Setting Brain into Action: A Brain Computing Interface (BCI) Investigation

Juhi Agarwal
Dept. of IT, Graphic Era University,
Dehradun, India

R H Goudar
Dept. of IT, Graphic Era University,
Dehradun, India

Abstract—**Brain Computing Interface (BCI) provides the direct link between brain and computer device. People do not need any muscle movement. Brain states can be detected and translated into actions. Two basic requirements of brain and computing interface are the features useful to distinguish several kinds of brain states and methods for classification of signals.BCI have three types: invasive, partially invasive and noninvasive BCI, but non invasive is a safe technique.EEG is the most popular non invasive technique. After acquisition of signals, the feature extraction and classification methods are performed. These methods will play the main role in BCI system's output. If the misclassification is performed, then the error or wrong command will generate. Currently we have so many methods available for the classification like Linear discriminate analysis (LDA), Support vector machine (SVM), multiple layer perception (MLP), bayes quaderatic etc. but there are many challenges and issues in BCIs. The challenges are Adaptation and learning is very tuff, BCI systems cannot be used autonomously by disabled people, Hard to adapt changes occurring continuously EEG and issues are like BCI requires extensive training from several hours to several months, BCI invasive technique can lead to damage of tissues, BCI provides low transfer-rate(5-25 bits/min).In the real life there are so many applications of BCI. So BCI is very useful technique for future, but BCI need some more good technology for capturing the EEG signals and handle the noise and methods for classification for improving the output of BCI. This paper discusses the architecture, tools and techniques, issues and challenges, research directions in Brain Computer Interface for setting Brain into action.**

I. INTRODUCTION

Brain states can be detected and translated into actions such as selecting a letters from a virtual keyboard, playing video games, surfing net and moving robot arm etc.[1].People can communicate just through their thoughts because bci provides the direct link of brain to outside world.BCI is a technology in which we do not need any muscle movement or in other words its muscles free communication channel.[2]

Examples: surfing internet, playing video games without activating muscles, driving robots, selecting letters from key board, clinical or medical applications, Control robots, BCI Speller for communication etc.

BCI research is multidisciplinary field integrating researchers from neurosciences, physiology, engineering, psychology, computer science etc.[7].

Two basic requirements are met for communication channel between the brain and computer.

I. Features those are useful to distinguish several kinds of brain states.
II. Methods for detection and classification of such feature implemented in real time.[3].

Now there are various types of methods for capturing the brain signals, which can be classified as non invasive and invasive.

Invasive BCI: In invasive BCI electrodes are implanted directory into the grey part of brain and produce the high quality of signals but this method can lead to rapture of tissues.

*Partially Invasive BCI***:** Partially invasive BCI are implanted inside the skull. Electrodes are placed on surface of cortex.

Non Invasive BCI: In non invasive electrodes are carefully placed on a cap that do not need any brain surgery but its very noisy and often misunderstood the computer.[4]

Different methods are EEG, magnetoencephalography, functional magnetic resource imaging functional near infrared spectroscopy (FNIRS), electrocorticography (ECOG).

At present EEG is the most popular method in BCI, for recording the signals the brain activity from the electrodes placed on scalp EEG it use. It has many advantages like EEG is simple and inexpensive equipment, flexibility and mobility[5].After acquisition of signals, the feature extraction and classification methods are performed. These methods will play the main role in BCI system's output. If the misclassification is performed, then the error or wrong command will be generated.

Current EEG based BCI are limited due to low channel capacity, low communication speed and low accuracy. [2][5]

II. ARCHITECTURE

Brain Computing Interface is basically combination of hardware and software devices. Basically in BCI signals should be identified, processed, and classified for any specified command. [6]

