Episteme: an online interdisciplinary, multidisciplinary & multi-cultural journal

Bharat College of Arts and Commerce, Badlapur, MMR, India

Volume 5, Issue 3 **December 2016**

BCI – THE NEW CLASS OF BIOENGINEERING

By Krupali Bhatvedekar

ABSTRACT

A brain-computer interface (BCI), which is sometimes called a direct neural interface or a brain-machine interface, is a device that provides the brain with a new, non-muscular communication and control channel. BCI allows users to act with the environment by using brain activity, without using peripheral nerves and muscles. The goal of BCI is to develop systems that allow disabled people to communicate with other persons, control artificial limbs, or control their environment. This Paper provides an insight into the architecture of BCI, its working, applications, benefits and problems.

KEYWORDS

Electroencephalography, Brain Computer Interface, invansive, non-invansive, Magneto encephalography, Functional magnetic resonance imaging, Blood oxygenation level-dependent, near infrared spectroscopy.

INTRODUCTION

Brain–computer interface (BCIs) begins with Hans Berger's inventing of electrical activity of the human brain and the development of electroencephalography (EEG). In 1924 Berger recorded an EEG signals from a human brain for the first time. By analyzing EEG signals Berger was able to identify vibrating activity in the brain, such as the alpha wave (8–12 Hz). BCIs are often aimed in assisting, repairing human sensory-motor functions. BCIs read electrical signals of brain activity and translate them into a digital form that computers can understand, process, and convert into actions of same kind, such as moving a cursor or turning on a TV.BCI can help people with inabilities to control computers, wheelchairs, televisions or other devices with brain activity. Among the possible brain monitoring methods, the scalp recorded electroencephalogram (EEG) constitutes an adequate alternative because of its good time resolution, relative simplicity and non-invasiveness. The EEG signals are analyzed and mapped into actions inside the computer rendered environment. A BCI allows a person to communicate with or control the external world without using the brain's normal output pathways of peripheral nerves and muscles. Messages and commands are expressed not by muscle contractions, but rather by electrophysiological signals from the brain. BCI provide an alternative communication and control option for the severely disabled.

WORKING

Each time we do something or we ‘think about doing something’, our brain generates distinct signals. Each activity by us generates corresponding signals on our brain, by reading these signals one can guess what the person is thinking at the moment!!

Though these signals are highly random, but still one can find some pattern in them, i.e. the pattern corresponding to the activity the user is doing or just ‘thinking about doing’, like moving his arm or leg. Finding this pattern is the main task of any BCI. This requires some very smart

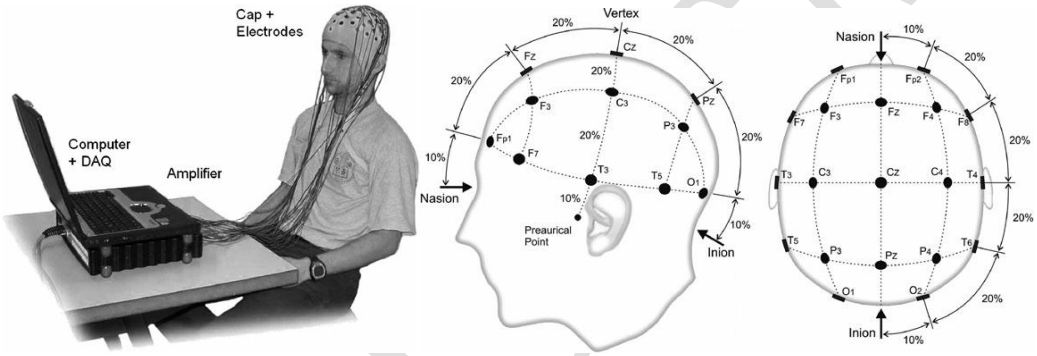
classification algorithm which once trained can work for a particular person in a particular domain of thought.

A BCI picks these signals from the brain of user in the form of EEG. Then after classifying what the user is thinking, it translates these signals into meaningful commands, e.g. it translates thoughts about hand movements in to corresponding cursor movements. To understand BCI operation better, one has to understand how brain activity can be measured and which brain signals can be utilized.

