ANALYSIS OF EEG SIGNAL FOR USING IN BIOMETRICAL CLASSIFICATION

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ABSTRACT

Aim of this article is to clarify the potential use of EEG signal in modern information age. The basic principle of Brain Computer Interface (BCI) lies in the connection of brain waves with output device through some interface. BCI technology represents a communication interface between brain and computer. To sense electric signal from the brain, it is usually used an equipment based on the last results of scientific research on neuro-technology. Communication is provided by wireless transmission through which the signal is transmitted from the equipment to personal computer. Then the signal is analysed, processed and used for finding appropriate classification parameters.

INTRODUCTION

Many scientific disciplines deal with the human brain; for example numerical neuroscience, neuro-informatics, informatics or medicine. All of them bring theories, which could explain different brain activities. Numerical neuroscience provides mathematical and biophysical models, which are able to model basic processes in neurons and neural networks. The main goal of neuro-informatics is 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 human brain is a complex system, which is an object of our research. It 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 (Sporns et.al. 2005). There are many publications, which deal with description of the brain (Adeli 2010; Damasio 1995; Sporns et al. 2005).

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 (Schalk et al. 2004).
Invasive methods of sensing the brain activity could provide very accurate data, but it is not both technically and user friendly; thus, it would not be further mentioned in this article. On the other hand, more accessible non - invasive methods can obtain relatively weak signal with amplitude ranging from units to hundreds of microvolts. Moreover, the signal is also prone to noise elements. Another disadvantage of this method is a summation of neuron signals; thus, obtained data are referenced to a specific group of neurons. 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 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. Due to the high number of these pulses, it is difficult to locate their source by means of multichannel sensor on the skin. This issue could be compared to full amphitheatre, in which there are chanting people and the task is to recognize from outside, which specific group of fans shouts. A different perspective on this issue may be such that the aim is to identify uniqueness of the signal for each individual subject. In the example shown above, it is as we would like to recognize the type of the stadium by the mass of chanting people. For example, there is noticeable difference between hockey and tennis fans. The biometric signatures are different for each creature on the planet Earth.

METHODS

There are several approaches for sensing brain activity. The most widely used is EEG technology, which

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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.

Sensing the brain activity

Recently, we have used Emotiv EPOC neuroheadset 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 (Adeli 2010).

Emotiv Corporation developed personal brain - computer interface for human – computer interaction using neuro-technology, which is based on processing of electromagnetic waves occurring in human brain. The interface has wide range of possible applications; for example in interactive games, intelligent adaptive environment, audio visual art and design, medicine, robotics and automotive industry. Moreover, it can be deployed in large amount of scientific research.

Emotiv EPOC neuroheadset (Figure 1) measures a signal wirelessly transferred to common personal computer. It is a device, which has a set of sensors intended for sensing the activity produced by human brain. Traditional EEG devices requires the use of conductive pasta to improve the conductivity between electrodes and hairs. On the other hand, the neuroheadset do not need any additional tools. It has 14 high resolution sensors, which are placed on optimal positions on the human head (Figure 2).

Figure 1: Emotiv EPOC neuroheadset (Emotiv 2012)

Moreover, it also includes gyroscope for determinate the position in the area. Each channel has its own label based on its position on the head: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4. Sampling frequency of the neuroheadset is 2048 Hz. More information about neuroheadset can be found in (Emotiv 2012).

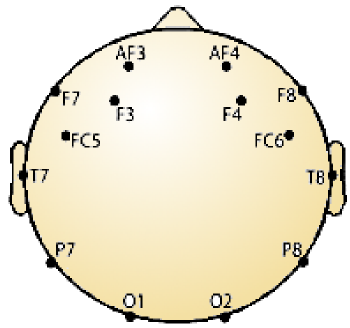


Figure 2: Placement of electrodes of Emotiv EPOC neuroheadset

Emotiv provide basic software set containing many tools, which can be used for recording various signals such as electric potential from all 14 sensors, power spectrum of individual EEG channels in real time and rotational acceleration of the head in horizontal and vertical axis using data from gyroscope. All of these outputs are shown in graphs. Data are also available in raw form, which can be used for further analysis. If it is required special functionality, which is not provided by native software, it is desirable to develop own application using Emotiv SDK (Software Development Kit).