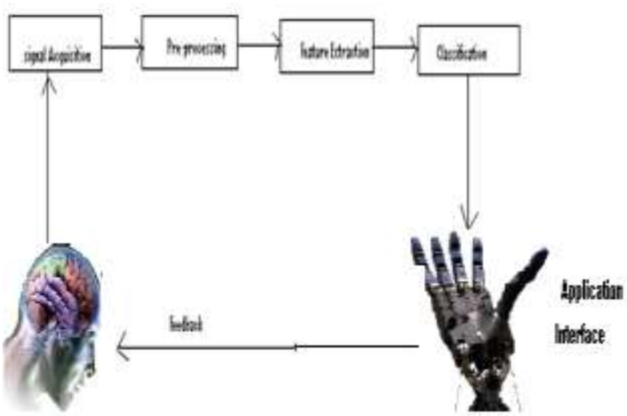

Figure 1**:** Basic Architecture of Brain Computing Interface

I. *Signal Acquisition:*-EEG data is recorded from the electrodes present in the EEG chip. Among the different neuroimaging techniques non-invasive electroencephalography (EEG) is the most realistic recording method. Current BCIs are based on EEG. Now different versions of EEG neuro-signals acquisition device have been released like emotive cap and Brainampcap.[2]

II. *Data pre-processing:*-this section amplifies the signal, filter the EEG signal, remove the possible artifacts/noise and convert the analog signal to digital signal. For removing the artifacts we are having many methods for example: AAS, Peak elimination, Rejection method etc.

III. *Feature Extraction and Classification:*-feature extraction and classification playing the main role in the BCI system. Right classification causes a right output and misclassification causes wrong command or rejection of command. Currently we have so many methods available for the classification. For example: Linear discriminate analysis (LDA), Support vector machine (SVM), multiple layer perception (MLP),bayes quaderatic [6][8].

IV. *Application Interface:*-classifications output is the input to the application interface. The electronic devices simply transform/convert the classification into a particular action.

V. *Feedback:*-Feedback improves the performance of brain computing interface (BCI).BCI feedback shows the output of experimental setup. For example: feedback task of moving cursor from the monitor.[9]

III. TOOLS

There are different methods for feature extraction and classification. All are having their own performance and accuracy. **For example:** Linear discriminate analysis (LDA), Support vector machine (SVM), multiple layer perception (MLP),bayes quaderatic etc.[6]

Table shows list of some commonly used tools for classifying data.

Package	License	Content
g.BSanalyse	Commercial	LDA, Minimum Distance Classifier (MDC), QDA,MutiLayer Perceptron (MLP), Radial Basis Function (RBF), Kmean
BIOSIG	GPL	Various LDA, QDA/MDA, Regularized Disciminant Analysis (RDA), MDC, Partial Least Square (PLS), RBF, various SVM and bayesian classifiers.
NMLT	GPL	This toolbox is associated with FieldTrip. Currently in development.
MATLAB	Commercial	LDA; Minimum Distance Classifier, QDA, HMM(Statistic Toolbox); MLP (Neural Network Toolbox),SVM, Kmean (Bioinformatics Toolbox).
CVX	GPL	Logistic regression, SVM, Gaussian process regression
GPML toolbox	GPL	Gaussian process classification
LibSVM	GPL	SVM, supports multi-class.

TABLE I. TOOLS FOR CLASSIFICATION

[18]

IV. METHODOLOGY

A.EEG Recordings: electroencephalography is the most realistic method for recording the signal. It's a medical instrument with different amount of electrodes present in the chip.BCI have different EEG acquisition devices, brain-Amp which contains 128 wet electrodes and wire connection on the other hand Emotive Cap with 14 dry electrodes and wireless connection.[2][10].

B.1. Data preprocessing and feature extraction: The EEG signals have been preprocessed. So that "high-level" features are build before feeding to the classifier. The preprocessing methods are applied to the signals that are obtained from the EEG signals.

B.2. Filtering: Filtering is used to reduce the noise, since certain types of artifact occur at known frequencies. The collected signals are band pass filtered from 0.1-60 Hz and digitized at 240 Hz. Some artifacts methods are given below:

*B.2.1 Average Artifact Subtraction (AAS) :*eliminates repetitive artifact patterns.

B.2.2 peak elimination: eliminates the corrupted sample from all EEG signals if the energy of the signal exceeds the considered threshold value for blinking.

*B.2.3 Rejection method:*can be unacceptable when the amount of data lost is much, blinking happens too frequently or the available data is limited

C. Machine learning and classification

Machine learning methods distinguish the EEG signals representing different types of brain activity. The performance of a BCI system depends on the features and the classification algorithm.

