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RESEARCH ARTICLE

Using Emotiv EPOC Neuroheadset To Acquire Data In Brain-Computer Interface

***Islam A. Fouad, and Fatma El-Zahraa M. Labib**
Department of Biomedical Technology, INAYA Medical College, Riyadh, KSA

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****Corresponding Author***

Islam A. Fouad

Abstract

This paper considers the issue of the brain-computer interface (BCI) – the human-machine interface (HMI) based on acquisition, processing and transformation of signals that generated by the central nervous system (CNS) as the aspect of its normal function. Brain-computer interface can be considered as the bridge which is building up direct one-way or two-way communication pathway between the external technical device and the brain. The work presents techniques based on non-invasive imaging of the brain used for acquiring data in non-invasive brain computer interfaces, and is emphasized on the reading neural activity of the brain using multi-channel electroencephalograph (EEG). As the part of this paper our experience with the commercially available equipment Emotiv EPOC Neuroheadset based on this technology is introduced.

INTRODUCTION

Brain-computer interfaces (BCIs) are systems that allow users to translate in real time the electrical activity of the brain in commands to control devices (Jonathan and Elizabeth, 2012). As reported by literature, these systems do not rely on activity of muscles and therefore can provide communication and control for those who are severely paralyzed (locked-in) due to injury or disease (Kübler et al., 2001) (J.R.Wolpaw et al., 2000). BCI is a promising technology both for rehabilitation and for interaction of patients with the surrounding environment. In this project, the patient-environment interaction through robotic devices was investigated. The scientific community in the last years has been working on new solutions to exploit the BCI advantages, but there exist only few examples of applications in which robots are driven by BCI to help patient in their daily life. At University of Washington Rao et al. are working on interface between BCI and a humanoid robot in order to locate and manipulate object (Christian et al., 2001). The ASPICE Project of Santa Lucia Foundation in Rome, Italy controlled an AIBO robot of Sony though a BCI interface (Christian et al., 2008). Fraunhofer Gesellschaft Institute developed a BCI wheelchair integration (F. Cincotti et al., 2006). Other applications about robot integrations and BCI were made by Geng et al. with BCI controlling simulated mobile robot (T. Geng et al., 2007) and by Vanacker et al. with assisted brain-actuated wheelchair drive (Vanacker G et al., 2007). Indeed, the control via a BCI system of a robotic wheelchair is one of the hot topics in this community (Vanacker G et al., 2007) (I. Iturrate et al., 2009), and new hopes to patients who are recovering from different types of neurological injuries and diseases that are often highly disabling utilizing the advances in information technology.

One of the main factors that make the life of any human being enjoyable is the ability to communicate with other persons. Persons suffering from the so-called locked-in syndrome do not have the ability of such ability. The locked-in syndrome is a case in which patients are fully conscious and aware of what is happening in their environment but are not able to communicate or move.

The possibility to use it as the new user interface of entertainment industry and personal computer is evaluating the (Vanacker G et al., 2007)Brain-computer interface or mind-machine interface (MMI) or brain-machine interface

(BMI) is the human computer interaction (HCI) that can be defined as the system which able to translate subject's thoughts or intent into the technical control signals without the use of the communication channel based on the use of the speech or any other neuromuscular activity. BCI is creating direct communication pathway between the computer or external technical device in general and the human brain with aim to build one-way or two-way interface of communication.

The main components in any brain-computer interface systems are :

1- The hardware of data acquisition based on the monitoring of signals produced normally from the activity of the central nervous system.

2- The software component that used to analyze the acquired signals and to extract features that can be translated into the technical control signals suitable for use and control of the external technical device.

According to the invasivity to the body of users, three main groups of brain-computer interfaces are formed.

Invasive brain-computer interfaces are surgically implanted into the brain directly, and are often relied on the use of arrays of microelectrodes that implanted into the visual or motor cortex. Invasive brain-computer interfaces are able to acquire best spatial and temporal signals' resolution. In the second group "partially invasive brain-computer interfaces", microelectrodes in arrays are located inside the skull but not inside the brain. Example of this technique is the Electrocorticography (ECoG).

