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**RESEARCH ARTICLE**

# "BEEG" The BCI…A Tech-Effort to Aid Disable People

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***Abstract— Brain Computer Interface helps and enables people through their mental activities to perform applications and to operate devices. Now-a-days research in this field has matured through many prototypes like brain controlled wheel chairs, games etc. Based on this BCI must come out of the lab to the world and to be applied to real time applications. This makes us to focus on the development on life of countless disabled people. Suitable signal processing methods are developed by the scientists to improve the communication signals of BCI to identify the user brain reading and also command from electroencephalography. We developed a system named "BEEG" an EEG based Brain Computer Interface that will recognize the words thought and will result them on PC. Two main approaches are used in this BCI they are: recognition of EEG pattern approach according to different mental task and based on the self regulation of the EEG response operant conditioning approach is done. The components of BCI and EEG measurements are also presented.***

***Keywords— BCI; EEG; Microcontroller; Brain Signals; Electrodes; Thought Processing***

## I. INTRODUCTION

One of the well known and successful technique is the Brain Computer Interface (BCI), in which using only the brain activity the patients can control their environment and any other external devices according to their wish. With the assist of neurophysiologic experimental methods brain activity measurement system, signal processing methods and classification techniques in a BCI system the activity of the brain is converted into simple commands.

To help the patient to express his/her thoughts in a flawless manner as in all BCI systems here the main challenge lies in the improvement of accuracy and to increase the speed of prediction techniques. In our work it is intentional to build a non-invasive EEG based BCI system "BEEG" that facilitates its use even outer of laboratory. This work consists of the design of a portable 3 channels EEG data acquisition system, the development of signal processing methods and application of machine learning techniques on this model.

The paper is presented with major sections covering details of BCI, EEG, EEG based BCI "BEEG".

 

## II. BRAIN COMPUTER INTERFACE (BCI)

A brain computer interface is a communication system that does not depend on the brains normal output pathways of peripheral nerves and muscles. Here in BCI the communication method is fully based on neural activity produced by the brain that is different from normal interfaces. The main aim of BCI is to grant a user control with a novel channel of output.

This BCI obviously helps the disabled people. Even though many computer interfaces are designed for this purpose they all require control on muscular activities such as neck, head, eyes or other facial muscles. It is only that neural activity is needed to monitor in case of BCI, but some involuntary neural activity is not included here. So this system is specially designed for disabled people those who have no control on their muscular activity with the surrounding.

Therefore in case of silent and immobilized user BCI make them able to identify their commands and wishes[1]. So here the monitoring of brain activity is required. Now to make this possible we have many technologies namely functional Magnetic Resonance Imaging (fMRI), Magneto encephalography (MEG), Positron Emission Tomography (PET), Single Photon Emission Computer Tomography (SPECT), Optical Brain Imaging, Single neuron recording with micro electrodes and electroencephalography (EEG).

### *A. BCI working and its Types*

The BCI technology is based on to sense, transmit, analyze and apply the language of neurons i.e. Brain Signals as shown in the left diagram.

It consists of sensors for acquiring brain signals. Based on the method of acquisition of brain signals, BCI can be of various types as shown in the right diagram.

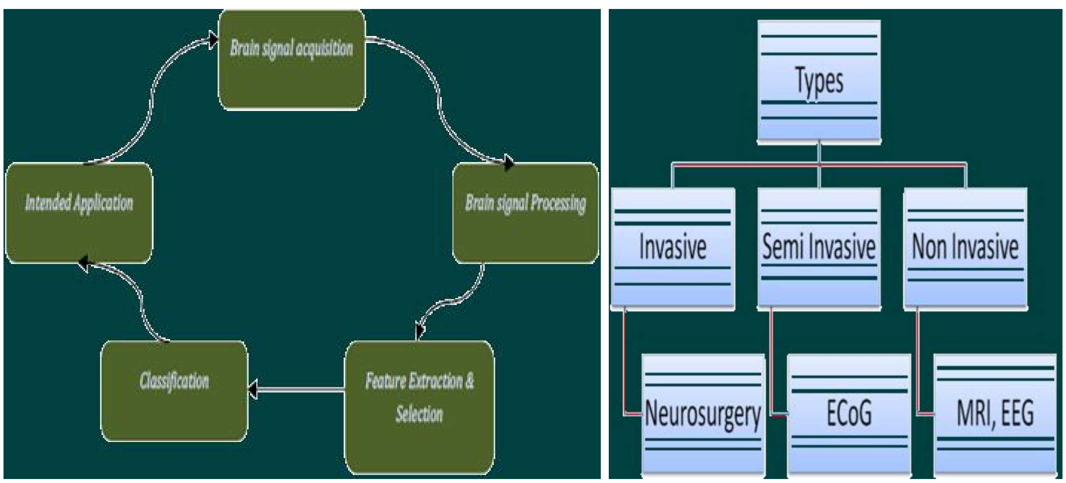


Figure 1: BCI working model and its Types

BCI can be classified further into many categories the following:

