Realm of Brain Computer Interaction

B.Veera Jyothi, V.Aditya Raman, T.Rohit Reddy
CBIT, Hyderabad,India

ABSTRACT—*The solicitous reason for dealing with Brain Computer Interface is it's plethora of applications which has an immaculate tendency to connect the present with the future. It plays a pivotal role in providing a sheer number of hosts an unprecedented life like reality. The cataclysmic consequences of a life changing and disenchanting mishap leading them to live a life which is being locked in their bodies-life of a Quadriplegic or victims of Amyotrophic lateral sclerosis. It would serve as a patronage to such people by providing them a new leash of life and happiness would be a concomitant of their daily routine.*

In measure of scales of security, BCI gives extraordinarily stupefying scope in life saving equipment; 'CYBernetic OR Ganisms' is the next revolution in terms after the discovery of decoding of the human genome. CY BORG exoskeleton gives a gargantuan amount of synergy to the fragile inner skeleton of Homo sapiens. Blink Bot is yet another magnanimous field of thought. On the lighter side of heavy-handed applications, gaming and social potential are the brightest hopes for the maximum penetration of BCI. As the name implies, the interface could be constructed by implanting an array of electrodes. In the spectacular case of Jose Delagado, where an array of electrodes were implanted in the brain of a Spanish bull which gave him the ultimate control over the thought process of the Bull.

Keywords— *BCI, Electrocorticography, Stimoceiver*

1. INTRODUCTION

Brain Computer Interface is a direct communication pathway between brain and an external device. It is a perfect collocation of technologies from an immaculate arena, including Computer science, Electrical engineering, Bio-medication, Neurobiology. It has evolved exceptionally as Deep Brain Simulation, which involves, shocking the brain electrically to edify muscular actions in individuals with movement disorders, epilepsy and depression. Richard Caton was the pioneer who discovered electrical signals on the surface of animal brains through his path-breaking research. In late 1950s, Dr. Jose Delgado, a neurosurgeon at Yale University, invented the Stimoceiver, an electrode device that can be controlled wirelessly by FM radio. He tested it in the brain of a bull and noted that it is pretty much possible to control the mind of the bull by deft maneuvering of buttons.

2. BRAIN COMPUTER INTERACTION

Having hitherto learnt about the sustained efforts of many scientists in the recent past, researchers in this field gained recognition only since the past two decades and the sole reason for this being the advent of BCI. This recent interest and activity reflect the confluence of four factors.

The first factor is the modern life-support technology which conciliates the greatly appreciated needs of people severely affected by motor disorders such as cerebral-palsy, spinal cord injury, brain stem stroke, amyotrophic lateral sclerosis (ALS), and muscular dystrophies and endows people, who may be totally "locked-in" to their anatomies, not in a position to lead a productable and delictable life and the primary impediment for that being lack of communication.

The second factor is the sophisticated analysis of the nature and operational constraints of EEG and other aspects of brain activity derived from animal and human research in tandem with this new knowledge have paved a way for the development of jaw-dropping techniques for recording these signals both in the short and the long term.

The third factor is the availability of compelling low cost computer hardware that allows intricate real-time analysis of brain activity which is mandatory for superficial BCI operation.

The fourth factor responsible for the recent surge in BCI research is new recognition of the extravagant acclimatizing capacities of the central nervous system(CNS),allowing the establishment of new interactions between brain tissue and computer-based devices, providing a pathway for the aggrandizement of brain's interaction with the outside aura.

What is a BCI?

A BCI is a communication and control system that is no way concerned with the brain's normal neuromuscular output channels and establishes real-time interaction with the user and outside world. The pivotal aspect of BCI is that user's intent is conveyed by brain signals rather than peripheral nervous system. For example, if a person maneuvers a robotic arm using BCI technology, the arm's position after each movement is likely to affect the person's intent for the next movement and the brain signals that convey that intent. Therefore, a system that is hell bent on simply recording and analyzing brain signals, without accentuating on the results can never be a BCI.

3. OPERATION PRINCIPLE OF BCI:

There is a false presumption among people that BCI is essentially a "mind-reading" technology that basically allows devices to read the intent of the brain and accomplish that intent directly without the entanglement of muscular actions.
This misconception evades the central feature of the brain's interactions with the external world: That is the devices which sense a person's intent, whether it be to walk in a certain direction, speak certain words, or play a certain sport, are annexed and perpetuated by initial and continuing adaptive changes in CNS function. This can be ascribed to neurons.CNS adjusts its outputs based on muscle aging, contraction or expansion to get efficient results. It is to be noted that the behavior of CNS remains same whether the person's resolution is in the normal fashion, that is, through peripheral nerves and muscles, or through an artificial interface (BCI).
The requisite for the usage of a BCI is the interaction of two adaptive controllers:1)The user, who generates brain signals that encodes intent.2) BCI system, that must translate the received signals into commands that preserves the user's intent. Thus, BCI usage is a skill-oriented tactic and there should be some alacrity when it comes to maintaining it. This mutual dependence of user and system forms the fundamental principle of BCI.

