LITERATURE REVIEW ON ACQUISITION OF NEUROCOGNITIVE SIGNALS USING BCI TECHNOLOGY

[1]Chalcy Nadar, [2]Abhimanyu Chaurasiya, [3]Zankhana Pandya, [4]Prof. Jyoti Kolap
[1,2,3]Student,[4]Head of the Department
[1,2,3]Department of Electronics and Telecommunication, Atharva College of Engineering, Mumbai
[4]Department of Electronics and Telecommunication, Atharva College of Engineering, Mumbai

Received: February 01, 2019 Accepted: March 13, 2019

ABSTRACT: *In all of the emerging technologies, the newest ones are the brain controlled devices that are entering the market. Devices which operate on the commands issued by brain are a boon for medical patients who suffer from paralysis and such diseases. Brain being a hub of neurons communicating with the help of electrical impulses. These impulses, called brain signals can be sensed on specific spots on the scalp of a human. The technology developed to study the brain signals and use them intuitively is commonly known as BCI (Brain Computer Interface). This paper is intended to give an outline of the technology developed and its applications.*

Key Words: : *BCI (Brain Computer Interface), EEG (Electroencephalogram), Brain-control*

I. INTRODUCTION

Communication is the base of human development, as it permits expression of ideas, desires, and feelings. The human brain is one of the most complex and fascinating elements of the universe. It helps one remember past events, process all of the present on-going activities, and project all the thoughts. This happens due to the brain signals, which are essentially electrical impulses generated when neurons interact with each other. One of the most preferred brain scanning techniques is Electroencephalography (EEG), which was developed to observe these brain signals. Electroencephalography helps translate the electric activity of the brain in the form of voltages. The synaptic transmission in neurons is triggered by the flow ofneurotransmitters, which causes a voltage change across the cell membrane. BCI (Brain Computer Interface) helps visualize and represent these brain waves so that they can be studied and used.

II. BRAIN WAVES

Brainwaves can be recorded by setting the electrodes on specific spots of our scalp .The concentration of different types of wave define the emotional state of humans.
Brain waves are organized into bands as follows:

Delta (1-3Hz)

The Delta wave is the slowest and is experienced in deep sleep and in profound spiritual meditation where one is away from awareness.

Theta (4-7Hz)

Theta waves (the ones associated with dreaming) are experienced when a person is asleep. Theta waves are also produced when one is in a hypnotic state. They are also related with peak performance, as well as when one does repetitive tasks.

Alpha (8-12Hz)

Alpha brain waves are influential when the mind is deeply relaxed and the eyes are shut or daydreaming. The alpha waves signify the intuition. This wave dominates as the person gets closer to 7.5Hz.

Beta (12-25Hz)

Beta brain waves are linked to the normal functioning, consciousness and an intensified state of awareness, logic and analytic reasoning. It gets superior when cognitive tasks are attended. They also can signify stress and anxiety.

Gamma (above 25Hz)

This range is newly discovered and has the highest frequency. Initial research regarding gamma waves suggests that they are associated with imagination and high-level information processing.

III. BCI (BRAIN COMPUTER INTERFACE)

BCI, also known as neural machine interface is a communication mechanism which permits exchange of messages from the brain to the computer. Unlike neuromodulator, BCI permits bidirectional transfer of

messages. The term BCI was coined by Jacques J. Vidal in 1971[1]. BCI technology initiated in the 1920s with the discovery that neurons transmit information by electrical spikes which can subsequently be recorded by placing a thin metal wire or electrode on the scalp at specific points. This discovery led to the development of techniques that use these brain waves to control devices. BCI is implemented using invasive techniques wherein electrodes are implanted in the subject and non-invasive techniques in which brain signals are recorded using electroencephalograph (EEG) by placing electrodes on the scalp. Initially, the research was focused mainly on applications in the field of neuroprosthetics[2]. Its main motive was to restore damaged senses such as hearing and vision or mobility of patients. BCI enables direct coupling: brain ↔ computer[3].The primary section in each BCI system is an algorithm that converts electrophysiological input from the subject's brain into suitable output which is used to control external devices. This algorithm may include linear or nonlinear equations, a neural network, or other methods, and might incorporate continual adaptation of important parameters to key aspects of the input provided by the user[4] .The BCI system follows the following process:

