

Conceptual study of Advancement in Brain Computing Interface (BCI) model for various bio signals: A Review

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Abstract

Brain computer interface (BCI) falls in simple communication system such as one way or bidirectional among human brain and an external device such as computer .It is great pledge for reintegrating subjects which are related to cognitive and physical working capacity of human.

BCI is one of the important and dominant field of research where controlling of the human brain is possible. It replaces the older scenarios like neural rehabilitations which advance technologies. This paper aimed to conceptual study of the brain computer interface model in review point of view. It also gave the details about general BCI system which is worked with bio signal generated in human body along with recent scenarios observed in the medical field.

Keywords: *Brain computer interface, bio-signal, EEG, Electrodes, Feature extraction, signal conditioning, signal processing.*

Section I

I. Introduction

The Brain-Computer Interface (BCI) is technology which has connected to the human brain and the outside resources. It is a real-time brain-machine interface system that is used to communicate with human brain with some external sensors named as electrodes [1]. This system executes by using brain activity signals and it is communication medium between user and the computer which further generates exact output.

There are various techniques used for BCI system. One of the popular techniques is noninvasive technique which is used mostly in applications devoted both to restoring the functionality of disabled subjects and to regular consumers. Initially experiments with animals and tried in control of artificial peg leg [2]. The simple tasks like moving a screen cursor has been completed at the end of 1990s. The electroencephalogram (EEG),+ECG,MRI are signals which are used as input for BCI system .All electrical tasks recorded by using electrodes positioned on the crown. The very popular noninvasive techniques are EEG-based BCI which is very popular from last decades. The summation of coincident tasks of neurons calculated in the BCI system which have the similar spatial orientation later then an external stimulus is take in action [2, 3].

The last decade interests of users are towards the use of BCI for entertainment applications and games. It is hard to achieve exact output and not easy to achieve with another input technique. The signals of BCI can be used in these types of application to specify the cognitive states of a user that has been used in changing a game to the player's cognitive and emotional conditions. However, the BCI gives data to game developers that are related to managing a gaming application. Also they can develop software and hardware products to execute humble interface [4].

Over the next decades, BCI system will permit to computers for first time, hold advanced analysis of cognitive and emotional states [5]. It going to be transforms the simple interactions people have, this changes not with system but also with each other. It means the BCI is one of the great platforms where human can resolve their own problem by taking proper guidance with advent methodologies.

This paper focused on the conceptual understanding of the BCI system .It includes literature with different bio-signal. Rest of paper is organized as: Section II gave literature survey and research gap. Basic model of BCI system explanation is given in section III. Conclusion and references are given in section in IV.

Section II Literature survey

Literature survey of various is carried out here along with used signal and description.

| Sr. No | Author name and year | Signals | Description |
|--------|----------------------------|-------------|---|
| | Mridha, M. F. et.al (2021) | EEG Signals | This study stated various applications of BCI and upholds the significance of this domain. Also includes, every element of BCI systems, including techniques, datasets, feature extraction methods, evaluation measurement matrices, existing BCI algorithms, and classifiers, are explained |
| | | | concisely. In addition, a brief overview of the technologies or hardware, mostly sensors used in BCI, is appended [6]. |
| | Xiaotong G. et.al (2020) | EEG signals | In this study, they survey the new advances in modern of the wearable devices, dry sensor, deep learning, signal enhancement, interpretable fuzzy models and transfer learning for BCIs with EEG signals. The different computational intelligence techniques enable them to gain reliable brain cortex features. They used this technique for understand human knowledge from EEG signals. They summaries the new interpretable fuzzy models and EEG signal sensing by using deep learning for BCI applications[7] |