4. BRAIN SIGNALS THAT CAN OR MIGHT BE USED IN BCI:

Numerous viable methodologies can be used to record brain signals in collaboration with BCI. Here are a few to list: Recording of electrical or magnetic fields, Functional Magnetic Resonance Imaging (fMRI); Positron Emission Tomography (PET); and Infrared (IR) Imaging. In reality, the above technologies suffice only theoretical demands and the impediments being abstruse technical demands, prohibitive expense, and limited real-time capabilities. Recording of electrical field would have a significant impact on the clinical applications in the near future.P300 wave is one of the vital signals, probably an event related component and adds an immense value to decision making. It is considered to be an endogenous potential, as its occurrence links not to the physical attributes of a stimulus, but to a person's reaction to it.

5. PRESENT DAY BCIS

BCI research has been detained to EEG studies and short-term ECoG studies by humans. Intracortical BCI data comes mainly from animals, primarily monkeys. The presently available human data indicate that EEG-based methods support simple applications and could well indulge in plenitude of applications in distant future. Invasive methods have immaculate tendency to deal with complex applications, but there are impending issues of risk and long-term recording stability which are not yet resolved.

6. EEG-BASED BCIS

A total of three different EEG-based BCIs have been tested in humans. The only feature that they differ in is the ability to support user's intent.P300 component of the event-related brain potential is used, which appears in the centroparietal EEG about 300 ms after presentation of a salient or attended stimulus. The P300 BCI system described by Donchin's group flashes letters or other symbols in quick succession. The letter or symbol that the user wants to select produces a P300 potential. The detection of P300 signals augments the chance of BCI system to detect user's intent. This BCI method appears able to support operation of a simple word processing program that enables users to write words at a rate of one or a few letters per minute. Most importantly, the effects of long-term usage of a P300-based BCI on its communication performance remain to be determined: The reliability of P300 improves with continued use paving a way for improved performance.
In normal brain function, negative Slow Cortical Potential's (SCP) reflect preparatory depolarization of the underlying cortical network, while positive SCPs are usually interpreted as a sign of cortical dis-facilitation or inhibition. Birbaumer and his colleagues have shown that, with appropriate training, people can learn to control SCPs so as to produce positive….?.

7. ECOG-BASED BCIS

ECoG is way too better in terms of spatial and temporal resolution than scalp recorded EEG. It can resolve activity limited to a few mm'sof cortical surface, comprising of not only mu and beta rhythms, but higher-frequency gamma (_30 Hz)rhythms, which are very small or absent in EEG. ECoG studies have been confined to short term experiments till date, which include experiments on individuals temporarily implanted with electrode arrays prior to epilepsy surgery.

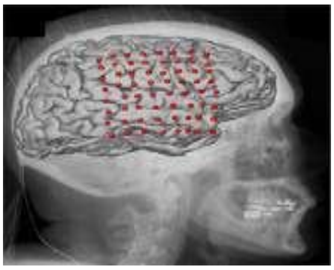

Fig 1: Artist's view of Electrode Implants.

8. INTRA-CORTICAL BCIS

Intracortical BCIs have revealed that it can gain an immaculate control over cursor movements in one, two, or even three dimensions.
Related data suggest that LFPs ???, which can be recorded by the same electrode arrays and reflect nearby synaptic and neuronal activity, might also support BCI operation .The pivotal aspect in the single-neuron studies has been to define the neuronal activity associated with standardized limb movements and to incline this activity to simultaneously control comparable movements of a cursor, and finally to prove that the neuronal activity can get on with the control cursor movements in the absence of actual limb movements. The most accurate study till date has been neuronal control of three dimensional cursor movement and it was clear that neuronal activity was found to adapt over sessions so as to improve cursor control.

The major issues that must be resolved prior to clinical use of intracortical BCIs include their long term safety, the stability of their signals in the face of cortical tissue reactions to the implanted electrodes, and whether their capabilities in actual practical applications (e.g., in neuroprosthesis control) substantially exceed those of less invasive BCIs.