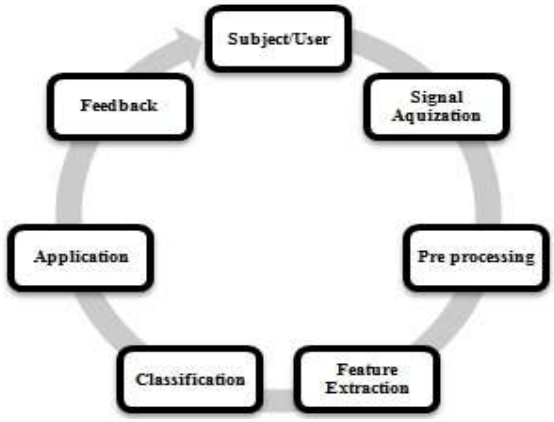

Fig.1 Structure of a BCI system

A BCI analyses real time brain activity for signal patterns that arise from particular brain areas. To get consistent recordings from specific regions of the head, scientists rely on a standard system for accurately placing electrodes, which is called the International 10-20 System[5].

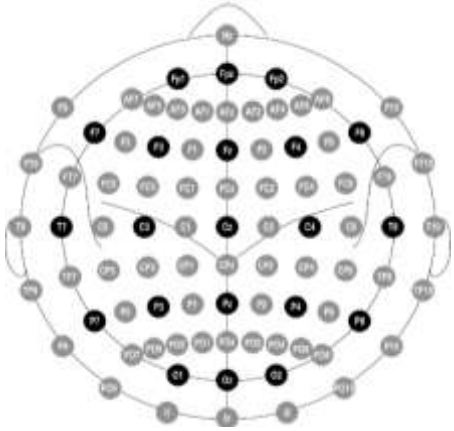

Fig.2 Electrode positions and labels in the 10 - 20 system.

Black circles indicate positions of the original 10–20 system, gray circles indicate additional positions introduced in the 10–10 extension[6]. Researches considering electrical signals generated from brain activities have revealed two main approaches[7] for studying these signals. The first method involved with exploring the effect of various conditions on them similar to evoked potentials (EP), while the second one focuses on detecting the brain activity that is not particularly associated with external stimulation. The signals harnessed by the electrodes are passed to the processing software where the signal can be visualized as well as interpreted based on pre-defined values and algorithms and then it is processed to make it suitable for the application. The application works and the feedback are translated to improve the subsequent results. The translated signals are then used for multiple applications. This field has tremendous

potential and research in this field has made it possible to fabricate applications that were unavailable earlier. There are certainly some limitations of this emerging technology like- issues relating to the technical aspects of collecting brain signals, high interference due to noise, non-linearity with regard to the brain as a system etc. Also, the use of BCI interfaces for healthy users has been uncertain as discussed in[8]. The issue of inferior information transfer rate (ITR) of BCIs and in turn slowing down the system has been discussed. It has been asserted that this problem limits the utilization of BCI for people with disability as it will not be able to keep up with normal communication ways or even current human computer interfaces[9] .A number of alternatives have been proposed to reduce as well as eliminate these issues which have greatly improved system dynamics and thus enhancing the results of the BCI system. The non-invasive technology is currently gaining momentum and being accepted by many practitioners. A better review of this technology is further carried out in the following sections.