- Synchronous and asynchronous BCIs
- Universal and individual BCIs
- Online and offline BCIs

### *B. BCI Approaches*

Basically there are two different approaches are used[2]. They are as follows:

- A pattern recognition approach based on cognitive mental task
- An operant conditioning approach that is based on the self-regulation of the EEG response.

#### *1) Pattern recognition approach*

Different functions are performed in different cortical areas. Some BCIs that include adaptive brain interface depends on various mental activities. Different EEG rhythms are generated by these activities that activate the cortical areas. This approach is said to be pattern recognition approach.

 

*2) Operant conditioning approach*

A couple of BCI research groups have based their BCIs on the self regulation of one of the rhythms or potentials mentioned below in chapter 3. This approach can be called the operant conditioning approach.

## III. ELECTROENCEPHALOGRAPHY (EEG)

The electrical activity of the brain is measured using the method called Electroencephalography (EEG). Neuron generates this activity using billions of nerve cells. Thousands of neurons are connected with each other neuron. Among these connections some of them are excitatory while others are inhibitory. The receiving neurons sum up the signals from all other neurons. The neuron generates nerve impulse when that sum crosses the limited potential level called threshold. The single neuron electrical activity cannot be measured with scalp EEG. Anyhow combined electrical signals of millions of neurons can be measured using EEG.

The temporal resolution of EEG is very good: millisecond or even better. But the spatial resolution is poor. This spatial resolution depends on number of electrodes. Here the maximum spatial resolution is in centimeter range but in other devices like MEG, PET or fMRI it is of millimeter range. At present EEG is differentiated by amplitude and frequency. The amplitude of the EEG signals normally varies from 10 to 100 micro volts. In adults it varies from 10 to 50 micro volts.

In every human brain this electrical activity continuously generated. In our life time we sleeps one third of our lifetime but our brain never sleeps or rest. Even for a unconscious person the brain remains active. Brain generates irregular waves and no similar patterns can be identified.

### *A. Summation of Electrical Potentials in the Cortex*

Brain activity of any network can be made visible in EEG signals by four prerequisites that are as follows,

- The electrical signals generated by neurons must be in a specific axis that is perpendicular to the scalp.
- The neuron dendrites must be allied to parallel to create a signal by summating their field potentials that is detected at a distance.
- The neurons should fire in near synchrony.
- The same electrical sign must be produced by the electrical activity of each neuron.

From the above prerequisites we understand that no overwhelming majority of neuronal communication is basically invisible in EEG. Anyhow there are different properties of EEG that acts as a basis for a BCI, they are as follows[6,8]:

1. Rhythmic brain activity
2. Event-related potentials (ERPs)
3. Event-related desynchronization (ERD) and event-related synchronization (ERS).

*1) Rhythmic brain activity*

Different rhythmic activities of brain are shown from normal people's brain depending on the conscious level. Even different stages of sleep can be recorded from EEG. During the state of walk also rhythmic waves are generated. Different actions and thoughts affect this rhythmic activity. For example a particular rhythm can be blocked or attenuated by planning of the movement. As the basis for the BCI, mere thoughts also affect the brain rhythms.

EEG can be classified into several frequencies and these frequencies are named after Greek letters namely alpha, beta, theta and delta. Brain rhythms are observed on the basis of these range limits. Many other rhythms are available in EEG literature. One of them is mu rhythm. Its significance is also included in BCI research.

*2) Delta rhythm*

Delta waves have the range from 0.1 to 3.5 Hz EEG waves. Infants' delta waves range between 2 to 3.5 Hz at the age nearby two months and amplitude of about 50 to 100 mu volts during the walking state. But in adults delta waves can be detected while they are sleeping deeply and so this cannot be used in BCIs.

