

EEG based Brain Computer Interface

ShubhiGarg¹,Vikas Kumar Sagar²,

Unnati Verma³, Sonu Kumar Pandey⁴

¹U.G. Student, Department of CSE, IIMT College of Engineering, Greater Noida, UP

shubhigarg711@gmail.com

²U.G. Student, Department of CSE, IIMT College of Engineering, Greater Noida, UP

sagarvikas901@gmail.com

³U.G. Student, Department of CSE, IIMT College of Engineering, Greater Noida, UP

unnatiwork18@gmail.com

⁴U.G. Student, Department of CSE, IIMT College of Engineering, Greater Noida, UP

ssonu.iimt@gmail.com

ABSTRACT

A brain-computer interface (BCI) is a process by which we can allow communication between a disabled user through their brain and the computer in the form of commands. Or we can say that a BCI allows the users to work on their own environment eliminating the use of peripheral devices for nerves or muscles. The BCI revival opens new methods of neurological rehabilitation for specially challenged people. Brain reading and communication have their own vital impact in multiple fields namely educational, self-regulatory, security, marketing, production as well as entertainment and games. This research is based on the various applications and advancements in the technology of brain computer interface and its various applications. An understanding of invasive and non-invasive technology to measure the brain activities will be carried out, brain control signals etc. Here we will talk about the recent advancements and all the possible applications that can be achieved with the help of brain waves. We will examine the various objective and subjective approaches and their limitations.

KEYWORDS-

Brain Computer Interface, EEG signals, Neurophysiological signals, BCI Applications.

1.INTRODUCTON

A Brain Computer Interface is known to be a device that coordinates with the brain and the nervous system to generate the artificial outputs accordingly. Individuals suffering from the locked-in syndrome do not have the ability to communicate easily. It is a condition in which patients are completely aware of

what is happening in their environment but are not able to communicate or move, in easier words it is the total loss of voluntary muscles. It is basically used to read the minds of those who cannot communicate in the other ways. The major goal of the BCI is to make sure that the disabled users are able to communicate with the outside environment and to understand their environment. Brain Computer Interface thus process and detect brain and nervous system activity in order to control and direct external devices, such as personal computers, robotic arms, wheelchairs, or to activate a person's own muscles. BCI systems are currently being examined for use in the assistive technology and multimedia communications. Amyotrophic lateral sclerosis (ALS) or Lou Gehrig's disease leads to total dead neurons which leads to the total loss of voluntary muscles. Also there are many other sclerosis and cerebrovascular incidents that leads to the degeneration of the parts of the brain that leads to loss of communication ability. It is explicit to say that the lives of the people are highly affected by the loss of such a basic human tendency to communicate and to express themselves to the world.

Relevant brain activity from BCI users can be detected through evaluation of invasive and noninvasive technologies to measure brain activity, evaluation of control signals which are the patterns of brain activity used for understanding their minds, algorithms can be developed for translation of brain signals into computer commands. There are basically three types of brain activity that can be detected using the BCI technology and applications. Passive BCI's use the brain activity which is mostly not voluntary but depending on the state of mind, stress level, mental ability and affective states. Reactive BCIs are related to changes in brain activity which occurs as a result of an individual's voluntarily focused attention on a specific external stimulus. Active BCIs are the mental strategy that the user creates in their minds themselves. Some of the essential applications of BCIs also is to use electrodes which have been implanted in the brain to apply stimulation to the brain, for instance in the treatment of epilepsy, or psychiatric disorders. BCIs can also be seen as a new and exciting means of communication that could be used as well by persons not suffering from disabilities. Apart from medical applications, in multimedia and other communication platforms BCI can be used as a modern approach along with the traditional approaches to make the system work better. For example in games, audios, videos etc. modalities can be added using BCI's. During this research paper we will have a look at all the various advancements in the BCI technology. The material presented here is purely focused towards BCI systems and the technology behind it. This paper should serve as a basis for future empirical studies and inform conceptual and ethical deliberations. We include studies considering various BCI stakeholders as well as quantitative and qualitative methods of social research.

