An Exploration on Brain Computer Interface- Issues and Challenges

Mandeep Kaur Ghumman #1, Dr. Satvir Singh #2, Navtej Singh Ghumman #3
1 Department of ECE, Faculty of AIET, Faridkot
2 Department of ECE, Faculty of SBSSTC, Ferozepur
3 Department of CSE, Faculty of SBSSTC, Ferozepur

ABSTRACT
A brain–computer interface (BCI) is a system that allows its user to control external devices with brain activity. Although the proof of concept was given decades ago, the reliable translation of user intent into device control commands is still a major challenge. Success requires the effective interaction of two adaptive controllers: the user’s brain, which produce brain activity that encodes intent, and BCI system, which translates that activity into device control commands. This paper describes the General Framework for BCI design and phases in BCI Interfacing. The issues and challenges on BCI signal processing also discussed.

Key words: Brain-Computer Interface, Framework, taxonomy, characteristics, beta rhythm, electroencephalogram (EEG), signal processing, electro cortiocogram (ECoG).

Corresponding Author: Mandeep Kaur Ghumman.

INTRODUCTION
Recently, electroencephalogram (EEG) based brain-computer interfaces (BCIs) have become popular in the study of brain science, neural engineering and rehabilitation. BCIs are devices that utilize the non-muscular channels of the brain (e.g., EEG) for communication and control. A BCI provides a direct communication interface between a brain and external device in which a message sent by an individual cannot pass through the brain normal output pathways but is detected through brain signals. Brain activities produce electrical signals detectable on the scalp on the cortical surface or within the brain. BCI’s translate these signals into output that allow total lock in patients suffering from brain or spinal cord injury to communicate without the participation of peripheral nerves and muscles via though is alone. BCI convert human intentions or thoughts into control signals to establish a direct communication channel between the human brain and output devices as presented in figure 1.

Fig.1. Fundamental structure of brain-computer interface (BCI)
This figure 1 depicts the basic structure of BCI technologies, on how a brain signal of a thought is passing on to a BCI system and how BCI system posseses those signals into a control signals for user application. [1]

The electroencephalogram (EEG) is a non-invasive method for recording bioelectrical brain activity which may be used for, amongst other things, neuroscience studies. It is a commonly used method because is relatively cheap, safe and convenient to use with humans, both in clinical and natural setting, when compared to many other neuroimaging technologies. The EEG may also be used for number of other applications. One example of this is the control of brain-computer interfaces (BCIs) [3]

The main application of BCIs has been and is to control assistive devices and provide communication for severing disabled users. BCIs can be used for basic communication, control of wheelchairs, robot arms or prosthetic devices and entertainment applications. Further, recent progressing BCI research has broadened the field of applications, in which the principal goal of the BCI is not the communication but rehabilitation and neuro-physiological regulation, which is known as neurofeedback. A BCI system can be considered to be the most advanced neurofeedback system available. [4]

GENERAL FRAMEWORK FOR BRAIN-COMPUTER INTERFACE DESIGN

There are four control signals within this model User control signals, logical control signals, Semantic control signals, and physical control signals shown in fig.2

Fig. 2 Functional Model of BCI System

1 User- The User is the person controlling the device in the BCI system. The User intentionally modifies his or her brain state in order to generate the control signals that operate the BCI system. The User’s abilities, their mental task and physical state, the task being performed, and physical and social factors in the operating environment all have a significant impact on the user and thus affect the functioning of a BCI system. For example, the usefulness of a particular system design is extremely dependent on the User’s internal processing methods and various human factors (such as motivation, engagement in the activity, task meaningfulness, and response to stress and fatigue). It is extremely important for system designers to characterize their target population, potential activities or tasks, and target operating environments as well as possible. So the target population, target task and target operating Environment where the BCI technology will be used are the main components in BCI design.
2 Logical control signals-To produce logical control signals we use electrodes, amplifier, feature Extractor, and feature translator in BCI system design. The function of electrodes to convert the User’s brain state into electrical signals. Several types of electrodes (e.g. scalp, intercranial and intercortical) have been used in various configurations. The amplifiers amplify and band pass filter the electrical signals from the user’s brain. The feature extractor transform the amplified signals into feature values that correspond to the underlying neurological mechanism used by user control. The output of the feature extractor will be referred as a feature vector. The feature Translator translates the feature vector into logical control signals.

