ISSN No. 0976-5697

Volume 8, No. 5, May – June 2017

International Journal of Advanced Research in Computer Science

REVIEW ARTICLE

Available Online at www.ijarcs.info

Brain Computer Interface and its Applications – A Review

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Abstract: Brain Computer Interface(BCI) is a emerging research topic nowadays for researchers. Its significant addition ranging from medical applications to education, research area , marketing, games and entertainment etc. BCI provides a channel between brain of living creature and external machine. It is a process in which brain accepts a mechanical device either by invasive method or non-invasive method as its natural part and by processing of signals, various applications are evolved and created. This paper shows the system of BCI, hardware and software components of BCI with its huge applications like wheelchair, bionic eye, honda's robot etc. At the end of this paper future work in BCI are discussed.

Keywords: Brain Computer Interface, BCI System, BCI Hardware and Software, BCI Applications.

I. INTRODUCTION

Brain Computer Interface is a technology that provides a direct communication path between brain and object to be controlled without requirement of any external peripheral device to issue commands. In the early days BCI was mainly used for medical purposes but nowadays it is used as research tool, military areas, education, production, games, entertainment etc.

BCI system takes and classifies brain activity into a signal to which a computer can respond. To supervise a apparatus, the user should produce various brain activity patterns, which are captured in the form of electroencephalogram(EEG) and converted to commands by identifying the signatures of EEG by BCI system[1]. Such classification was undertaken by various BCI methods.

BCI methods are divided into two groups: Endogenous and Exogenous. Endogenous BCI means the BCI is based only on spontaneously generated brain patterns having signals SCPs or Sensorimotor rhythms possesses advantages like autonomous to any simulation, convenient for cursor control applications and useful for people with affected sense organs. Exogenous BCI means the BCI is based on brain responses to external stimulus having signals SSVEP or P300 grabs advantages such as high bit rate and minimal training.

BCI systems can be categorized into following types[23]:

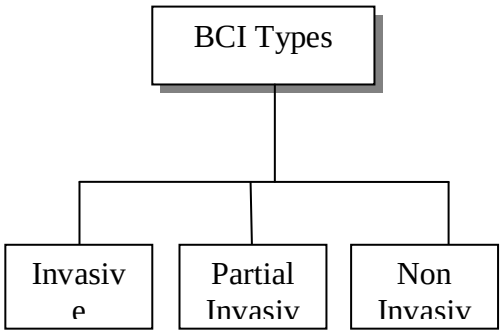

Figure1: Types of BCI

A. Invasive BCIs

They are embedded directly into the gray matter of the brain by neurosurgery. Invasive devices produce highest quality of signals as they are embedded in gray matter but signals become weaker as they are prone to scar tissue build-up.

B. Partial Invasive BCIs

This implemented inside the skull but outside the brain. Electrocorticography[2] is the example of partial invasive BCI. An electrode Grid is embedded by surgical dissection.

C. Non-Invasive BCIs

This most useful neuron imaging method which is applied to the outside of the skull. Brain Imaging techniques used in non-invasive BCI are[3]:

1) *Functional magnetic resonance imaging (fMRI):* It is a technique for measuring brain activity. fMRI can be used to develop activation maps representing which parts of the brain are captivated in a particular mental process.

2) *Electroencephalography (EEG*): It is the measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. The resulting traces are known as an electroencephalogram (EEG) and represent an electrical signal from a large number of neurons.

3) *Magnetoencephalography (MEG):* It is an imaging technique used to measure the magnetic fields produced by electrical activity in the brain via extremely sensitive devices known as SQUIDs. These measurements are commonly used in both research and clinical settings.

4) *Near infrared spectroscopy:* It is an optical technique for measuring blood oxygenation in the brain. It works by shining light in the near infrared part of the spectrum (700-900nm) through the skull and detecting how much the remerging light is faded. How much the light is attenuated depends on blood oxygenation and NIRS can contribute an indirect measure of brain activity.

II. BRAIN COMPUTER INTERFACE SYSTEM

BCI System has following three main steps to complete its working[4]:

A. Signal Acquisition

It is required to take signals from the brain. These signals are used by computers so they require to be digitize and amplification because the strength of signals are usually low. These electric signals could be recorded from scalp, surface of brain or from neural activity.