IV. EEG ANALYSIS OF BRAIN SIGNALS

In the late 1800s, Richard Caton first reported the presence of bi-potentials on the surface of the human skull. Since then, electroencephalogram (EEG) has been used for studying various neurological conditions[10]. EEG is a cheap, non-invasive and completely passive recording technique. The nature of EEG signals is very non-linear, non-Gaussian, random and non-correlated[11]. Electroencephalography (EEG) circuit is an electrical signal recorded from a person's scalp and signal can be drawn using electrodes, then is used to monitor the neurological state of the patient, can be viewed using a oscilloscope, voltmeter or on a computer screen[12]. Brain wave patterns consist of raw EEG signals of fundamental frequencies (Delta, Theta, Alpha, Beta and Gamma). Brainwave sensing devices sense the electrical signals, they are then amplified in EEG circuit and then it is transferred to the computer for visualization and processing. Brain sensing module which decodes brain signal as well as connects it with computer to observe our brain activities is the EEG module[13]. The amplitude of the EEG signal is in the range of 1μV-150μV, which is quite noise-sensitive during acquisition. Improved sensor technology, higher signal to noise ratio (SNR) and sufficient gains of filter and amplifier are all important and necessary for EEG signal acquisition[14].EEG being a non-invasive technique, uses electrodes that are placed on the forehead to acquire the brain signal. They maintain the signal quality for long-term physiological monitoring, and also overcome the discomfort and inconvenience of invasive methods. After the signal is acquired, the amplification unit is applied to filter out the noise. The EEG circuit comprises of a differential pre-amplifier having a gain of 99, an isolating amplifier that protects the subject and a band-pass filter that is formed of a low-pass filter and a high-pass filter to conserve the 1-25 Hz signals. Also, a differential amplifier with a gain of 51, and a 60-Hz notch filter is used to eliminate the noise due to power line. The capacitors in the band-pass filter can also compensate the DC-offset[15].

Fig.3 Block diagram of a functional EEG circuit

V. APPLICATIONS

The BCI system has been developing at a terrific speed and more research is being done to incorporate this technology to make it useable and available to larger masses. Early BCI applications have targeted disabled users who have mobility or speaking issues. With regard to this, many BCI research groups have attempted to develop BCI-driven wheelchairs with the aim of restoring some form of mobility[16]. While it has been speculated that the totally locked-in state constitutes a different BCI-resistant condition[17], the issue still persists. One of the most common and researched applications of BCI is its use in gaming. User-controlled brain activity has been used in games that involve moving a cursor on the screen or guiding the movements of an avatar in a virtual environment by imagining these movements[18]. With the evolution of BCI many games are being developed. Games in which helicopters are controlled to fly in a 2D or 3D virtual world[19]. Also, illustrations with Virtual Reality (VR) [20] systems promise that this technology can be extended to form a Virtual Synthesizer Museum, in which one could use BCI to move within a virtual space and, at a certain point, allow the user to compose music with a selected synthesizer and possibly control a few parameters[21]. The study by Cincotti et al[22] attempted to use BCI technology into a domestic environmental control system to help people with physical disability to perform common actions like switching devices on and off or controlling temperature of room etc. by using BCI. The Neural Music program developed transfers the brain waves and brain-signal patterns directly to musical instrument device interface (MIDI), thus facilitating a tonal representation of thesignal[23]. It can hence be derived that BCI has great potential and is a powerful

technology. As fascinating as this technology seems to be its implementation is not easy. Users are trained to think in a certain way so that expected brain signals are generated to perform the desired task.

VI. CONCLUSION

BCI technology interfaces two different fields: neuroscience and computer science. Different implementation methods of this technology were reviewed. Non-Invasive method of harnessing the brain signals using EEG has been more preferred and reliable. The review conducted implies that EEG technology has high potential in terms of data acquisition and translation of data to control many familiar devices. Further development in this technology can lead to a world-wide revolution in the field of information exchange.