2.HUMAN BCI RESEARCH

2.1 Invasive BCI's-

In this type of BCI, they are implanted into the brain only with the help of neurosurgery. There are micro electrodes in the brain which are responsible for collecting the signals in the brain with the help of single and multiple units. Single units are those which collect the signals from a single unit of brain cells and multiple unit collect them from the multiple units of brain cells. There are also several risks involved in the translation of the signals.

2.1.1 Vision-

They are placed in the grey matter of the brain with the phenomenon of neurology and its objective is to provide sight to the visually impaired and also process the activity which is going on in their brain. This invasive technology produces the best quality signals, due to their position in the grey matter.

2.1.2. Movement-

The major motive behind the Brain computer Interface technology is to make the lives of the paralysed people easier by either providing them with a robotic assistance or making a connection with their brain activity through neurological methods. A group of researchers at the Braingate group at Brown University, have achieved glory and success in controlling the prosthetic robotic limbs to an extent of freedom with the help of immediate connections to arrays of neurons in the motor cortex of patients with tetraplegia.

2.2 Non-invasive BCI's-

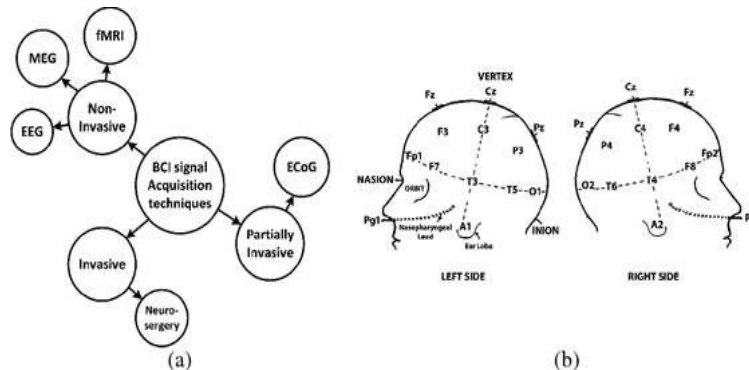
A noninvasive process is the one where there is no physical change with one's body or organs and exchange the information directly with the use of non-invasive EEG based technology. There is a lot already written priorly and been discussed about this phenomenon. Noninvasive EEG-based technologies and interfaces are capable of being used in multitudinous everyday applications and advancements. EEG based technology is easy to carry, wear and does not create any physical change in the body of the person but it also has its own limitations.

3. EEG based brain-computer interfaces-

There are some people who lose their basic means of communication which has to be established medically by using the upcoming technology. One such technology we are going to discuss here in this topic. We all know about the electrodes that we have studied in the basic sciences in our elementary education, in a very popular phenomenon called Electroencephalogram, we make their use to sense some disturbance and activity going in and around the brain and scalp in the form of electrical signals and convert them into information by decoding them into human understandable language. In this particular we are going to discuss about the details of this topic and also the specialities and limitations related to this technology called EEG.

Electroencephalogram (EEG) is a tool which is used to measure the brain activity and use the brain produced commands to detect this activity. It is true though, that the EEG has a very strong relation with the medical problems like heart, eye, etc. Therefore, the use of BCI employing only EEG has limitations, so other bio-signal detection modalities are usually included as supplementary modalities, including those such as electrocardiogram (ECG), electromyography (EMG), photoplethysmography, electrooculogram, and galvanic skin reflex (GSR), (fNIRS) -functional near-infrared spectroscopy is used to measure the brain activity since it cannot be measured by other modalities.

In this type of detection what happens is that the electrodes are made to rest on the scalp according to the standards and the same electrodes are connected with a Bio-amplifier to keep a record of each and every signal activity that is happening in the brain, also these electrodes can be wore manually in the form of a cap. These electrical signal recorded in the amplifier are then stored in the computer system where these signals are displayed in the form of a wave (converted from electrical signal) and displayed using a chart. In this way, the differential amplifier receives the brain activity of the human being.



4. ARTIFACTS

When we try to detect the cerebral activity in the brain it is not necessary that the activity recorded is only cerebral rather we simultaneously get some other signals produced by the extra other organs of the body along with cerebral detection, these extra signals in the form of waves in EEG are known as Artifacts. Artifacts also can be further classified into two categories i.e. Physiological signals and extra physiological signals, in this the physiological signals are those which detect the activity which are taking place inside the body itself while the extra physiological signals are those which detects the external signals which are created by the external environment and influences.