1> Measuring Brain Activity (Without Surgery / non-invansive)

Non-invansive technique of measuring brain signals in done with the help of EEG. Electroencephalography (EEG) refers to recording electrical activity from the scalp with electrodes. EEG equipment is inexpensive, light weight, and comparatively easy to apply. The EEG is susceptible to so-called artifacts, which are pollutants in the EEG caused by other electrical activities. Although the EEG is not very technically demanding, the setup procedure can be cumbersome. To achieve adequate signal quality, the skin areas that are attached by the electrodes have to be prepared with special electrode gel. Because gel is required, these electrodes called wet electrodes. The number of electrodes required by current BCI systems range from more than 100 electrodes. Since electrode gel can dry out and wearing the EEG cap with electrodes is not convenient or fashionable, the setting up procedure usually has to be repeated for each session of BCI use. This is one of largest drawbacks of EEG-based BCIs. A possible solution is a use of technology called dry electrodes. Dry electrodes do not require skin preparation or electrode gel. A BCI analyzes ongoing brain activity that originate from specific brain areas. To get consistent recordings from specific regions of the head, scientists used standard system for precisely placing electrodes, which is named as the International 10–20 System. The name indicates that the most commonly used electrodes are positioned 10, 20, 20, 20, 20, and 10% of the totalnasion-inion distance. The other electrodes are placed at similar fractional distances. The inter-electrode distances are equal along from left to right

andfrom front to back line and the placement is symmetrical. While most BCIs rely on sensors placed outside of the head to detect electrical activity, other types of sensors have been used as well .Magneto encephalography (MEG) which records the magnetic fields associated with brain activity. Functional magnetic resonance imaging (fMRI) which measures small changes in the blood oxygenation level-dependent (BOLD) signals are associated with cortical activation. Like fMRI also near infrared spectroscopy (NIRS) is a hemodynamic based technique for recording of functional activity in human cortex. Different oxygen levels of the blood result in different optical properties which are measured by NIRS. All these methods have drawbacks which make them impractical for most BCI applications: MEG and fMRI are very large devices and prohibitively expensive. NIRS and fMRI have poor temporary solution,

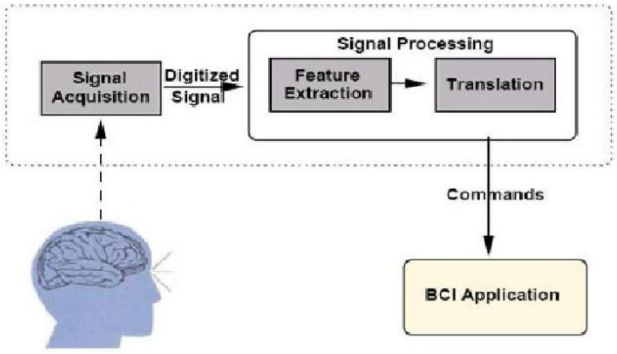


The international 10–20 system

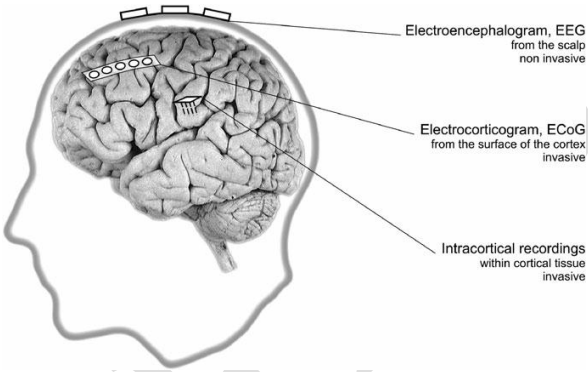
2> Measuring Brain Activity (With Surgery / invansive)

Surgery includes opening the skull through a surgical procedure called a craniotomy by cutting the membranes that cover the brain. When the electrodes are placed on the surface of the cortex, the signal recorded from these electrodes is called the electro corticogram (ECoG). ECoG does not damage any neurons as no electrodes penetrate the brain. The signal recorded from electrodes are called intra cortical recording. Invasive recording techniques combine excellent signal quality, very good resolution, and a higher frequency range. Artifacts are less problematic with invasive recordings. The ECoG records the

integrated activity of a much larger number of neurons that are in the proximity of the ECoG electrodes. However, any invasive technique has better spatial resolution than the EEG. However, these advantage come with the serious drawback of requiring surgery. Ethical, financial, and other considerations make neurosurgery impractical except for some users who need a BCI to communicate. Even then, some of these users may find that a noninvasive BCI can meets their needs. It is also not clear whether both ECoG and intra cortical recordings can provide safe and stable recording over years.