*3) Theta rhythm*

Waves ranging between 4 and 7.5 Hz are called theta waves. Its role is important in infancy and childhood. For adults this wave is detected in states of drowsiness and sleep. When disturbed from sleep this theta activity will be only in little amount and theta rhythm cannot be observed.

*4) Alpha rhythm*

At the back of the head with higher voltage during waked state 8 to 13 Hz rhythm is generated over the posterior regions of the head is the alpha rhythm. It has variable amplitude but is almost below 50 mu volts in adults. It has best rhythm at the state of closed eyes, under the conditions of physical relaxation and also relative mental activity. It is blocked or the strength is reduced by the person attention, visual and mental effort.

 

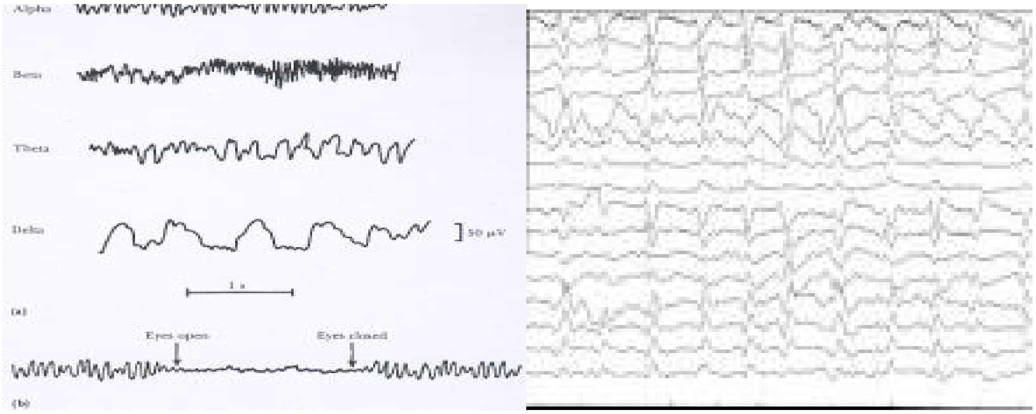


Figure2: Different EEG signals from various brain activities [3, 4]

*5) Mu rhythm*

Frequency of mu rhythm is around 10 Hz and amplitude mostly below 50 mu volt. It seems to be similar with the alpha rhythm but it is different from alpha rhythm in both topographically and physiologically. Mu stands for motor and the mu rhythm is strongly related to the functions of the motor cortex, but also to the adjacent somatosensory cortex. On movements or by light tactile stimuli this rhythm is blocked. This also can be blocked by the thoughts of performing movement and also readiness to move. This facts are important in BCI search.

*6) Beta rhythms*

Beta rhythm frequency ranges from 13 to 30 Hz. Related amplitude is above 30 mu volts. Frontal and central regions of the brain generate this rhythm. Here central beta rhythm is related to mu rhythm and it can be blocked during motor action and tactile stimulation.

*7) Event-related potentials (ERPs)*

In response to the event or a stimulus if the changes occur in the potential of EEG then it is said to be Event related potentials. These changes are very minute so to reveal them many repetitions of EEG samples have to be averaged. From this randomly occurring irregularity can be removed from the EEG that is not blocked stimuli.

*8) Event related desynchronization (ERD) and event related synchronization (ERS)*

Event-related desynchronization (ERD) and event-related synchronization (ERS) can be defined as follows:

Event-related desynchronization (ERD) is said to be an amplitude attenuation of a certain EEG rhythm and Event-related synchronization (ERS) is defined as an amplitude enhancement of a certain EEG rhythm.

*B. Features of EEG*

According to the detecting features of EEG using BCIs EEG feature can be categorized. Following are the EEG features: SCP, or rhythm amplitude, P300, RP, EEG power spectrum features and action potential of single cortical neuron.

*1) Measuring EEG*

The electrical activity of the brain in the scalp EEG is recorded non-invasively that is recorded from the outer surface of the scalp generally using the tiny metal plated electrodes. The electrodes are typically arranged based on the international 10 to 20 system even though the number of electrodes differs from study to study. Either reference electrodes or bipolar linkages are used to record the activities. By many artifacts the EEG signal may be get affect that comes from the equipment or the subject.

*2) Electrodes*

With the help of electrodes the EEG signals can be recorded. Small plates of electrodes conduct electricity. This electrode converts the ionic signals from the scalp to the electric signals in the wire and then it provides the electric contact between the scalp and the EEG recording system. Good stability in the signal can be gained only when the outermost layer of the scalp namely stratum corneum is partly detached from the electrode under part. To gain good electrical contact electrolyte gel is applied in between the skin and the electrode. Generally in the EEG recording tiny metal plate electrodes are used.