We need to inculcate a proper method to distinguish between the artifacts from the EEG signals. There are some of the features of the artifacts that can help us to make out the difference.

4.1 Physiological Artifacts

These are the kind of artifacts which are caused by the electrical activity taking place inside the parts of the body other than the brain also they can be classified as the following, related to the eye blink, eye lid movement etc.

4.2 Cardiac Artifacts

Heart also produces some artifacts in the form of waveforms which are known as Cardiac Artifacts, they are formed around the scalp as ECG waveform, there frequency is in Hz.

4.3 Muscle Artifacts

They are based on the surface electrode of the EEG, they are formed according to the amount of muscle contraction, weak contraction form a low amplitude artifact and so on.

4.4 External Artifacts

The waves that are produced by the external signals are known as External Artifacts, originated through mobile, computers, transmission cables etc.

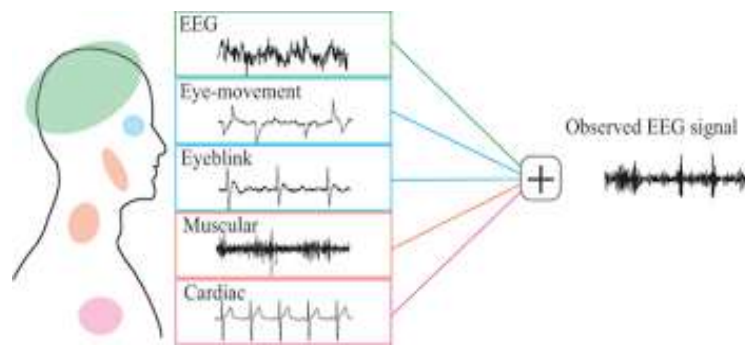


Fig 1. Artifact rejection method

How to remove artifacts from your BCI?

There are various methods through which you can avoid and remove artifacts of any type. The method can be manual or automated

Manual Method: Here the volunteers themselves try to remove the artifacts using manual technique by visually inspecting for the artifacts. Manual method is also known as Offline method.

Filter Method: This is not a very effective method though for removing artifacts because it uses frequency filtration to remove the artifacts of some particular bandwidth but it is not reliable as they we do not have a definite idea of which frequency the artifact is.

Mathematical Detection: They use the mathematical algorithm to remove the artifacts some examples are principle component analysis and EOG subtraction etc.

5. NEUROPHYSIOLOGICAL SIGNALS FOR BCI:

Neurophysiological signal is an EEG based method itself to determine the activity of the brain. For a Brain computer Interface to work you first need to understand the activity of the brain which can be known through the following methods, the first methodology is by focusing on the activity of a single stimuli. Due to the processing of stimuli there are some modifications in the neurological signals which are termed as Event-Related Potentials while the second methodology is when users pick a particular activity to be done, in this we try to store a feedback for a similar pattern of movement for the next time.

Slow Cortical Potentials

It allows deliberate activation for the distinct brain areas anatomically, an EEG- based BCI can make use of SCP's which are a result of intracortical and thalamocortical inputs. They are the slow voltage shifts that takes place in EEG. We can control the activation of positive or negative corticals.

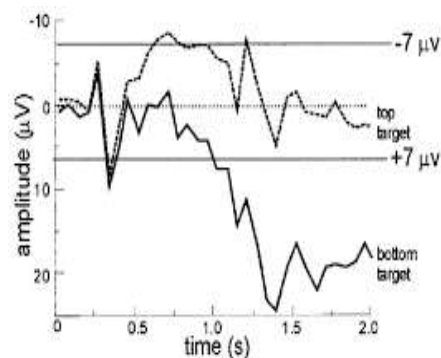


Fig 2. Slow Cortical Potentials

Oscillatory Brain Activity

These are the brain activities that change according to the state of mind that is why they are called as Oscillatory activity. It can be represented in the form of a sinusoid. It can change its characteristics according to the movement like between running and walking, studying and playing etc.