3 Semantic control signals-The control interface translates the logical control signals from feature translator into semantic control signals that are appropriate for a particular type of device. This mapping may be instantaneous (i.e. its output is calculated directly the current logical control signal input). The semantic mapping in control interface are usually dynamic. The device controller translates the semantic control signals from the control interface into physical control signals that are used within the device. There is an unlimited range of devices that can be used in a BCI.

The functional model defines the minimal set of components required to describe BCI system design. [6]

The Taxonomy used in BCI design systems is as follows:

- Target Population –Description of the people for which the BCI system is designed.
- Target Tasks-Description of the tasks the system is designed to facilitate.
- Target Operating Environment-Description of where BCI technology will be used.
- BCI Control-Description of neurological mechanisms that the User uses to generate the user control signals. The feature extraction and feature translation is done in BCI control to generate the logical control signals.
- Control Interface-Description of how the logical control signals are translated into output with semantic meaning for the device being controlled.
- Device Controller- Description of how the semantic control inputs are mapped into physical control signals.
- Device- A general description of the device.

The model and taxonomy are used to represent the design of the BCI systems. [6]

PHASES IN BRAIN COMPUTER INTERFACING

There are many phases in brain computer interfacing. The main phases are as follows.

Signal Acquisition
- Signal pre-processing
- Signal classification
- Computer interaction

1. Signal Acquisition:-

The electronic signals generated by the neurons are acquired and processed by signal Acquisition and processing techniques and devices. There are two types of brain signal acquisition techniques
1. Invasive acquisition
   2. Non-invasive acquisition
   1. These techniques are used to capture the brain signal using in panned electrodes in brain tissue directly from the cerebral cortex.
   2. Non-invasive techniques are used to capture the signal or electro physiological signals from the scalp.

2. Signal pre-processing:-
   EEG recording typically not only contain electrical signals from the brain but also several unwanted signals also
   Interference from electronic equipment
   Electromyography (EMG) signals evoked by muscular activity.
   Ocular artifacts, due to eye movements or blinking.
   The signals must be pre-processed to remove the noise these are several pre-processing techniques to remove unwanted signals from EEG.
   1. Basic filtering
   2. Adaptive filtering
   3. Signal Classification:-
   Brain signal or EEG are continuously captured by the capturing devices that have numerous electrodes there waves are classified on both frequency and on their shape.
   1. Beta waves
   2. Alpha waves
   3. Theta waves
   4. Delta waves
   5. Gamma waves
   6. MU waves

4. Computer Interaction:
   Once the signals are classified, they will used by appropriate algorithm for the development of certain application based on their types of application like character recognition, object movement and it also possible to reconstruct the images on the screen from brain signals.

CHARACTERISTICS OF BCI SYSTEM

High Information Transfer Rate- a BCI device should be able to carry information at high speed with a sensible accuracy.
Ease of use- BCI system should be easy to set up so that anyone can use the system without extensive training. It should be small enough to be portable and inexpensive enough to be affordable for those who need a BCI.[11]
Robustness- The system should be robust and stable. It should be used in real world applications.
Safety-Safety of the system is most important when it is operated by a person with reduced motor abilities.[8]
ISSUES REGARDING ON BCI SIGNAL PROCESSING (FEATURE EXTRACTION AND TRANSLATION)

Signal Processing (i.e., feature extraction and translation) is a fundamental requirement for operation of brain-computer interfaces (BCI’s) which take signals produced by the brain and translates them into useful output commands with no interaction of muscles. The issues relevant to brain computer interface (BCI) feature extraction and translation are discussed below.

1 Optimization Schemes – Several aspects of a BCI can benefit from effective optimization including modelling, feature extraction, classifier training and on line adaptation. It is essential that an appropriate optimization technique is identified for a particular problem and that the optimization technique not be limiting factor system design.

2 Adaptation–Each step in the processes of feature extraction and translation may involve estimating Parameters that are derived from the observed data. When the data are not stationary, some form of Adaptation may optimize BCI performance. Successful adaptation should be fast and stable.

