (functional magnetic resonance imaging) [5], EEG (Electroencephalography) [6], MEG (Magnetoencephalography) [7] etc.
Further, received signal has to be processed and prepared for translation algorithm. This phase involves a feature extraction during which the most expressive characteristics of obtained signal are discovered. In the case of EEG signal, these characteristics usually relate to some physiological activity such as eye blink, eye movement, raise brow etc.
Finally, the translation algorithm transfers selected features to commands of external device or software. Translation method may differ for each application due to either nature of the application or specific target user requirements.

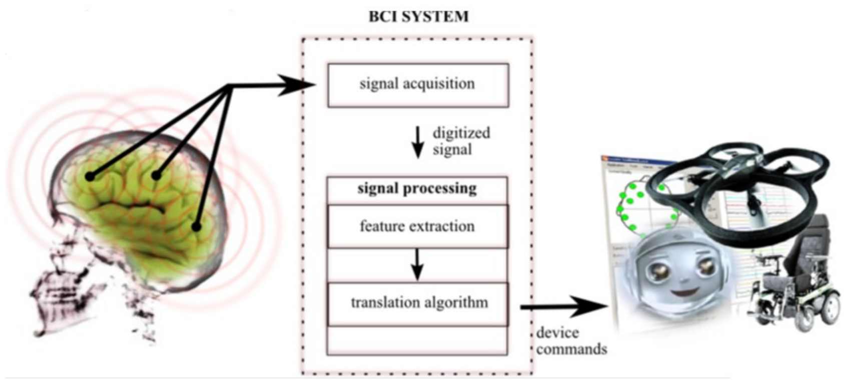

FIGURE 1. Basic principle of BCI system

Signal Sensing

There are several approaches for sensing brain activity. The most widely used is EEG technology, which belongs among the non-invasive methods. Devices based on EEG technology provide signal with very low voltage amplitude because the signal has to pass through the relatively low conductive skull. The amplitude ranges from tens to hundreds microvolts.

Recently, we use Emotiv EPOC neuroheadset [10] to obtain EEG signal from the human brain. Sensing of EEG by Emotiv EPOC neuroheadset has a number of advantages, because it already involves solved elementary issues in the processing of the measured signal. Due to this fact, it is not necessary to operate with raw data. It depends on the further usage of the data. Although the spectrum of this data could be used in many applications, it is not simple to understand the entire significance of the whole signal even if the proportion of the noise is minimal. This technology has the greatest expansion and certainly also the priority significance in diagnosis of various diseases in medicine [2].

Signal Processing

Signal processing is the most important part of BCI system; therefore, this area has to be deeply examined. This part is responsible to either physiological or mental activity recognition. Current recognition methods are based on artificial neural networks and they are able to detect following states of mind:

Instantaneous excitement - introduced as a consciousness or feeling of physiological excitement with positive value. Excitement is characterized by activation of sympathetic nervous system, which is responsible for physiological responses such as dilated pupils, stimulation of the sweat glands, pulse frequency etc.

Long-term excitement - similar to instantaneous excitement. Detection of this state is designed and set to obtain more precise measurement of excitement changes in longer time periods (minutes), [9].

Engagement - known as both alertness and directing attention to suggestions to the tasks. It is characterized as a growth of physiological excitement. It can be observed in beta-waves and alpha waves of EEG record. Contrary of this state is called boredom. The more attention or concentration is performed, the higher value is recorded during detection phase. The writing of text to the paper or writing on computer rises a value of engagement state, while closing eyes almost always rapidly decreases that value.

The most pronounced physiological activity is facial expression; thus, movement of brow, mouth or eyes can be detected. The brain signals of these activities is similar among all people; therefore, universal signatures can be used to detect facial expressions of almost each person.

External System Control

External system can be either software or hardware model. For the purposes of our research, robotics device Mindstorms EV3 was chosen as an external system, because it supports most of communication interfaces such as Bluetooth, Wi-Fi, USB connection etc. It consist of many static parts from which it is possible to construct various robotic solutions. Further, robot can be equipped with colour sensor, ultrasonic sensor, gyroscope sensor or touch sensor. Robot's motion is assured by interactive servomotors. Communication and logic of robot's behaviour is controlled by programmable intelligent EV3 Brick.