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| | Lukas A. W. Gemeinet al. (2020) | EEG Signal | This study proposes deep neural networks and feature based framework depends on an EEG to the task of pathology as compared to non- pathological EEG classification. They choose Temple University Hospital (TUH) that includes approximately 3000 EEG recordings. Six results for pathology decoding were published, EEG's five from used TUH abnormal EEG corpus. Another one from used handcrafted feature and classified through a CNN with MLP [8]. |
| | Maitinet, A.M et al. (2020) | EEG Signal | This paper uses machine learning (ML) technique to diagnose PD through motor activation electroencephalography (EEG) tests. A review process was performed for diagnosis of Parkinson's disease (PD). The focus was on the diagnosis and evaluation of PD and evaluated the structure and content of title. |
| | Ahn, J et al. | HRV and | In this study, they experiment study by using EEG |
| | (2019) | EEG Signals | signals and 14 young subjects' participated. They found significant time and frequency characteristics of EEG. In two different irritant HRV were found mental arithmetic Stroop color word tests. Stressor situation are modified by different EEG and HRV feature selections. It also uses a to help vector machine technique [8]. |

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| | Nanda, M. and Kamath, A (2019) | EEG Signal | In this study, they stated home based system using BCI technology like ceiling fans, lights and switches. They experienced on two devices that are a fan and a smart bulb. They choose four subjects for their system that includes three trials. The result of this study that for home-based system achieved effectively and efficiently by applying an individual's ASSR [9]. |
| | MythiliThirugnam <i>et. al.</i> (2019): | EEG Signal | This paper describes EEG technique for detects stress that is used to captures electrical signal produced in brain. Neurosky mind wave device was used to avoid minimum amplitude EEG. The extracted features were fedto various classifiers like KNN, SVM, Bayes, decision tree and neural network for detection of emotions as unstressed state while angry emotions as stressed state. Matlab 2016 software was used to implement results and were compared with proposed algorithms[10]. |
| | Lahane, P. <i>et. al.</i> (2018) | EEG Signal | This study considers 32 channels which includes 10 – 12 electrode placement system for analysis of EEG. A recent technique is frequency Cepstral coefficient (FCC) was used to extract features. Then, those extracted features were passed through K nearest neighbor (KNN), which categorize |

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| | | | <p>different features into various emotions like happy and sad. They carry out detection of stress using these emotions, for a stressed and unstressed person. This FCC gave an accuracy of 93.33% which was higher than that of the Kernel Density Estimation (KDE) and Relative Energy Ratio (RER)[11].</p> |
| | <p>Billones, R et al (2018)</p> | <p>EEG and ECG Signals</p> | <p>For psychological and physical abnormalities the electroencephalography (EEG) and electrocardiography (ECG) are common method for explore the connection between the signal complexity of the brain and cardiac activity. The co-relation between ECG and EEG signals is check and tries out with different task at the same time it check recording ECG and EEG measurements. This study they experiment on eight subjects participated in that four are male and another four are female. The results showed accretion in both brain activity and heart rate upon stimulus activation. The connection of brain and heart activity is complex and results also not getting accurate. In future work they may be use sensor with lower sensitivity to motion [12].</p> |

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|--|---------------------------------------|---------------------------|---|
| | Shaikh, P et.al (2013) | EEG signals | In this paper, they used important technologies such as a sensing module for signal acquisition, amplification, and Wireless transmission, a dualcore embedded system for real-time EEG signal processing and an automatic bio-feedback loop for online warning and reminding. By combining all this technologies a flexible BCI system is implemented and it can be applied to different applications.[13] |
| | Ramy Hussein et al. [2013] | EEG Signal | In this paper, they evaluated features and their performance terms of overall complexity and accuracy. They carried out extensive experimental work and trade-offs were reported, it also shows that combination of frequency and time domain data improves the classification performance using EEG signal [14]. |
| | Singh, Y. et al. (2012) | EEG and ECG signals | In this study, they survey the advantages of bioelectrical signals in that they prefer EEG and ECG signals as biometrics for separate authentication. The EEG and ECG signals has some benefits in biometric. The EEG or ECG is private to an individual, so they are harder to imitate. Signals are much secured, therefore it is impractical to stolen. Some challenges are occurs in the domain of biometric applications.[15] |

Above statistical analysis shows the number of research publication in the area of BCI.