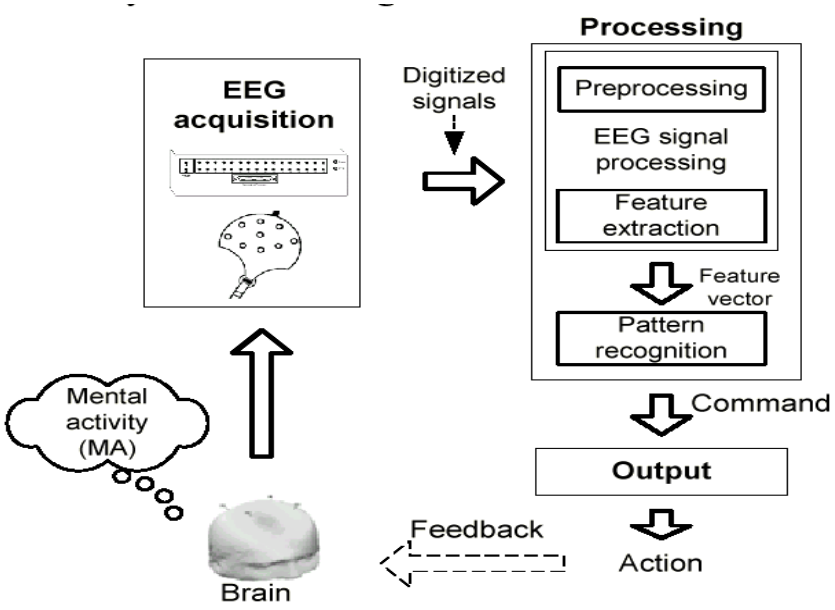


Block diagram of BCI



Invansive technigue

Architecture of BCI



Architecture of BCI

The processing unit is subdivided into a pre-processing unit, which is responsible for piece detection, feature extraction and recognition unit identifies the command sent by the user to the BCI. The output subsystem generates an action corresponding to this command. This action constitutes a feedback to the user who can modulate her mental activity to produce EEG patterns which make the BCI accomplish her/his intents.

In the first step, the brain signals are acquired through invasive or non-invasive methods. Once the signals are acquired, it is necessary to clean or remove the noise in order to improve the accuracy of the signal. After that the brain signals are classified to find out which kind of the metal task the subject is performing. And then this classification signals are used according to the specified applications.

The application also generates feedback to inform the subject about the outcome of classification. Based on the measures of the electrical activity of the brain i.e. EEG signals, the basic idea is to record the user's thoughts in order to develop interface between a human and a machine for spell words, identifying emotions or feelings etc. The emotion is one form of the state of human's mind. Basically, emotions are unconscious mechanisms controlling behaviour and feelings are unconscious or conscious representations of emotions that are more detailed and larger in number. There are two basic reaction patterns:

- Approach (love, joy): Influenced by positive emotions.
- Avoidance (sorrow, fear): Influenced by negative emotions.

Applications

1. EEG Biofeedback

EEG was first implemented as a biofeedback modality by Kamiya, Brown, and others, in the beginning of 1960's. Initial work was based primarily on the alpha rhythm. Training was often done for the strengthening of the alpha rhythm, without regard for other brain rhythms.

It was found that developing the alpha rhythm, in and of it, had limited value. Continued work has developed methods that use other rhythms, or combinations of rhythms, in both encouragement and discouragement protocols, to teach users to control their relative amounts of rhythms, providing much more precise control of the brain.

2. Computer Control & Communication

The use of the EEG to control or communicate with a computer is an application that has undergone steady development from 1960's. Recently, investigators have been looking for signals that appear controllable, and adapting the system to them. One of these is the "sensor motor rhythm" (SMR) that has been found to be under a certain amount of conscious control.

Generally, the user uses thoughts, such as "feeling light" or" stopping thinking" to cause the desired rhythm.

3. Entertainment, Virtual Reality

Entertainment application includes EEG-controlled composition and performance, including "audience-participation" situations. Virtual Reality displays uses EEG to modulate, alter, or otherwise control any aspect of the virtual world.

For example, a system could be made sensitive to the individual's overall emotional state. This include changing the colours or sizes of objects, controlling sunrise and sunset, or causing the appearance or removal of features, or even of the entire location.

4. Military, Commercial

The military has a long history of studying the EEG; some of the analysis was done by NASA during the 1960's, in connection with the space program. This was designed primarily to monitor the pilots' state of health and consciousness. In addition, the Air Force has develop EEG-based pilot controls for the cockpit. These detecting and acting upon changes in the pilot's stare/look, or level of attention, to a display item.

5. Medicine

Medicine has currently used advancement in BCI technology. Sensory devices can be interfaced with a BCI to repair or improve hearing, sight, and smell, and many achievements have already been developed in this area. BCIs can be used to control robotic prosthesis that replace missing limbs, and could repair many types of damage to the human body.