Functional brain imaging techniques are the basic idea behind the third group "non-invasive brain-computer interfaces", which mostly based on multichannel electroencephalography (EEG). Although the lowest accuracy of the acquired signal in noninvasive BCIs, because of the deflection resulted from the skull, there is advantage in minimal discomfort for the user of the interface and no modification of the human body.

Implementing of non-invasive brain-computer interfaces is possible under the most naturalistic conditions of use with minimal demand of the wearable hardware and with advantage of wireless connection to the host computer that is analyzing and transforming signals to the technical device that is controlled with use of brain-computer interface.

Techniques of Imaging the Brain

The main component of the BCI is the hardware of data acquisition which intended for monitoring of the normal neural activity of the central nervous system. In non-invasive brain-computer interface the data acquisition is based on the brain imaging and this category includes several techniques that are directly or indirectly capable of imaging the structure (structural brain imaging) and function (functional brain imaging) of the brain.

1. Structural brain imaging

Structural brain imaging is the technique that deals with the brain structure imaging and there is a possibility to use it for diagnosis as in the case of various injuries or in case of intracranial diseases including tumors.

Computerized Axial Tomography (CAT) or Computed Tomography (CT) uses series of head x-ray images that taken from different directions and builds the brain cross-sectional images.

Magnetic Resonance Imaging (MRI) uses radio waves and magnetic fields to acquire data for formation of two- or three-dimensional brain images. The advantage of MRI is that it doesn't use the ionizing radiation or radioactive tracers.

2. Functional brain imaging

Brain functional imaging is used for diagnostic purpose in case of metabolic diseases and lesions. It is also suitable group of techniques which can be used for the creation of brain-computer interfaces and for neurological and cognitive psychology.

Single Photon Emission Computed Tomography (SPECT), using gamma-ray emitting radioisotopes, Positron Emission Tomography (PET), using trace amounts of short-lived radioactive materials, functional Magnetic Resonance Imaging (fMRI) and Near Infrared Spectroscopic Imaging (NIRSI) are techniques that measure and localize changes in cerebral blood flow, which are related to the activity of neurons and it is possible to use it for the brain regions identification, which are activated when subject is performing certain tasks.

Other imaging techniques, including the magneto-encephalography (MEG) used for both clinical purpose and research, electro-corticography (ECoG) and electro-encephalography (EEG) are suitable techniques for recording of the changes in magnetic fields and electrical currents, which are produced as the manifestation of the brain normal function.

Electroencephalography (EEG) can be defined as the brain electrical activity measurement, realized by recording the electrical signals scanned by electrodes, which are placed on the scalp.

The measurement result, which is called electroencephalogram (EEG), shows the set of electrical signals acquired from large groups of neurons.

This technique is usually used in research and development aimed at building of the BCI, because the process of its usage is non-invasive for the user. Another merit is the ability of EEG to give a high temporal resolution with brain electrical activity measurement on the level of milliseconds.
All of described techniques have their limitations and differ in advantages and disadvantages. For example EEG, or MEG, which measure the brain neural activity with high temporal resolution, are limited in ability of spatial resolution and fMRI with its high capability of the localizing the neural activity has disadvantage because of its lower temporal resolution.

Emotive EPOC Neuroheadset

To build a novel application of the brain computer interface, low-cost 14 channel EEG hardware commercially available Emotiv EPOC Neuroheadset (Figure 1) was used, for acquiring the raw data from electrodes that are positioned at F3, FC5, AF3, F7, T7, P7, O1, O2, P8, T8, F8, AF4, FC6 and F4 positions, according to the international 10-20 system.
Left hemisphere of the brain are reserving the odd numbers of electrodes; even numbers of electrodes are reserved for brain right hemisphere.

Fig. 1 Commercially available EEG signal acquisition hardware Emotiv EPOC Neuroheadset

The electrodes F3, F4, AF3, AF4, F7 and F8 are used for neural activity imaging in the lobus frontalis of the subject's brain. Electrodes T7, T8, FC5 and FC6, are imaging the lobus temporalis of the brain. The lobus parietalis is scanned by P8 and P7 electrodes. Neural activity of the lobus occipitalis is acquired with use of the O2 and O1 electrodes (Figure 2).
CMS (on the left side) and DRL (on the right side) are two referencing electrodes used for signal noise reduction.