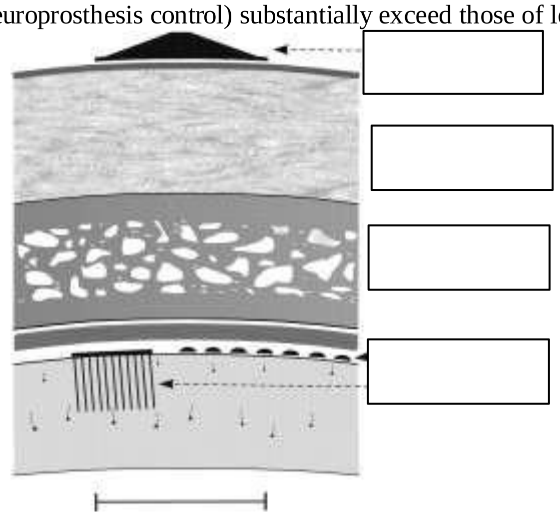

Fig 2: Cross section of the skull.

9. ALTERNATIVE SIGNAL RECORDING TECHNIQUES

The electrical signals produced by brain activity can be recorded from the scalp (EEG),from the cortical surface (electrocorticographic activity, (EcoG),or from within the brain (local field potentials (LFPs)) or neuronal action potentials (spikes)).Each of them is associated with pros and cons.
EEG recording has limited topographical resolution, frequency range and is easy and non-invasive, and may also be contaminated by artifacts such as electromyography (EMG) activity from cranial muscles or electro Oculography (EOG) activity. Intra-cortical recording (or recording within other brain structures) requires collocation of multiple electrode arrays within brain tissue but still it is capable of providing highest resolution signals. All the techniques mentioned above entails tissue damage and scarring but ensures long-term recording stability.
Each of these recording techniques provides better practical standards with minimal errors when the range of communication and control applications, which it ought to support are predetermined. Practically, the information transfer rates obtained through Intra-cortical recording are no greater than the lesser-invasive methods as mentioned above.

The issue of the relative value of non-invasive (i.e.,
EEG) methods, moderately invasive (e.g., ECoG) methods, and maximally invasive (e.g., intracortical)
Methods remain unresolved. On one hand, stable, practical, and safe techniques for long-term recording within the brain may not prove that difficult to develop. On the other hand, despite expectations to the contrary, practically the information transfer rates possible with intra cortical methods may turn out to be no greater than those achievable with less invasive methods (e.g., ECoG).

10. POTENTIAL USERS

BCI, being in it's nascent stage of development is of at most importance to people with the most severe neuromuscular disabilities, people for whom conventional assistive communication technologies, all of which require some measure of voluntary muscle control, are not viable options. These include people with ALS who elect to accept artificial ventilation as their disease progresses, children and adults with severe cerebral palsy who lack any useful muscle control, patients with brain stem strokes who are left only with minimal eye movement control, those with severe muscular dystrophies or chronic peripheral neuropathies.

People with disabilities of different origins are likely to differ in the BCI methods that are of most use to them. For some, the CNS deficits responsible for their disability may affect their ability to control particular brain signals and not others. For example, the motor cortex damage that can be associated with ALS or the sub-cortical damage of severe cerebral palsy may compromise generation or control of sensor motor rhythms or neuronal activity. In such individuals, other brain signals, such as P300 potentials or neuronal activity from other brain regions, might provide viable alternatives. Prosaic and even ostensibly trivial factors are also likely to play significant roles in the eventual practical success of BCI applications. Issues such as the steps involved in donning and doffing electrodes or in accessing a BCI application, or a person's appearance while using it, may greatly affect the number of people interested in the system and the extent to which they actually use it.

11. APPLICATIONS

Hacking Human Vision System:

It is a unique method of tapping into one's vision system to search for meaningful messages in wide plethora of data. Let us consider a case where ina thinking cap (containing an array of gelled electrodes) is placed on a person's scalp to tap the EEG signals. For this a clump of images are screened and the corresponding EEG signals are recorded. Generally a spike (P300) is observed when a person finds something appurtenant. To extend the horizons of this application, it can be used to curb terrorism.

Medical Applications:

BCI gives a new leash of life for people who have lost a sense, such as sight or touch (i.e., Quadriplegic and ALS victims) wear an artificial sensor. This might be a video camera, or a touch sensitive glove. Then, electrical pulses which encode the sense are sent to brain via a strip on their tongue. Pertaining to the medical field, the most popular devices are Cochlear Implants and Bionic-Eye which actually augment the sensory perceptions.

A. Dream Recording Machine:

Japanese devised a dream recording machine by reading a subject's mind using MRI scanning technique and reserving the images directly from the subject's brain. For this, the team calibrated a translational algorithm to reconstruct the subject's images from the Visual Cortex, which would actually produce a glorified image rather than the gloomy black and white image.

Social Potential:

A. Cyber-Chauffeur:

In a futuristic world, where cars can be driven by a sense of thought, provides us with a world in which the number of mishaps are greatly dwindled because when the thought schema goes awry, a backup plan emerges and drives us into safety.

B. Social Networking:

With the advent of BCI, the mode and method of networking will take a gigantic leap forward in dispensing a wide variety of information. For example, let us consider a person accessing a social networking website, it is very much possible to exchange information by means of retinal movement rather than laborious activities such as handling any input device.