*3) Electrode placements*

International 10 – 20 system is used in order to compare the record of the signals over time. This system facilitates the electrode placement. The space stuck between the definite anatomic landmarks is calculated after which the electrodes are placed on the scalp using 10 and 20 % inter electrode distances. Each electrode placed has a letter to categorize the fundamental brain lobe and a number or an additional letter to classify the hemisphere location. Odd numbers are on the left side and even on the right side. Z (for zero) refers to electrode placements at midline. The system allows the use of additional electrodes.

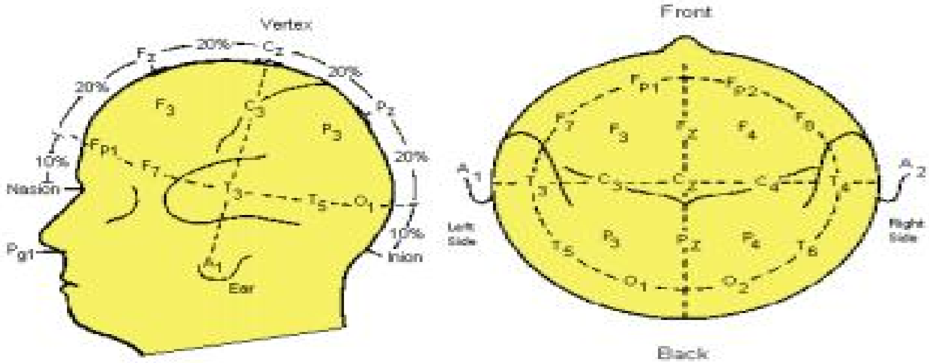


Figure 3: the international 10-20 electrode system: side and top views [5]

*4) Reference and bipolar recordings*

The EEG recordings can be divided into two major categories:

- Reference recordings
- Scalp to scalp bipolar linkages.

In the reference recording each electrode is referred to either distant reference electrode, one regular electrode on both side of the head or to joint movement of two or more electrodes. The reference electrodes must be placed on the parts of the body where potential remains fairly constant. Generally reference electrodes are placed on the ear lobes or on the mastoid bones behind the ear. In addition to one single reference electrode two reference electrodes shorted together can be used. In bipolar recordings differential measurements are made between successive pairs of electrodes.

## IV. EEG BASED BCI "BEEG"

As discussed earlier electroencephalography records the electrical signals from the scalp with the help of electrodes. For many decades it is used in clinical and research centers. It is a well established technique. EEG equipment is less expense, easy to lift and easy to apply when compared to other equipments. Some electrical activities cause contaminations of EEG. One of them is External electromagnetic sources like power line contaminates the EEG. Adequate signal quality can be achieved by preparing the skin areas that are contacted by the electrodes with particular abrasive electrode gel. This electrode as it requires gel it is said to be wet electrodes[2]

Electrode range of few to 100 electrodes is needed by the BCI systems currently. Setting time and hassle can be reduced by reducing the number of electrodes and this is expected by many groups. This setting up procedure must be done before each BCI session as the electrode gel dries out and wearing this cap is not comfort and fashionable. This tends to be drawback of EEG based BCIs. To overcome this problem we have a solution called dry electrodes. This type of electrodes neither requires skin preparation nor wet electrode gel.

Brain patterns that generate from specific brain areas are recorded by BCI form ongoing brain activity. Based on the standard system called International 10-20 System electrodes are placed accurately in the specific regions of the head to get regular recordings[9]. This pattern is used widely in clinical EEG recording and EEG research as well as BCI community. The name 10–20 indicates that the most commonly used electrodes are placed 10, 20, 20, 20, 20, and 10% of the total nasion inion distance. At similar fractional distances remaining electrodes are positioned. From left to right the inner electrodes remains in equal distance and from front to back that is of anterior posterior line the arrangement is symmetrical.

All the above methods serve as a brain computer interface. But they all have draw-backs which make them impractical for most BCI applications. MEG and fMRI are large in size and it is highly expensive. NIRS and fMRI have poor temporal resolution, and NIRS is still in an early stage of development.