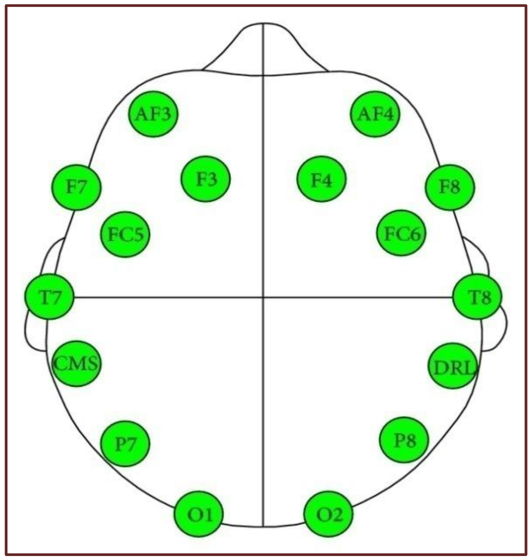

Fig. 2 Acquiring electrodes positions on the brain according to the 10-20 model

Signals are sampled with sampling rate equal to 128 Hz and sent to the dongle through the wireless connection, which is connected to the USB port of personal computer and used as a receiver. Computationally expensive analysis of acquired data and transformation into the control signals for software applications is performed by host computer.

There is a chance to get characteristic patterns in EEG signals that are connected with facial expressions including right or left wink, blink, right or left look, raise or furrow of brow, teeth clench, laugh , right or left smirk, and smile and those patterns are recognizable in signals from respective electrodes.

For example, look left or right is mostly depending on signals from F8 and F7 electrodes and also on signals from FC5, O2, P8, FC6 and AF4 as shown in Figures 3 & 4 and in table 1.

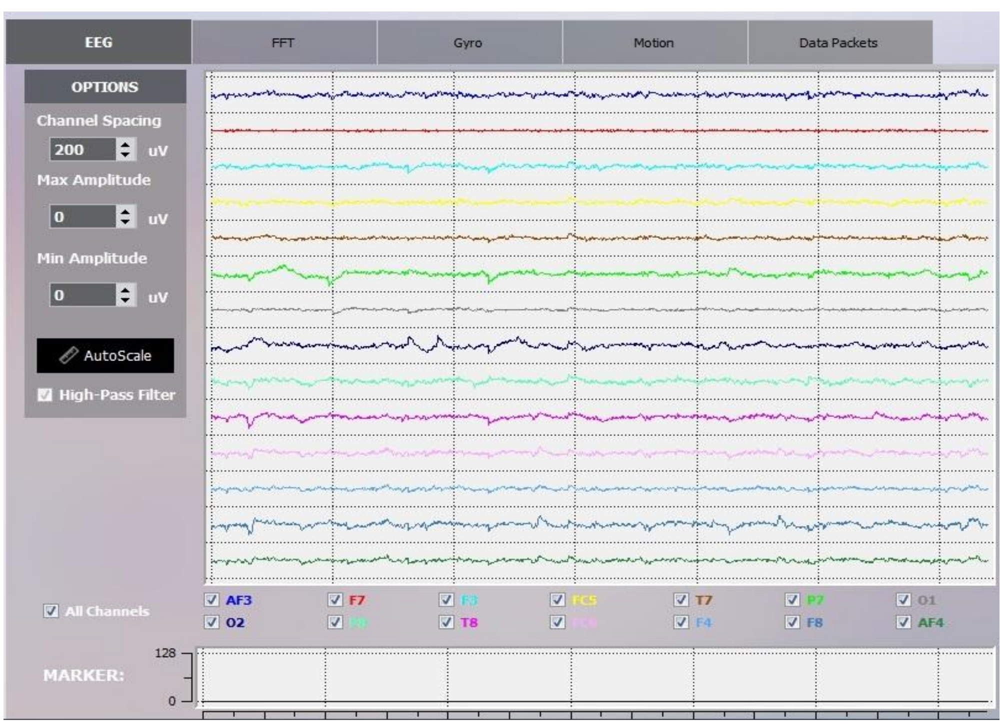

Fig. 3 Characteristic patterns in EEG signals for smile facial expression

Table 1 Recognisability of characteristic patterns of facial expressions in EEG signals