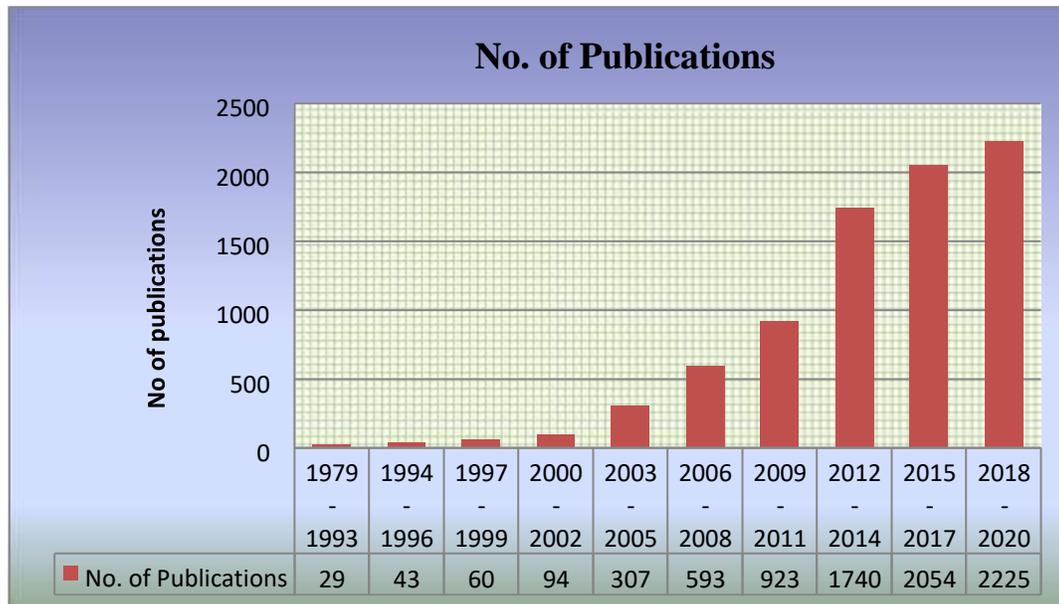


Fig. Approximate Available publications per year for BCI

Research gap

- Tiwari, N. et al. [16] stated basic introduction to brain functioning and the evolution of BCI. In this study, they describe analysis about human brain, BCI, and its phases, extracting methods and algorithm. A human brain structure is complex, thought of human are non-stationary and generated signals are irregular. So, the challenging factor is to create a system to determine extensive perception from the human brain and after that BCI system will give better extensive perception.
- Abiri, R. et al [17] estimate the present analysis on EEG-based different experimental paradigms which is applied by BCI technology. The researchers experimented for every experimental paradigm with various classification methods and EEG decoding algorithms. They examined the paradigms like Body kinematics, Visual P300, Evoked potential, Motor imagery paradigms and error related hybrid and potential paradigms. They have faced various problems while survey BCI paradigms with signal processing, fatigue and training time and novel decoders.
- Bonci, A et.al [18] reported nine semi-structured interviews with help of medical BCI users. User can understand only that BCIs can give to regaining or retaining capacity of human and it includes elements which are common and challenging from experience. The most of users feel that BCI has benefits and exceed risk because BCI system is includes valuable capabilities and qualities. BCI user motivate for regain lost capabilities.

Recent issues

The BCI system is improving their performance towards accurate solution and more dynamic of the connection between machine and brain. However, some parts are repelling achieving the exact goal. There are some following challenges faced by BCI system.

- Technical Challenges

The difficulties related to the recorded electrophysiological of brain impulses are non-stationary, noise, non-linearity and also limited training sets.

- ✦ Non-Linearity

The brain is a very difficult nonlinear system in that some activity about chaotic neuronal ensemble may be seen. This techniques can describe better EEG data that linear system [19].

- ✦ Non-Stationary

In developing BCI system, there is challenging factor that the nonstationary of electrophysiological brain signals to allow human identification. The results are not fixed about signals with time. EEG signals flexibility can be affected by emotional and mental state backdrop across sessions. Different emotional states like happiness, fear, sadness and anxiety can be changed on daily basis that reflects non-stationarity.

- Ethical Challenges

In BCI system, there are many ethical issues which contains psychological, social and physical factors. In the case of biological factors, this system finds a human sensors to recognize signals which is familiarize with electrodes [20]. This electrodes wear by human so it is always risky for them and possible to damage human body during signal acquisition.