Military Applications:

A. Cyborg Beetles:

The purpose of the cyborg beetle is for border surveillance. Ideally, they could be used for search-and-rescue missions. However, using the beetles to carry biological or chemical weapons would be completely illegal. Accordingly, this part-robot, part-beetle could only be used by military for indoor and outdoor operations in urban warfare situations, to serve as couriers to inaccessible locations.

General Applications: A. NeuroPhone:
This application is the next paradigm shift in the world of communication. A subject will have to wear a wireless EEG headset and this headset will be concomitant with the subject's phone. When a certain requisition is made by the subject it reflects in the P300 of the dial Tim and it will be processed.
B. Neural Screen Navigation:
The transit of a cursor from two distinct points on the screen of a computer by the nudge and shove method of the axons of the brain will lead to a new interface never thought of.
Brain Trainer-Subject Training **:**
This project deals with the most potent method of training a subject's brain. It is in its nascent stage and research is being conducted on methods of attaining feedback via visual and auditory sustenance methodologies.
Drawbacks of BCI
BCI systems would certainly need an adept futuristic enhancement because of them being slow. Most importantly, the users are to amass a specific domain of skills, taking all the miniature aspects into consideration. Special care ought to be taken to avoid the risk of scar formations and potential disorders. More over dealing with CNS involves many potential risks and any malfunction could result in chronic disorders.
Nature and needs of BCI research and development

BCI research and development is an inherently multi-disciplinary task. It involves neuroscience, engineering, applied mathematics, computer science, psychology, and rehabilitation. BCI research is not merely a signal-processing problem, a neurobiological problem, or a human-factors problem, though it has often been viewed in each of these limited ways in the past. There is at most need to select appropriate brain signals in order to achieve reliability. The intent should be to provide functions of practical value to people with several disabilities .This reality requires either that each BCI research group incorporate all relevant disciplines, or that groups with different expertise's collaborate closely. Such interactions have been encouraged and facilitated by recent meetings drawing BCI researchers from all relevant disciplines and from all over the world and by comprehensive sets of peer-reviewed BCI articles. Up to now, BCI research has consisted primarily of demonstrations, of limited studies showing that a specific brain signal processed in a specific way by specific hardware and software and applied to a specific device can supply communication or control of a specific kind.
Successful development and widespread clinical use depend on moving beyond demonstrations. They require effective and efficient techniques for comparing, combining, and evaluating alternative brain signals, analysis methods, and applications, and thereby optimizing BCIs and the usefulness of their applications. This requirement has been the impetus for the original and ongoing development of BCI2000, the first general-purpose BCI system.

12. CONCLUSION

The possibility that EEG activity or other electrophysiological measures of brain function might provide new non-muscular channels for communication (i.e., BCI) has been a topic of speculation for the past decade. The research primarily focuses on developing new augmentative communication and control technology for those with severe neuro-muscular disorders, such as ALS, brain stem stroke and spinal cord afflictions. The immediate objective is to give these users a modus operandi of proper channels of communication or neuroprosthesis. Current BCI's determine the intent of the user from electro-physiological signals recorded noninvasively from the scalp (ECG) or invasively (ECoG) or from within the brain (neuro action potentials).
BCI spans its areas in neurobiology, Psychology, engineering, mathematics, computer Science and clinical rehabilitation. Its future progress and eventual practical impact depend on a number of critical issues. The relative advantages and disadvantages have to face their litmus test of time and should be rather positive in outcome. With the help of BCI, countless new approaches and applications can be made available to the real world. Medical and military ideologies would take a gigantic leap forward with the likes of such resourceful technology.
BCI systems could eventually be important new communication and control options for people with motor disabilities and might also provide to people without disabilities as a supplementary control channel or a control channel useful in special circumstances.

13. REFERENCES

[1] The Next Brainiacs *Wired Magazine*, August 2001.
[2] Pitt team to build on brain-controlled arm, *Pittsburgh Tribune Review*, 5 September 2006. [3] Birch and Baumer06
[4] Marion Kurtz Wilhelm Alder Florian , Landolt Brain computer Interfaces
[5] Brain–computer interfaces for communication and control Jonathan R. Wolpaw1 and Niels. [6] Sony patent neural interface.
[7] Chaos control and synchronization of two field., *School of Electrical and Automation Engineering, Tianjin University, Tianjin 300072, China.*,23 March 2006
[8] Van den Bergh, F. Engelbrecht, AP. *Cooperative Learning in Neural Networks using Particle Swarm Optimizers*. CIRG 2000.
[9] Arbib, Michael A. (Ed.) (1995). *The Handbook of Brain Theory and Neural Networks*.