1) *"BEEG" The BCI*

"BEEG" is EEG based Brain Computer Interface which is a non- invasive method for providing a new communication channel between human brains with the computer. The analysis of EEG- BCI can be done in two ways: Online (real time) and Offline. Offline EEG BCI uses recorded dataset and thus offers very limited practice over common parameters provided with toolboxes available in the market (for eg. EEGLAB toolbox in MATLAB, BCI200 toolbox). With online or real time EEG BCI more accuracy can be obtained by real time processing of important information from EEG recordings. Real time huge dataset can be tested on multiple subjects for research. As the area of BCI is still a big research area, depending on the specification and the application of the BCI, one can decide which technique meets the requirement. "BEEG" can work on both type of analysis.

A single PCB with a headset for various non invasive EEG BCI application is presented that is specially designed and made to navigate a computer system and recognizing words using brain signals. The PCB is integrated with the electrodes (brain signals reading sensors) which are directly connected to the microcontroller using amplifier. The hardware system presented allows disable persons to communicate or navigate with the computer system using their brain signals.

The objective of the invention "BEEG" is to create a low cost system that allows patients who have damaged their sensory/motor nerves severely to activate outside mechanisms (eg. system navigation) and identifying, analyzing words, emotions/feelings through brain signals. Electrodes will be placed on certain sensory points on brain scalp. The integrated module can be used to study the acquired brain signals using sensors (dry electrodes).

The system goes through main design requirements viz.: brain signal acquisition, preprocessing, classification and communication with PC. Sensors (dry electrodes) installed in the headgear will read the brain waves and amplify the signals then send to microcontroller input ADC (Analog to Digital Convertor). The signal will be converted into Digital by ADC. The PC will compare the value with the help of software developed and execute the desired command using .net framework. The board has a rectangular shape and equipped with an LCD to show the accumulated brain signal reading. The board also equipped with amplifiers, Micro controller unit, and RS232 interface to PC. The system can be easily programmed using a USB connection and the software.

The logical diagram of the BEEG is presented here:

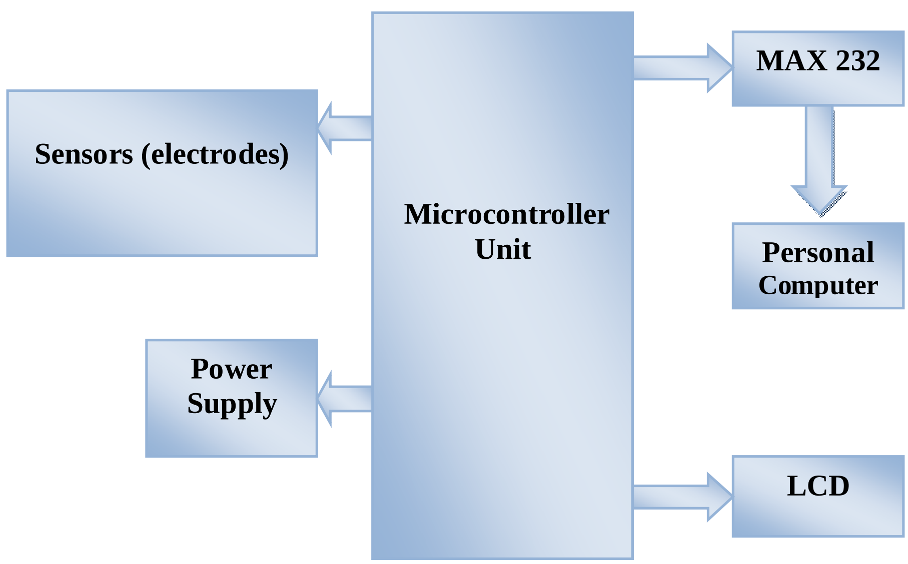


Figure 4: the logical diagram of BCI developed "BEEG"

2) *Software behind BCI*

The technology is comprised of three main components; a signal capture system, a signal processing system, and a display system. The signal capture system includes the electrodes themselves and the isolated electronic amplifiers. The signal processing system includes amplification of brain (analog) signal and after conversion into digital signal; further processing is done for storing and comparing with stored values, to display results.

## V. CONCLUSIONS

The "BEEG" is tested and trained over more than many subjects for its better performance. The results of BCI are spectacular and almost unbelievable. BCI can help paralyzed people to move their limbs to navigate devices by controlling their own electric wheelchairs, to communicate by using e-mail and internet-based phone systems, and to be independent by controlling items such as televisions and electrical appliances. Conclusively, BCI has proved to be a boon for paralyzed patients .

 

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