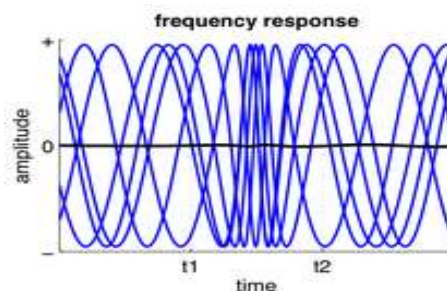


Fig 3. Neural Oscillations

Event Related Potentials

When there are some cognitive, sensory or some motor event taking place then our brain reacts according to it in a properly estimated manner, this gives a better way to study the psychophysiological activities inside the brain. It is a non-invasive approach (avoiding any physical impact or input from the body) to measure the brain activity. The potential examples is P1 (P100) , it is an ERP which is recorded through the human scalp by the use of Electroencephalography(EEG). This type of BCI depends on the focus of the person, their attentional capacity and a good vision , but we generally notice that people with some brain disability has these things compromised within themselves thus this method is not very efficient for practical use.

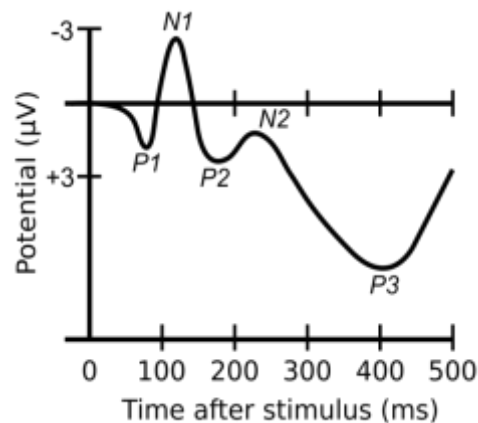


Fig 4. Event Related Potential

Neuronal Ensemble Activity

The interaction between the neurons and the primary amount of information in the brain is carried out through the Action Potentials. We can determine the activity in the BCI with the help of the number of action potentials per unit time which is known as the firing rate. An example can be microelectrode rays.

6.USE OF MACHINE LEARNING IN BCI'S.

So far we have seen the use of various techniques to make the BCI's and how the neurophysiological signals work, but is there a way to figure that how do these neuro-signals differ from each other and in what way can they be classified?

This can be done with the help of machine learning algorithms, we can determine the use of different signals which can be divided into two categories i.e. Feature extraction and Classification.Let's see how

6.1. Signal Processing or Feature Extraction

There are multiple features in a BCI system depending on the type of system. There are many different features that are being extracted from distinct channels and systems and then assembled together in a

single feature identity. Some of these features are band power, time constraint, frequency representation , and etc.

6.1.1.Frequency Representation: Frequency domain features are essential for the Oscillatory activities because since the oscillations cannot be time locked so it is not possible for the user to get information about the action of the users. The brain feature extraction is also important because it gives information about the synchronization of signals from the different brain areas by which we can identify different tasks.

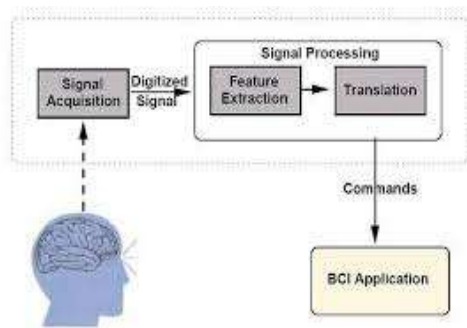
6.1.2. Time Domain Features: The presentation of the stimuli occur time to time in a BCI system due to which there is a change in the amplitude of the neuro signals and that's why we have certain time domain features which can help us through the process. A common feature that is used in this method are the number of neuronal activities occurring per unit time.

The time domain feature are responsible for dividing the EEG's based on the frequency band , because of the non-linearity and non-stationary behavior of the EEG signal.

6.1.3. Spatial Features: Spatial extraction aims at bringing the best out of the combinations of different electrodes. There are many systems in which information is being received by many electrodes. We can also make a combination of electrodes with the help of spatial filtering method by using the following formula.

$$S \in R^{C \times T}$$

Where S contains the filtered signals at time T.