3 Criteria for BCI Evaluation- There are number of different measures available for evaluation of BCI systems. These are the error rate or classification accuracy. BCI performance can also be evaluated in terms of time to complete a particular task. Several measures are used for evaluation of BCI performance.[10]

DIFFERENT CHALLENGES FOR THE USE OF BRAIN COMPUTER INTERFACES PATIENTS

1 Predictors of Successful Self –Regulation and communication-Acceptance and Rejection of Patients-

Autonomous BCI use is the final goal of BCI training. Patients should be encouraged to use the system in the absence of a trainer. Different neuropsychological, demographical, and personality trait variables have been tested as predictors for success in self–regulation and communication. Other variables contributing to the acquisition of self–regulation are self-efficacy, the belief in one’s capabilities to manage future events and capacity for imagery. Whether these variables can be used as predictors for successful use of a BCI system. These variables are to be used to predict the success of self-regulation of the patient’s ability.

2 Communication and Social interaction with patients- When contacting a patient for the first time, it is important to learn his or her idiosyncratic signs for yes and no respectively. Failure to recognize these signs may result in the trainer misinterpreting the patient’s desires, wishes, and needs. Questions have to formulate unequivocally and issued one at the time. Allow sufficient time to answer. To avoid misinterpretation, it may be help to videotape the communicative interaction and show it unbiased colleagues. Proper communication and interaction between patient and BCI trainer should be required.

3 Social, Familial, and Institutional context and its effect on training and communication- Before starting BCI training, one should clarify the expectations of the patient. It is important to ensure that there is somebody who can set up the BCI when trainers are absent. Introduce the application in small, pre-defined steps. Teach caregivers how to set up the BCI in order to attain autonomous BCI use.

4 Motivational factors /Remaining Reinforces-Eiucidate the patient’s intrinsic motivation. Clarify whether it is the patient and/ or the family who is interested in the training. Adopt a
warm, empathetic attitude toward the patient. Develop policies about how to deal with requests for help in administrative and practical affairs. Thus a warm, empathetic attitude towards patients constitutes a powerful social reinforce and may help to maintain the patients effort and motivation during weeks, months, even years of self-regulation training and BCI use.[7]

ETHICAL AND CHALLENGES INVOLVED IN TRANSLATING BCI SYSTEMS FROM THE LABORATORY TO WIDESPREAD CLINICAL USE-

BCI research and development raises certain challenges and ethical issues-  
1 The electrical fields produced by the brain can be detected at the scalp (EEG), at the cortical surface (ECOg activity) or within the cortex(local field potentials(LFPs) or neuronal action potentials(spikes). EEG recording is easy and noninvasive. It may be contaminated by artifacts such as electrooculographic (EOG) activity and electromyographic (EMG) activity from cranial muscles. Invasive techniques are used to capture the brain signals using implanted electrodes in brain tissue directly from the cerebral cortex. Intra cortical recording can provide the highest resolution signals. Implantation of electrode arrays within brain or even just on the cortical surface entails some measure of acute trauma. It may initiate prolonged reactive processes leading to scarring and possibly significant neuronal loss and risk of infection, particularly if long-term percutaneous connections are necessary. Risk–benefit considerations will ultimately determine whether implanted devices (whether in or on the cortex) or non–invasive methods will best provide BCI function for a given patient.

2 The potential invasion of privacy inherent in the possibility that a BCI might be used to obtain information (e.g., answers to specified questions) from a person without consent. However, most, and possibly all, BCI –based communication requires active interaction between the user and the BCI system.

3 The other BCI-related ethical issues are those related to the creation of cyborgs- an integrated man-machine system. The brain’s normal output are the result of complex interactions.[5]

CONCLUSION

At present and for the immediate future, BCI-based communication and control will be most useful to people who retain only minimal and unreliable voluntary muscle control; and clinically useful BCIs are likely to be those that use electrophysiological signals, whether obtained noninvasively from scalp electrodes or invasively from implanted devices. BCI framework provides us with a common language for describing BCI technology and BCI Systems. BCI research and development raises standard ethical issues and challenges, which needs to be resolved earliest.

REFERENCE

[1] Siuly Siuly and Yan Li, Member, IEEE, Improving the Separability of Motor Imagery EEG Signals Using a Correlation-Based Least Square Support Vector Machine for Brain-Computer Interface,IEEE,VOL.20, NO.4, JULY 2012