There are different types of classification methods, for example: LDA, MLP, HMM, SVM and Bayes quadratic. All the methods have their [11]

C.*1.LDA:* Linear Discriminate Analysis is considered to be a stable classifier and not being affected by small variation. It is the most popular algorithm applied for BCI application. LDA is simple to use and does not need complicated computation and more importantly, tend to be a right choice for real-time classification. Moreover, in many trials for BCI systems, it has been successful.

C.2.SVM: Support Vector Machine is a statistical learning theory with margin principal. Based on the choice of Kernel function it can be among linear or nonlinear classifiers.

C.3.HMM: Hidden Markov Models has been mostly applied for speech recognition.

C.4.Bayes quadratic: assumes independent binomial conditional density models. This classifier is not so popular for BCI.[6]

V. CHALLENGES

Although in BCI technology many applications have been designed but there are still some challenges to employing BCI control for real-world tasks.

I. The information transfer rate provided by BCIs is too low.
II. Adaptation and learning is very tuff in BCI.
III. The high error rate further complicates the interaction.
IV. BCI systems cannot be used autonomously by disabled people, because BCI systems require assistants to apply electrodes or signal-receiving devices before the disabled person can communicate.
V. Hard to adapt changes occurring continuously EEG. [12]

VI. ISSUES

There are lots of issues which are interferring the technological development of BCI. The lack of precise tools and softwares are responsible for making the development of BCI difficult. [13].So there are several issues in BCI explained below:

I. BCI requires extensive training from several hours to several months.
II. BCI invasive technique gives the good quality of signals, but this method can lead to damage of tissues.
III. BCI provides low transfer-rate, offering maximum transfer rate of 5-25 bits/min. for example: who are totally paralyzed, a BCI might give the ability to answer simple questions, at the rate 20 bits/min and perform slow word processing (i.e 25 bits/min could produce 2 words/min).[3][14].So how far BCI goes, it depends upon the issues, which are faced by BCI.

VII. APPLICATIONS

In the real life application of BCI usage of bulky, expensive and wired EEG devices and signal processing platforms causes discomfort and inconvenience to the user but also affect their ability to perform routine tasks in real life. BCI‘s will have the ability to give people back their vision and hearing.
There are so many application of BCI, which are explained below:

I. Provide disabled people with communication, environment control, and movement restoration.
II. Mostly used in clinical applications for the persons who are paralyzed or having spinal cord injury.[15]
III. Control robots that function in dangerous situations
IV. BCI Speller used for communication purpose.[16].
V. Provide enhanced control of devices such as wheelchairs, vehicles for people with disabilities.[17]
VI. Monitor attention in long distance aircraft pilots , send out alert and warning for aircraft pilots.
VII. BCI can be used in playing video games, surfing internet etc.

VIII. RESEARCH DIRECTION

There are some areas that need to be improving to get a good quality response with a major focus upon:

I. Improving physical methods for gathering EEGs: Currently there are different types of EEG chips available, but EEG based BCI are limited due to low channel capacity, low communication speed, handle noise and low accuracy. So the capturing EEG signal method need to improve, so that good and accurate signal can generate accurate result.[2][5]

II. Improving knowledge of how to classify the signal: Feature extraction and classification methods are playing the most important role in any BCI systems. Misclassification can cause an error or wrong command. Currently there are so many methods for classifying the signal like Linear discriminate analysis (LDA), Support vector machine (SVM), multiple layer perception (MLP), bayes quaderatic etc.SVM shows better performance compare to LDA. But still some work is needed in classification for more accuracy.[6]

CONCLUSION

Brain-Computer Interface (BCI) is a method of communication based on brain signals. The brain activity used in BCI can be recorded using invasive, partially or Noninvasive techniques. BCI's will have the ability to give people back their vision and hearing. BCI will totally change the way a person looks at the world. The possible future applications are numerous like it provide disabled people with communication, movement restoration, Control robots, Provide enhanced control of devices such as wheelchairs, vehicles and used in medical application. But some development in BCI is still needed like good methods for classification for good accuracy and good signal capturing method using EEG, so that the noise can be handled.

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