7.APPLICATIONS OF BCI SYSTEMS

For the applications of BCI systems sky is the limit, with some modifications they can be used in multitudinous fields varying from medical to educational to commercials. It acts as a communication medium between many different set of media. Some of them have been explained below:

7.1 Creating a Smart Environment: The use of BCI's is now not limited to humans or human brains but it has been extended to a number of uses which are materialistic and can automate some common

activities going on in our environment. With the blend of technologies like Internet of Things (IoT), Artificial Intelligence and Brain Computer Interface it is possible to build homes, transportation service and organizations work smarter.

7.2 Gaming: The whole sole motive of modern gaming is to create some animated characters with the same mental, physical and emotional capacity as that of a human being. Here also BCI plays a major role in synchronizing the human brain in a virtual environment which we call virtual reality.

7.3 Advertisements and Commercials: Even in the field of marketing and advertisement the use of BCI can prove to be a great victory. For instance, we can determine the impact of a particular commercial on the brain of a human being through the BCI and can further plan the campaign accordingly. Another research now has also shown that we can also determine the time that a particular advertisement stays in the brain of a person through BCI.

7.4 Neurological Feedback system: We can use this feedback system in various fields such as customers, students, spectators etc. For example it is easy for a teacher to know about the clarity of a subject in a student's mind, when we have a large number of students and also the impact of a particular product on a customer.

7.5 Medical Applications of a BCI system: Health field is highly benefited from this technology and has seen recent advancements in treating the earlier impossible problems of disabled and physically challenged patients.

- **Diagnosis and Detection:** The medical workers now find it easy to determine any mental disorder or issue in the brain through the mental state monitoring system which uses the EEG based BCI. This is not only a more efficient way of detection but also the cheapest as compared to the hefty amount an MRI take from a patient.
Also EEG signals have been useful for detection of breast cancer and tumors in the other parts of the body as well.
- **Disabled users get a chance to live a better life:** The major and the foremost advantage of a BCI system is to help the disabled users to get an ecosystem through which they can communicate with the outside world and give their presence both mentally and physically.
- **Rehabilitation:** There are many people who lose their mobility due to injuries or accidents and also some lose their normal brain activity due to a sudden stroke or a haemorrhage. In such a case some Neuroprosthetic devices also known as BCI limbs can be used by the amputees to resume a normal life. Rehabilitation activity takes place in a way such that some recorded activity from normally functioning people are being transferred to the BCI users to restore their actual behavior.

CONCLUSION

In this paper we have tried to elaborate the working and implementation of a Brain- Computer Interface with the use of EEG signals mainly neurophysiological signals. We have the classification of BCI in the very beginning of the research paper and then we came to the EEG part where we saw in detail how the EEG signals make use of amplifiers and oscillators to decode the activity of the brain.

We also studied the proven effectiveness of the EEG based devices in terms of cost and availability and also the reliability on its sensors. We also introduced quite a lot of information about the feature extraction and classification methods of signal processing. Though there is a lot in these field that is still not known to anyone but can be explored if the research on the same concepts is further continued in the future.

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Authors

Pushpendra Kumar, Assistant Professor, Department of Computer Science and Engineering, IIMT College of Engineering, Knowledge Park III Greater Noida, UP.

ShubhiGarg is pursuing her B.Tech Degree from Department of Computer Science and Engineering, IIMT College of Engineering, affiliated by Dr. A.P.J. Abdul Kalam Technical University batch (2017-2021).

Vikas Kumar Sagar is pursuing his B.Tech Degree from Department of Computer Science and Engineering, IIMT College of Engineering, affiliated by Dr. A.P.J. Abdul Kalam Technical University batch (2017-2021).

Unnati Verma is pursuing his B.Tech Degree from Department of Computer Science and Engineering, IIMT College of Engineering, affiliated by Dr. A.P.J. Abdul Kalam Technical University batch (2017-2021).

Sonu Kumar Pandey is pursuing his B.Tech Degree from Department of Computer Science and Engineering, IIMT College of Engineering, affiliated by Dr. A.P.J. Abdul Kalam Technical University batch (2017-2021).