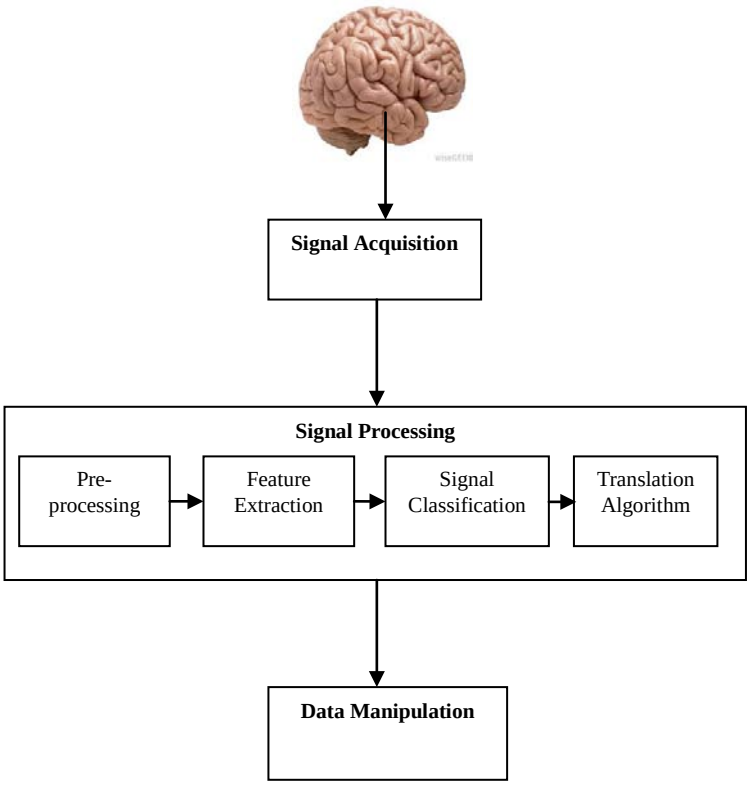

Figure2: BCI Signal Processing

B. Signal Processing

It [1] is used to analyse the signals which are recorded during signal acquisition. It consists of following sub operations:

1) Preprocessing: It is first step of signal processing. Some filtering techniques are used to make the features for clear detection. The most common types of preprocessing are artifact detection, spectral filtering and spatial filtering.

2) Feature extraction: It is an important operation to predict outcomes from raw signal. It extracts features of specific signals. EEG recordings not only contain electrical signals from the brain, but also several unwanted signals. Those unwanted signals may bias the analysis of the EEG and may lead to wrong conclusions. Therefore, the digitized signals are subjected to feature extraction procedures such as K-Fisher coefficients, sequence forward selections, principal component analysis etc.

3) Signal Classification: It uses features extracted in feature extraction process. The main algorithms able to perform classification are Support Vector Machine, Linear Discriminant Analysis, Naïve Bayes Classifier and Multilayer Perceptron.

4) Translation Algorithm: It is operation of converting the extracted features into device command orders that carry out user's intent.

C. Data Manipulation

It is step in which output is manipulated after classification of signals to suite the output devices such as cursor movement, letter selection, command a robot arm etc.

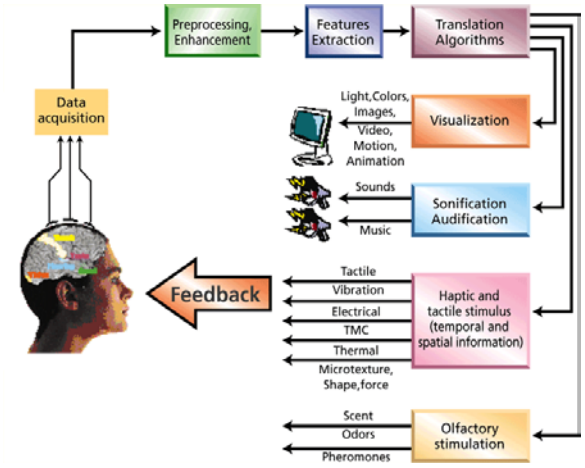

Figure3: Conceptual BCI system with various kinds of Neurofeedbacks[5]

III. BCI MONITORING HARDWARE AND SOFTWARE

A. BCI Hardware

It[4] is used to amplify the weak signals received from brain that require special treatment to display them in digital format. BCI Hardware is divided into following types:

1) The first type is ***Electrodes*** made up of gold. It is of two types:

a) ***Active Electrodes*** contain an amplifier with gain 1–10 inside it in which it reduces the noise and cable interferences.

b) ***Passive Electrodes*** are usually distributed on the scalp from 10 to 20 electrodes and do not include any amplifier.