Native software consists of three classification suites. Each of them enables the usage of algorithm developed by Emotiv. First of them is Expressive suite, which contains identification system for recognition of facial expression such as smile, eyewink, etc. The muscle signals are used for this purpose. The sources for these signals are obtained by sensors, which are located around the face.

The second suite can be used to measure and identification of emotional state; for example nervousness, alertness, concentration, etc. Therefore, it is called Affective suite. Muscle signals and ocular signals are filtered by specially designed filters; thus, identification algorithm uses clear brain signal.

The last suite is called Cognitive. This classification mode uses whole measured signal, which contains both clear brain signal and muscle signal. Classification algorithm is based on artificial intelligence methods. Type and structure of applied neural network is patented by Emotiv Corporation; therefore, the specific information about the algorithm is protected.

If it is required other processing of the signal than the native software allows, it may be processed by another software application.

Measured raw data can be subjected to offline analysis to research.

Processing the brain activity

If person could be recognized by custom EEG traces, it would mean that the person could be uniquely identified by EEG signal and it could bring new ways of authorization routines. Critical phase lies in signal classification. Even if the meaning of both the waveform and the signal content is not very important for classification purposes, there is another issue which have to be considered. EEG device provides large amount of data which has to be effectively and quickly processed in order to perform correct classification of the subject from the signal in real time. Classification tasks could be realized by using neural networks. However, it is difficult to predict, which neural network could use its cognitive potential for classification task mentioned above (Hazrati and Erfanian 2010). Investigation of the most appropriate classifier requires testing of many subjects. Furthermore, it is necessary to find algorithm with the shortest response time with respect to the credibility of obtained output. Another issue is to determinate which output is suitable. There could be considered the theory of large numbers; thus, maximum possible number of subjects needs to be tested. Therefore, it is more important to select key parameters of the signals that are different for each person. Even though the parameters are different for different people, the question remains whether the parameters remain constant in different time frames for the same person.

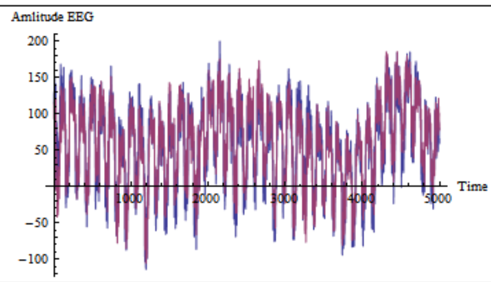
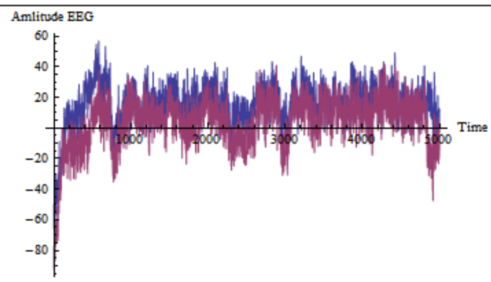
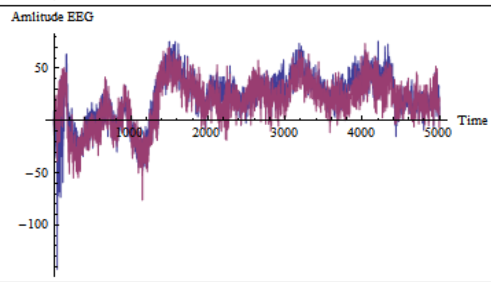
RESULTS

Idle state of mind was chosen as the optimal for the measurement. The relative idle state is such that the EEG signal does not contain any artefacts. Some artefacts are already filtered out before the signal processing. That mostly includes elements in signal that related to some physical responses such as eye blinking, motion and muscle activity, heartbeat etc. Furthermore, external artefacts interfering the signal are primarily eliminated in analog-to-digital conversion.

In order to perform classification, it has to be set unique characteristics of the signal (hereinafter called as classification parameters). That task is the first step of our research. The most important is to find appropriate classification parameters. However, the device returns fourteen channels with various amplitudes. Therefore, it is necessary to normalize the signal by applicable algorithm. This procedure count with sampling frequency of the neuroheadset, which is 128 Hz.

Prepared set of data is ready for another mathematical or statistical analysis. Firstly, it was performed a correlation analysis between channels of the first subject's EEG signal. All combinations of signals were tested in order to find which pair of channels influence each other. Further aim of the analysis was to find out whether another subjects have different relations between the channels. Correlation was calculated for each compared pair of channels.