There are some issues related to data acquisition of EEG signals in BCI system. Such issues examine the identification of the optimal location while identifying with high-density sponge electrode nets. In this system , various channels record the signals to keep strong spatial accuracy. The general fact is that, this process takes large data which increases the number of signals so there is need of some type of machine learning algorithm to extract relevant features.

Section III Basic Model of BCI system

Basic details of block diagram

General block of the diagram are signal conditioning, feature extraction and classification. In Signal conditioning block the bio signal received from human body part is converted into electrical signal For further analysis .Feature extraction is an important block where required features are extracted based on their nature and certain conditions. Once the all features are extracted then they are classified into different groups using various classifier .Those classifier uses the algorithms like k-NN, NN, SVM etc. Then finally based on the classifier result the decision is takes place [21].

In BCI system, signal processing is very important factor. In case of interpretation and classification of EEG signals there is need to first extract and select their features. The feature exaction describes the signal properties which delivers a set of values (data) [22]. The feature exaction can take place after some transformation or directly in the time domain. In the case of large amount of data set feature selection is commonly used and choose best one and reduce their number at the same time[23] and [24].

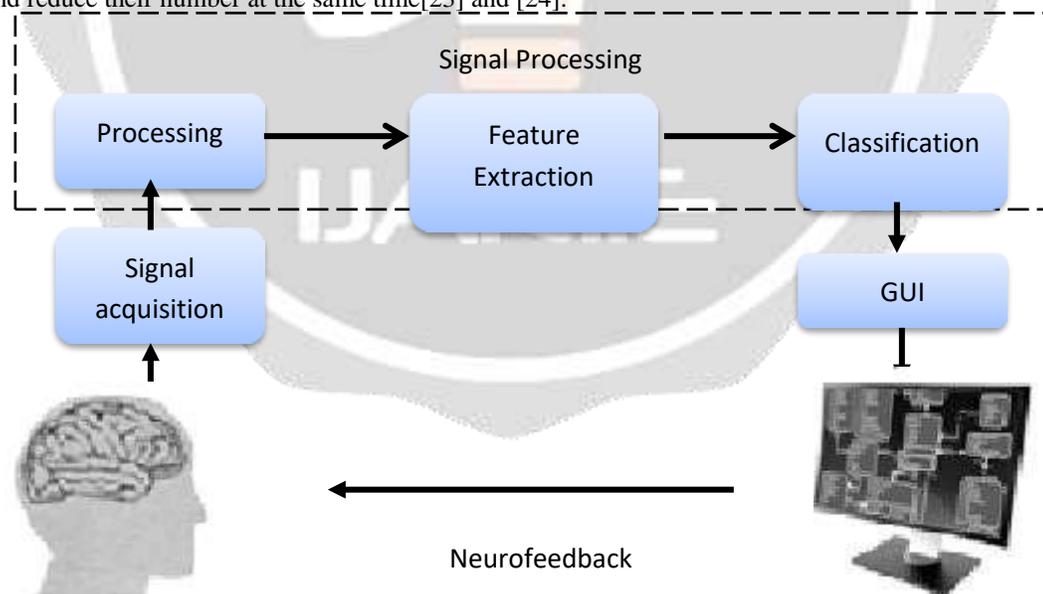


Figure 1. Brain Computer Interface System

There are various methods of feature selection for build up the effectiveness of classification, minimizing computational effort, reducing the amount of stored data and - reducing data redundancy. Above figure 1 shows a typical solution of a brain-computer interface.

Section IV

Conclusion

The BCI is one of the important technologies that deal with brain activities. We hope that this system will have better and more efficient and helpful for detection of various emotion and diseases based on bio signals in our daily life. There are different types of signals used in BCI technology but EEG signal is preferably used for analysis purpose. It also support to better result as compare to others. From the research we have seen that there are some issues in BCI system which are sorted with the help of machine learning algorithm for better results. In future, there is need to research on BCI and cognitive computation integration, how it will possible to communication between the brain and the computer to reduce current issues by improving conventional types of human communication.

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