2) The second type is ***Signal Amplifier*** is important part of physiological recording and analysis in which the brain signals are very weak and it is used to amplify them.

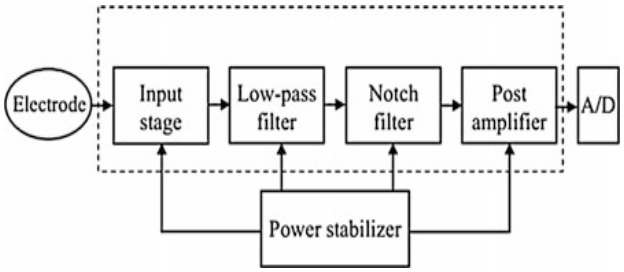

Figure4: Sample of BCI amplifier[6].

3) The third type is ***Real Time Signal Handling*** is managed on different Operating Systems including windows and Linux as well as Mac OS. C++ is one of the most used language for analysis over C++ LabVIEW (National Instruments Corp., Austin, TX, USA) and MATLAB (The MathWorks Inc., Natick, USA) are mostly used as programming languages.

B. BCI Software

It[4] is available in commercial kits. Some of them are as given below:

1) ***Neurobci*** [7] in which it allows users to develop their own Brain Computer Interface (BCI), bio- or neurofeedback application, as created in Html/Jscript, C++, or Matlab.

2) ***FieldTrip*** [8] is a MATLAB toolbox that is used for analysis. It utilizes TCP connections for multiple clients as at the same time.

3) ***DataSuite***[9] is another software tool for data acquisition. The DataSuiteconsists of two parts including the DataRiver and MatRiver. DataRiver is a data management and synchronization real time engine while MatRiver is a MATLAB client toolbox for DataRiver.

4) ***Emotiv EEG***[10] neuroheadset is a wireless BCI set; this set is a neuro-signal acquisition and processing wireless neuroheadset. The set can be wirelessly connected to a computer. One advantage of the set is it has 14 saline sensors offer optimal positioning for accurate spatial resolution

5) ***ModularEEG***[11] is another EEG hardware created by the OpenEEG hardware developers. The modularEEG has two or more than two EEG amplifiers, and a 6-channel signal capture board that connects to a PC via a standard serial cable. The modularEEG has two types of electrodes which are active and passive electrodes. Some skin preparation is required while there is no preparation is required when active electrodes are used.

IV. BRAIN COMPUTER INTERFACE APPLICATIONS

BCI is interesting research area to researchers nowadays because its applications reached beyond medical applications. In early days BCI mainly focused on health sector but now it is used in military, marketing, production, security, games etc[12].

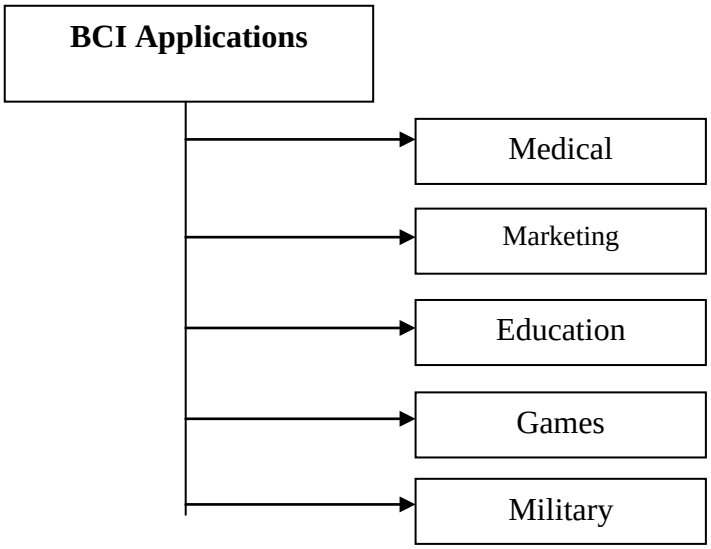

Figure5: Applications of BCI

A. Medical Applications

Healthcare has wide variety of applications with collaboration of brain computer interface. Following are some examples:

1) ***Motor neuroprosthetics*****:** The aim of these BCIs[13] is to either restore movement of individuals with paralysis or provide some special devices to assist them. Special devices can be different types of interfaces with computers or even robot arms for control.