REFERENCES

1. William Merrin Digital War: A Critical Introduction, Routledge; 1 Edition (31 July 2018)
2. Farwell, L.A., Donchin, E. (1988). Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. ElectroencephalographzClin. Neurophysiol.
3. Remigiusz J. Rak, MarcinKołodziej, AndrzejMajkowski Warsaw Brain-Computer Interface As Measurement And Control System The Review Paper Metrol. Meas. System.
4. Jonathan R. Wolpaw, NielsBirbaumer, William J. Heetderks, Dennis J. McFarland, P. Hunter Peckham, GerwinSchalk, Emanuel Donchin, Louis A. Quatrano, Charles J. Robinson, and Theresa M. Vaughan. Brain–Computer Interface
   Technology: A Review of the First International Meeting. IEEE Transactions On Rehabilitation Engineering.
5. E. Niedermeyer and F.L.D. Silva, Electroencephalography: Basic principles, clinical applications, and related fields (Lippincott Williams &Wilkins, (2004))
6. Robert Oostenvelda, Peter Praamstrac .The Five Percent Electrode System For High-Resolution EEG And ERP Measurements Clinical Neurophysiology.
7. Navarro AA, Ceccaroni L, Velickovski F, Torrellas S, Miralles F, Allison BZ, R.Scherer R, Faller J. Context-awareness as an enhancement of brain-computer interfaces. Ambient assisted living. Springer; 2011.
8. Sarah N.AbdulkaderAymanAtiaMostafa-Sami M.Mostafa Brain computer interfacing: Applications and challenges Egyptian Informatics Journal · July 2015
9. *Richard Caton (28 August 1875).* British Medical Journal.
10. Xun Chen, Jane Wang Design and Implementation of A Wearable, Wireless EEG Recording System 2011 5th International Conference on Bioinformatics and Biomedical Engineering.
11. SwatiVaidPreeti Singh ChamandeepKaur EEG Signal Analysis For BCI Interface: A Review 2015 Fifth International Conference on Advanced Computing & Communication Technologies.
12. Suraj R. Gaikwad1 , Shruti S. Kshirsagar .Review: Analysis of EEG Signal based BrainComputer Interface International Journal of Science and Research (IJSR).
13. Kalyani, Bipasha Chakrabarti Banik, AbhijitDas,MoumitaGhosh,SudiptaPaulBatanagarBiswarup Design of Mind-controlled Vehicle (MCV) & Study of EEG Signal for Three Mental States.. Devices for Integrated Circuit (DevIC).
14. J. C. Chiou, L. W. Ko, C. T. Lin, C. T. Hong, T. P. Jung, S. F. Liang and J. L. Jeng, Using novel MEMS EEG sensors in detecting drowsiness application, IEEE Int. Conf. in Biomedical Circuits & Systems.
15. Chin-Teng Lin Fu-Chang Lin Shi-An Chen Shao-Wei Lu Te-Chi Chen Li-Wei Ko. EEG-based Brain-computer Interface for Smart Living Environmental Auto-adjustment. Journal of Medical and Biological Engineering.
16. Joseph N. Mak and Jonathan R. Wolpaw. Clinical Applications of Brain-Computer Interfaces: Current State and Future Prospects IEEE Rev Biomed Eng.
17. Birbaumer N. Breaking the silence: brain-computer interfaces (BCI) for communication and motor control. Psychophysiology.
18. Nijholt, A., Erp, J., van Heylen, D.K.J. BrainGain: BCI for HCI and Games. Proceedings AISB Symposium Brain Computer Interfaces and Human Computer Interaction: A Convergence of Ideas, Aberdeen, UK.
19. A. Finke, A. Lenhardt, and H. Ritter, The mindgame: a p300-based brain–computer interface game Neural Networks.
20. A.S. Royer, A.J. Doud, M.L. Rose, B. HeEeg Control of a virtual helicopter in 3-dimensional space using intelligent control strategies. Neural Syst Rehabilitation Eng, IEEE Trans, 18 (6) (2010), pp. 581-589.
21. F. Lotte, A. Van Langhenhove, F. Lamarche, T. Ernest, Y. Renard, B. Arnaldi, and A. Lecuyer, Exploring Large Virtual Environments by Thoughts using a Brain-Computer Interface based on Motor Imagery and High-Level Teleoperators and Virtual Environments.
22. Brain-Computer Interface (BCI) based Musical Composition. BrahimHamadicharef Tiara Kim SengWalk ,MufengXu, SheelAditya School of Electrical & Electronic Engineering Nanyang Technological University November 2010 IEEE Xplore.
23. Cincotti F, Mattia D, Aloise F, Bufalari S, Schalk G, Oriolo G, Cherubini A, Marciani, Babiloni F. Non-invasive brain- computer interface system towards its application as assistive technology.