One potential scenario has to deal with memory- human long term memory is degradable, meaning that we forget things we have experienced or learned over time. Magnetic memory or non-volatile flash memory seems to be more stable over the time span of a human life. Improving memory is one of the most significant applications of a BCI device- because the BCI

device could allow a human brain to store and retrieve memory from an external device in a more efficient manner.

Stakeholders:

- Doctors
- Patients

Patients obviously have the highest stake on the medical applications of BCI technology- we have the potential to repair or replace damaged organs of the body, controlled by the brain. BCIs could restore sight, hearing, or damaged limbs! Although BCIs wouldn't cure disease, they have already gone a long way to reducing disabilities.

Doctors likely used this technology because it has the potential to reduce long term medical care with an immediate repair. Although in the short run, this may make medicine more expensive for insurance companies, in the long run, health care costs may be dramatically reduced by efficient manufacturing of BCI devices.

6. Manufacturing

Precision manufacturing makes use of machinery and robotics to create a product effectively, efficiently, and at a lower cost. However, these robots and machines are limited to the tasks they can perform, many of them are able to perform only one task at a time. Programming for these machines is complicated. By interfacing a human to a controller that is much less error prone than a joystick, such as BCI, a single robot can be made to manufacture precisely, as well as do multiple tasks that a human can process.

Stakeholders:

- Manufacturers
- Factory workers
- Consumers

Industrial Revolution has been replacing factory workers because they tend to cost less and are more productive. However, many machines are needed to facilitate this, causing a higher overhead cost. With BCIs, a machine-human pair might become more productive and cost effective than a set of assembly machines.

7. Gaming

Virtual reality would necessarily be improved by a BCI. Sensory input and virtual control could both be handled by a BCI- no longer requiring 'caves' with projectors on 4 out 6 walls, etc. Virtual reality models have many applications in and of themselves- including design and simulation, not just gaming.

Stakeholders:

- Gamers
- Designers
- Simulators
- Educators

Design simulations are placed in the gaming category because of the potential for virtual reality. Games are often used as simulation tools, example, the U.S. Navy uses a fleet game to educate midshipman on naval tactics. Games like Cid Meir's Civilization incorporate some advanced concepts concerning economies, government, and culture. Math games, spelling games, typing games, and geography games were all vital parts of education. Therefore the use of virtual reality for gaming and education is a major potential for BCI.

8. Communications

Communication applications and technologies that we currently use are wide and varied, from voice communications to text communications like email and chat. Video communications uses multiple applications and interfaces- but we generally all carry cell phones or smart phones to achieve this communication technology all into one place. Think about the improvements in

communication, especially text-based communication that could be achieved via a BCI to communications technology.

Advantages

1. It allows paralyzed people to control prosthetic limbs with their mind.
2. By transmitting visual images to the mind of a blind person, can allow them to see, transmitting auditory data to the mind of a deaf person, can allow them to hear.
3. It allows gamers to control video games with their minds.
4. It allows a mute person to have their thoughts displayed and spoken by a computer.

Disadvantages

1. Virus attack can occur to brain causing ill effect.
2. The brain is very complex hence surgery is difficult.
3. The signals are weak and prone to interference.
4. The equipment is less than portable.
5. Resulting in the loss of feelings or movement.

Conclusion

This paper provides the overview of BCI, its working including the techniques that are used to record brain activity. The paper also includes various application of BCI that are currently in use. BCI is the new emerging technology which is mainly used for the patients who have lost their speech or who are paralyzed. Many experiments have shown that people unable to move can use simple BCI systems using EEG for point-and-click, robot control, etc.

However EEG has its own drawback that is it measures tiny voltage potentials where signal is weak and prone to interference. Future work in this regard would be searching new approaches which can increase the reliability of EEG recordings. As detection techniques and designs improve, the BCI will improve. BCI future development is on-going and challenging.

References

[1] Jonathan R. Wolpawa, Dennis J. McFarlanda, Theresa M. Vaughana "Brain Computer Interface for communication and control ".

[2] "Brain Computer principles and practices", Oxford University 2012.

[3] Desney Tan and Anton Nijholt "Brain interfaces and Human Computer Interaction"

[4] Bernhard Graimann, Brendad Allison and Gert Pfurtscheller "Brain Computer Interface – A gentle introduction"

Bio

Ms. Krupali Bhatvedekar is an Asst. Professor in Department of Computer Science and Information Technology, Bharat College. She can be contacted at krupalibhatvedekar@gmail.com