2) ***BrainGate:*** The system is a brain implant and is designed to help patients who have lost control of bodily functions, such as patients with spinal cord injury, brainstem stroke or amyotrophic lateral sclerosis[14]. The computer chip is implanted into the brain. The chip uses an array of 96 hair-thin electrodes that convert the electro-magnetic activity of the neurons into electrically signals [15]. Signals are decoded by a computer program and used in controlling robotic arms, a computer cursor or a wheelchair.

3) ***Cochlear implant***: It is a form of BCI technology that is used to give hearing to the deaf. The implant is applauded for young children, ages 12 months and over. This provides a more natural development of speech and language understanding[16].

4) ***Bionic Eye:***The bionic eye system[17] will consist of a small digital camera, external processor and a implant with a microchip and stimulating electrodes surgically placed in the back of the eye. Electrodes on the embedded chip convert these signals into electrical impulses to activate cells in the retina that connect to the optic nerve. These impulses are then go with the optic nerve to the vision processing centres of the brain, where they are depicted as an image.

5) ***Honda's Brain Machine Interface:***Honda Research Institute, Japan, has determined Brain-Machine Interface (BMI)[18] that allows a user to control an ASIMO robot using nothing more than thought. Wearing a headset containing both electroencephalography (EEG) and near-infrared spectroscopy (NIRS) sensors, the user simply imagines moving either his right hand, left hand, tongue or feet - and ASIMO makes a corresponding movement.

6) Detecting Fatigue and Driver Alertness: Driver drowsiness is one of the major causes of serious traffic accidents. For this reason, a technique that can detect real-time driver drowsiness is of utmost importance to prevent drowsiness-caused accidents. If drowsiness consequences can be precisely disclosed, incidents can be prevented by countermeasures, such as awakening of the driver. The sleep cycle is divided into no-rapid-eye-movement (NREM) sleep and rapid-eye movement sleep. Sleepiness in drivers has been identified as a causal component in numerous accidents, because of the marked decrease in drivers' view of danger and acknowledgment of threat, and their lessened capacities to take care of their vehicles[19].

B. Marketing and Adverisement

Marketing and advertisement field has also importance for researchers of BCI[12]. The benefits of using EEG evaluation for TV advertisements related to both commercial and political fields. BCI based assessment measures the generated attention accompanying watching activity.

C. Education

Neurofeedback is a promising approach for enhancing brain performance via targeting human brain activity modulation. It invades the educational systems, which utilizes brain electrical signals to determine the degree of clearness of studied information. Personalized interaction to each learner is established according to the resultant response

experienced[20]. Learning to self-regulate through noninvasive BCI has also been studied. It provides a mean for improving cognitive therapeutic approaches. BCI technology has been elaborated in self-regulation and skill learning via functional Magnetic Resonance Imaging (fMRI) neurofeedback[12].

D. Games and Entertainment

Entertainment and gaming applications have opened the market for nonmedical brain computer interfaces. Various games ar like helicopters are made to fly to any point in either a 2D or 3D virtual world. Combining the features of existing games with brain controlling capabilities has been subject to many researches which tend to provide a multi-brain entertainment experience. The video game is called BrainArena. The players can join a collaborative or competitive football game by means of two BCIs. They can score goals by imagining left or righthand movements.

E. Security

Security systems involve knowledge based, object based and/or biometrics based authentication. They have shown to be vulnerable to several drawbacks such as simple insecure password, shoulder surfing, theft crime, and cancellable biometrics. Cognitive Biometrics or electrophysiology, where only modalities using biosignals (such as brain signals) are used as sources of identity information, gives a solution for those vulnerabilities[21].Electroencephalogram (EEG), as a biometric modality, could be used to send covert warning when the authorized user is under external forcing conditions.

V. CONCLUSION

Brain Computer Interface provides a channel between brain and external devices. System with faster speed, accuracy, signal processing, user training are require to have successful BCI system in real world. Brain Computer Interface have huge possibility in every application where machine interact with human beings such as medical application, 3d games, security etc.

But the main challenges of BCI are user acceptance, technical issues like noise in signals, low information transfer rate etc. which can be resolved by interdisciplinary research between engineers, computer programmers, psychologists and neuroscientists. For creation of successful application of BCI will be relying on analyze relevant user group and study the requirements of user.