Intelligent EV3 Brick can be programmed in native graphics program language in LabView software. Moreover, there is also an option to develop own software application in some other supported languages such as Java, C# etc.

APPLICATION OF BCI TECHNOLOGY

An architecture of proposed software interface for specific BCI system is depicted on Figure 2.

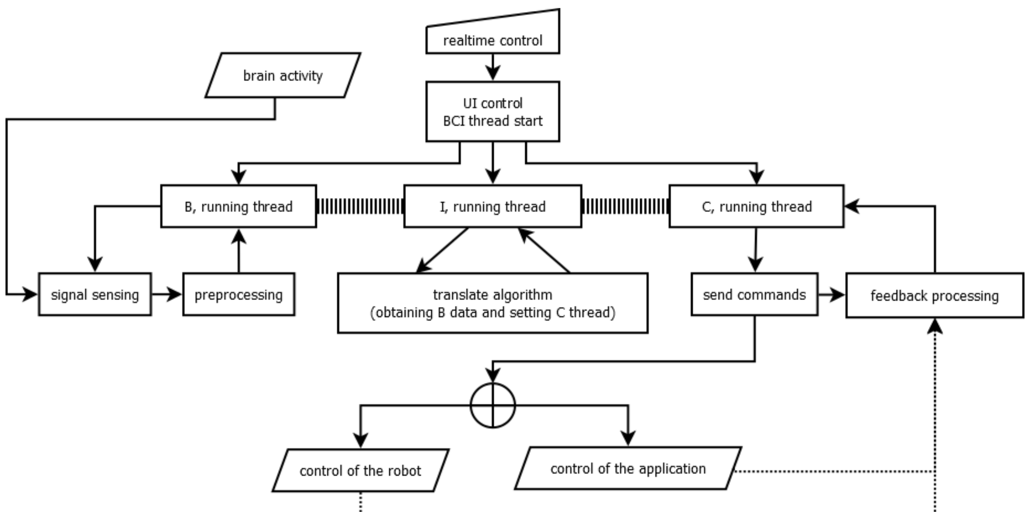

FIGURE 2. Architecture of proposed software interface

The whole application interface was realized on the higher abstraction level. Its architecture was designed with emphasis on mutual compatibility among available technical resources. One of our main requirement for the BCI software interface was to ensure its usability in real-time applications; therefore, three individual threads are used to maintain three main parts of BCI system. They are labeled according to part for which they care about. All of them run in parallel mode. Each thread also communicates with user interface in order to receive user commands.

Thread B ensures communication with neuroheadset, which provide data measured from the brain. These data has to be preprocessed to a form, which is more suitable for translation algorithm. The data are periodically read from neuroheadset. The default value of period is 1s, but its value is adjustable. Moreover, gyroscope embedded in neuroheadset requires 550ms for calibration process.

Thread I contains translation algorithm, whose base aim is to map brain activity into specific commands for external device. Currently we use activities which are recognizable by neural network using universal signatures provided by the producer of neuroheadset.

Thread C maintain communication with external system. In our case, it is robot Mindstorms EV3 mentioned above. The main task of thread C is to switch servomotors of a robot according to states, which are transmitted between threads B and C.

DISCUSSIONS

Our research examined practical issues associated with currently one of the most advanced EEG equipment intended for technical utilization. The time, which one spends with its installation on the subject head, is approximately from 5 to 10 minutes. It depends on whether it is the very first installation of the equipment or whether it is reused in the same day. Even if the device does not need any special gel, which will be applied on subject's head, it still requires application of saline solution on sensor pads. Further, the important part of the installation is also to find the right position for the neuro-headset on the head. This process is usually controlled by software, which provides information about contact quality of each sensor. This issue is not problem in laboratory conditions, but it could bring complications in practical applications; thus, it could be the one of the main reasons of making the whole system unusable because of the time needed to set the system up. On the other hand, current EEG devices provide EEG signal in the highest possible quality depended on the current technical progress.

Currently, we developing software application, which is based on Brain – Computer Interface principle. Its core part was described in this article. Our further research will deal with the gradual expansion of functionality of proposed software architecture. Its functionality will be based on the requirements of target user group. In the case of our study, the primary user group are people with disabilities.

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