Enhancing The Usability of Brain Waves in Brain Computer Interface (BCI)

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Abstract - This paper conducts research on the recent trending development in Brain Computer Interface (BCI), including the types of brain waves and types of BCI. Although the growth in computer hardware and software has been huge in recent decades, but the development of human-machine interaction (HMI) has been very slow but discontinuous. BCI makes use of the electrical activity of the brain due to certain actions/thought processes used by algorithms to understand the objective of the user, and directs the same to the computer. This paper highlights and reviews those brain waves extracted from electrical activities classified by various algorithms and shows up the different types of BCI, with a short report on recent scenario.

Keywords: Brain Computer Interface, EEG, Brain Waves, HMI, Invasive, Noninvasive.

1. Introduction

Brain computer interface (BCI) is a system that converts brain signals or brain activities to control instructions, without the help of secondary nerves and muscles. BCI depends on the brain's electrical activity that is Electroencephalography (EEG). In this paper we will explore about the basics of brain waves and also the methods used in BCI in short. BCI is bringing easiness to that group of people who are disabled like Paralyzed, Locked in State, or other nerves related issues in their muscle's activity.

BCI is also bringing services to regular users and building their environment easy, as in entertainment, home appliances controlling, military and other daily life routines. These all above depend on Brain Waves and their feature Classifications. This paper highlights review of Brain Waves extracted from electrical activities classified by various algorithms and show up the different types of BCI. It also summarizes recent trends of BCI research and BCI development. New researcher may utilize this study for looking for knowledge related to Brain Waves in BCI.

2. Electrical activities in Brain

Brain is commonly divided into cerebrum, the cerebellum and brain branch. The cerebrum being rich in neurons is the middle of electrical action in brain. Currently EEG does not trace the electrical activity of individual neuron but the standard of all the neurons in between the 2 electrodes. Neuron generally differs in fundamental shape but their basic formation is same. It contains few biologically important parts and contains high value of positively charged (K+) ions and small amount of positively charged sodium ions (Na+). While the neighboring as opposite position. It contains small amount of potassium and high absorption of sodium. This output is concentration grade [3][5]. Neuron cell becoming semi permeable membranes, they permit diffusion of these charges hence produce electrical activity in brain.

3. Brain Waves

Because of the electric activity in brain and ions' excitation there seems to be the release of low frequency Electro Magnetic waves those are brain waves. Study of those waves supply us the insights into the performance of the brains subsequent type of waves produced by the brain, from delta the Lowest to Gammathe complex. We can imagine them to be a type of musical notes from small to higher frequency.

3.1. Beta wave (14 to 30 Hz)

Beta waves are with normal task of the body. These are significant for helpful functioning of the body. They are also related with logical calculation decision making. They are additionally divided into three bands low beta, beta high-beta with rising order of difficulty. Normal problem-solving thinking action are done during beta wave. These waves are shown in Figure 1.

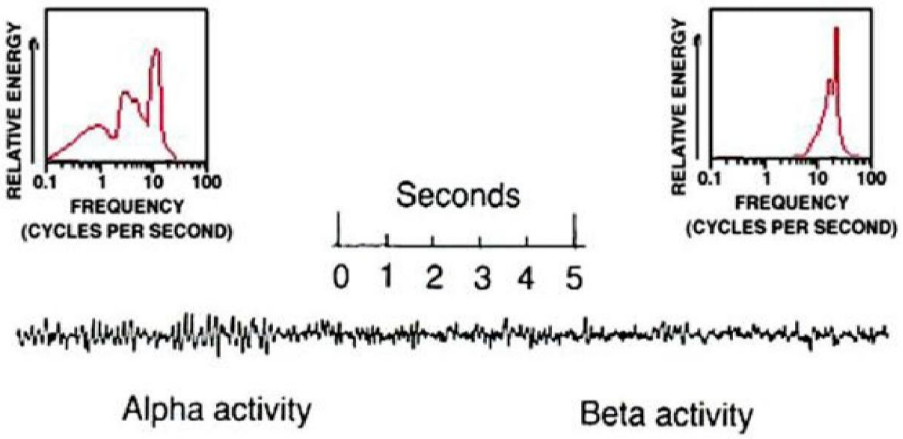

Figure 1. Alpha and Beta waves

3.2. Alpha wave (8 to 13 Hz)

Alpha waves are related with normal or deep state rest and the resting activity of the brain. They assist in overall coordination and doorway to subconscious mind and form the subordinate base of self-consciousness. Super learning, where the brain is switched for quicker and deeper than in beta is result of alpha state [6]. These waves are shown in Figure 1.