	Smile	Left smirk	Right smirk	Laugh	Teeth Clench	Look left	Look right	Blink	Left wink	Right wink	Furrow of brow	Rise of brow
AF3	√		√	√	√			√	√	√	√	√
F7	√		√	√	√	√	√	√	√	√	√	√
F3				√	√			√		√	√	√
FC5				√	√	√	√	√	√		√	√
T7	√	√		√	√				√		√	√
P7		√		√	√				√		√	√
O1				√	√							√
O2	√			√	√	√	√					√
P8	√			√	√	√	√					√
T8	√		√	√	√	√	√					
FC6	√		√	√	√	√	√	√		√	√	√
F4	√			√	√			√		√		√
F8	√		√	√	√	√	√	√		√	√	√
AF4	√		√	√	√	√	√	√	√	√	√	√

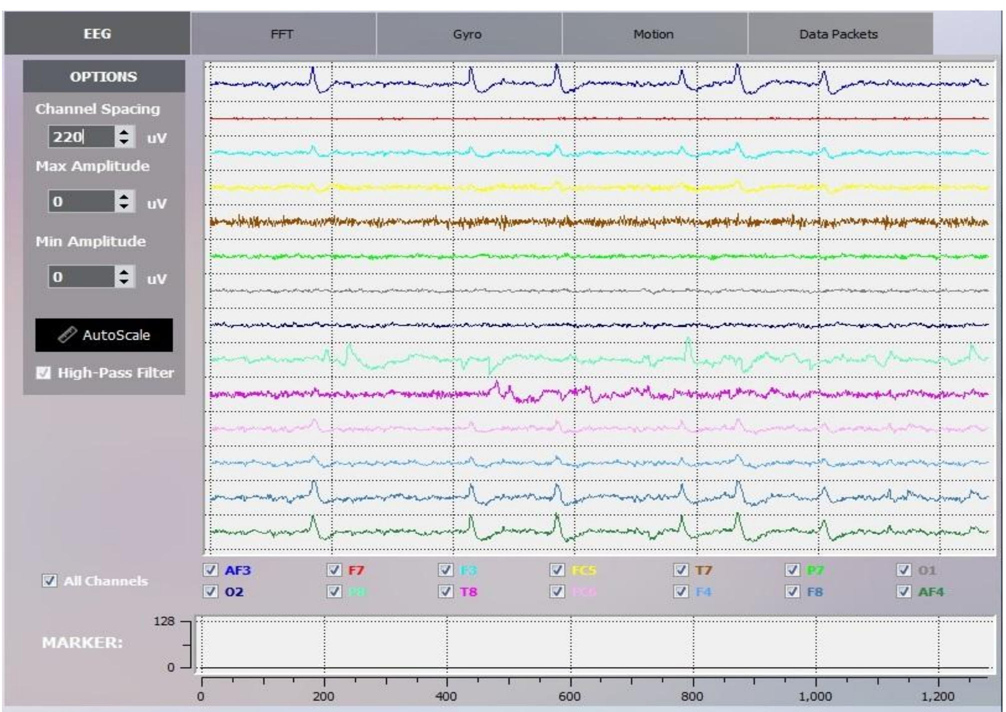

Fig. 4 Characteristic patterns in EEG signals for right smirk facial expression

Affections of the subject are also displayed in EEG signals and there is possibility to detect characteristic patterns for boredom, engagement, frustration, meditation, long term excitement, or instantaneous excitement which are connected to the alertness, vigilance, concentration, stimulation, interest, contemplation, negative feelings or expectation.
Intentions of the subject to pull, push, move left, right, up and down and to rotate clockwise, counterclockwise, right, left, backward and forward are detectable. Intents are connected with virtual objects or real life. There is possibility to detect intent of the subject in case of virtual objects to let those objects disappear.
The capability of proper level of concentration of the subject during the process of signal scanning will determined by the ability to control the external technical device.

Conclusion

This paper presented brain-computer interface as the technology capable of building the communication channel between external technical device and central nervous system and enables one-way or two-way communication. Brain imaging techniques with emphasis on the functional brain imaging techniques and especially the multi-channel electroencephalography (EEG) were introduced and also the experience with low-cost EEG hardware Emotiv EPOC Neuroheadset was described.

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