VI. REFERENCES

[1] Nasim Alamdari, Ali Haider, Riadh Arefin, Ajay K.Verma, Kouhyar Tavakolian, “A Review of Methods and Applications of Brain Computer Interface Systems”, 2016 IEEE International Conference on Electro Information Technology (EIT), pp.0345-0350, 2016.

[2] Mashael M. AlSaleh, Mahnaz Arvaneh, Heidi Christensen and Roger K. Moore,” Brain- Computer Interface Technology for Speech Recognition: A Review”, Signal and Information Processing Association Annual Summit and Conference (APSIPA), 2016 Asia-Pacific

[3] Gui XUE, Chuansheng CHEN, Zhong-Lin LU, and Qi DONG,” Brain Imaging Techniques and Their Applications in Decision-Making Research”, Xin Li Xue Bao. 2010 Feb 3; pp: 120–137,2010.

[4] Rabie A. Ramadan, S. Refat, Marwa A. Elshahed and Rasha A. Ali,” Basics of Brain Computer Interface”

[5]http://www.brain.riken.jp/bsinews/bsinews34/no34/research1e.html

[6] Xian-Jie, P., Tie-Jun, L., De-Zhong, Y.: Design of an EEG preamplifier for brain-computer interface. J. Electr. Sci Technol China 7(1), 56–60 (2009)

[7] Kameswara, T., Rajyalakshmi, M., Prasad, T.: An exploration on brain computer interface and its recent trends. Int. J. Adv. Res. Artif. Intell. (IJARI) 1(8), 17–22 (2013)

[8] Robert, O., Pascal, F., Eric, M., Jan-Mathijs, S.: FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. J. Comput. Intell. Neurosci. 2011, 156869 (2011).

[9] Lingaratnam, S., Murray, D., Carle, A., Kirsa, S., Paterson, R., Rischin, D.: Developing a performance data suite to facilitate lean improvement in a chemotherapy day unit. J. Oncol. Pract. 9(4), 115–121 (2013)

[10] Arindam, D., Robins, K., Suruchi, M., Sanjay, C., Alakananda, B., Anirban, D.: A low-cost point-of-care testing system for psychomotor symptoms of depression affecting standing balance: a preliminary study in india. Depression Res. Treat. 2013, 640861 (2013)

[11] Setijadi, A., Novanda, O., Mengko, T.: Development of an experimental portable electroencephalograph (case study: alpha wave detector). International conference on electrical engineering and informatics (ICEEI), vol. 1, no. 6, pp. 17–19 (2011)

[12] Sarah N. Abdulkader , Ayman Atia, Mostafa-Sami M. Mostafa,” Brain computer interfacing: Applications and challenges”, Egyptian Informatics Journal (2015) 16, pp.213–230

[13] C.C. Postelnicu, D. Talaba, M.I. Toma,” BRAIN COMPUTER INTERFACES FOR MEDICAL APPLICATIONS”, Engineering Sciences, Vol. 3 (52),pp.99-106 – 2010

[14] BrainGate - Turning Thought into Action. Available at: http://www.braingate 2.org/.

[15] Donoghue, J.P., Hochberg, L.R., et al.: Neuromotor Prosthesis Development. In: Medicine and Health, Rhode Island 90 (2007) No. 1, p. 12-15.

[16]Brain Computer Interface Technolog. Available at: http://sites.lafayette.edu/egrs451-sp13-burds/medical/cochlear-implants/.

[17]The Bionic Eye, Available at: http://bionicvision.org.au/eye.

[18] Honda's Brain-Machine Interface: controlling robots by thoughts alone, Available at: http://newatlas.com/honda-asimo-brain-machine-interface-mind-control/11379/.

[19] T. Shashibala, Bharti W. Gawali,” Brain Computer Interface applications and classification techniques”, International Journal Of Engineering And Computer Science ISSN: 2319-7242, vol.5,pp. 17260-17267,2016.

[20] Sorudeykin KA. An educative brain-computer interface. arXivpreprint arXiv:1003.2660; 2010.

[21] Karthikeyan DT, Sabarigiri B. Enhancement of multi-modal biometric authentication based on iris and brain neuro image coding. Int J Biometrics Bioinform (IJBB) 2011;5(5):249–56.

[22] Szilard Bulkara, Aurel Gonteam,”Brain-Computer Interface Review”,2016

[23] Luis Fernando Nicolas-Alonso* and Jaime Gomez-Gil, “ Brain Computer Interfaces, a Review”,pp1211– 1279.,2012.