Table 1: Example of data analysis

Person	Marginal match [%]	Name of channels	Correlation [%]	Correlated channels
Subject 1	31.8681	{AF3, F3}	95.7985	
Subject 2	2.1978	{O2, P8}	81.7761	
Subject 3	1.0989	{P7, O1}	87.9316	

Further, the same correlation threshold is set for all pairs. Then it is count the number of similarities moving over the threshold. Obtained value is converted into percentage (marginal match). Course of marginal match for 5000 samples is shown in Table 1. It can be observed that the marginal match is different for each subject. Even if the marginal match could be one of the appropriate classification parameters, it is necessary to confirm all complex biometric links on higher number of subjects. That remains as another object of our further research. However, good result is obvious from the waveform of the signal with the highest correlation. Further possible conclusion from data presented in Table 1 is that signals seem different even if they all had relatively similar initial conditions including closed eyes, no muscle motions and also the same time range.
Further, it was investigated how the correlation changes with variety length of examined data. Figure 3 depicts three subjects compared in various offsets. The offset's length changes from 1000 to 30 000 with step 1000. It seems that a larger amount of data slightly decreases the correlation.

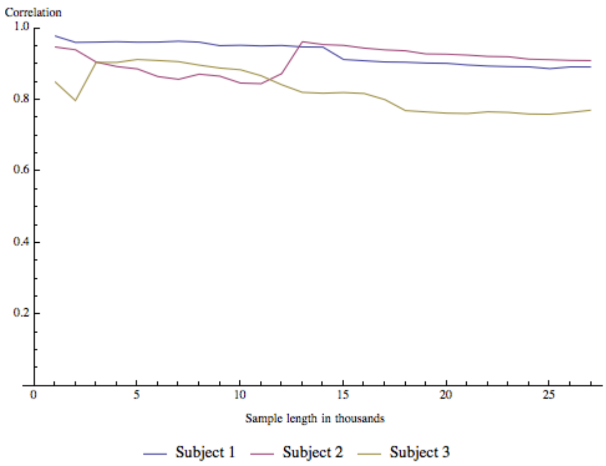


Figure 3: Dependence of correlation value to sample length

DISCUSSIONS

Human brain is the most complex known system in the universe. Study of its activity is extremely important mainly due to the more precise diagnosis of brain diseases and their treatment. Furthermore, acquired knowledge could be used in modern technologies with BCI systems, where an interaction between brain and computers appears.
We are currently performing the measurement of the EEG signal in our research. Our aim is to discover interesting regularities in the EEG signal waveform, which could contribute to the improvement of current approaches of brain activity simulation. Moreover, these regularities could be used to recognize some specific states of the brain, which can be then used to control the software or equipment connected to the computer.
There are many approaches to analysis of data. Moreover, EEG signal belongs to group of biometric signals which are usually very complex. The question remains whether it is possible to involve significance of all characteristics and signal history of EEG signal to classification process.
Biometrical data are typically represented as an image or a quantification of measured physiological or behavioural characteristics. As these data should refer to very complex human behaviour or describe very precisely physiological characteristic (typically iris scan, fingerprint, palm vein image, hand scan, voice, walk pattern etc.) these data can easily became very large and hard to process. For this reason a modern ways of data processing and classification are applied for biometrical data. The leading method is the usage of neural networks (Tangkraingkij 2009).
Correlation analysis demonstrates that there are relations between individual EEG channels. Further, it shows that the highest value of correlation was always found between neighbouring electrodes. Subject 1 has the highest correlation between electrode AF3 and F3 which are both located in frontal region of the brain. On the other hand, the subject 2 has the highest correlation between electrodes O2 and P8, which are located in rear regions of the brain. Both subject were measured in the idle state of mind. That behaviour of the subject's brains should be proven on more measurements of the same subjects. If the behaviour remained the same, it would mean, that it could be set as another classification parameter.
From obtained results we concluded that our future research could possibly answer the question which statistical characteristics are the most suitable for usage in classification algorithm based on neural network. For example, difference between individual subjects is the feature, which could be used as another classification parameter. Results described in this article are the first part of future extensive research.

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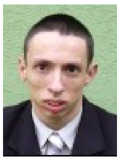

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