3.3. Mu waves (8 to 12 Hz)

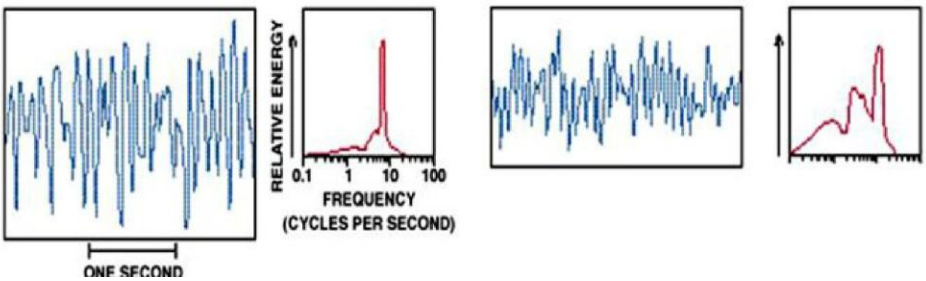

Figure 2. Mu and Alpha waves [4]

These waves are emitted with impulsive nature of the brain like motor activities etc. These waves appear like alpha waves but alpha waves are traced at occipital cortex and mu waves are

traced in motor cortex. Mu waves, also known as mu rhythms or mu oscillations, are a type of neural oscillation in the brain that occur in the frequency range of 8 to 12 Hertz (Hz). They are a specific type of sensorimotor rhythm (SMR) and are associated with the activation of the motor cortex during both movement execution and observation of movement. These waves are shown in Figure 2.

3.4. Theta wave (4 to 8 Hz)

Theta is the edge between the conscious and unconscious world these waves are related with light sleep or deep meditation. The reason for deep spirituality connection and unity comes from these waves. These are storage of our secret's nightmares. Unlike the further waves these are quiet and calm it is at the alpha theta edge our brain activity is at its finest functioning. These waves are shown in Figure 3.

Figure 3. Theta waves [4]

3.5. Delta wave (0.5 to 4 Hz)

Delta waves are the lowest frequencies as they are produced in asleep, dreamless sleep or especially deep sleep. Their sphere of influence is the unconscious mind. When point properly these waves induce healing procedure faster as they decrease the neural activity. Delta waves are a type of brain wave pattern that occurs in the frequency range of 0.5 to 4 Hertz (Hz). These waves are one of the several types of neural oscillations detected in electroencephalography (EEG) recordings. Delta waves are typically associated with deep sleep, particularly during the slow-wave sleep (SWS) stage. This is why deep healing sleep is essential sometimes. These waves are shown in Figure 4.

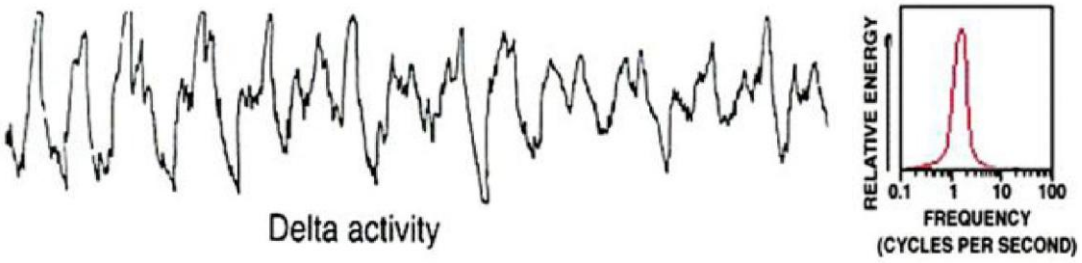

Figure 4. Delta waves [4]

3.6. Gamma waves (30 to 100 Hz)

Gamma waves are the highest waves. These are also related with production of ideas, verbal communication processing, memory processing. Extended consciousness is due to existence of gamma waves [2]. The Table 1 Continuous Brain Waves shown below the types of waves and its related details.

Type	Frequency	Location	Use
Delta	<4 Hz	Everywhere	Occur during sleep, Coma
Theta	4-7 Hz	Temporal and Parietal	Correlated with emotional stress (Frustration & Disappointment)
Alpha	8-12 Hz	Occipital and Parietal	Reduce amplitude with sensory stimulation or mental activity
Beta	12-36 Hz	Parietal and Frontal	Can increase amplitude during intense mental activity
Mu	9-11 Hz	Frontal (Motor Cortex)	Diminishes with movement or Intention of movement
Lambda	Sharp, Jagged	Occipital	Correlated with visual attention
Vertex			Higher incidence in patients with epilepsy or encephalopathy

Table 1: Continuous Brain Waves

4. Types of BCI (Brain ComputerInterface)

4.1. Invasive BCI

Here the electrodes are implanted into the brain so they can represent the highest quality signals. Usually, electrodes are inserted inside the brain (Figure 5). These methods are used in case of paralytic or sensory disability. In vision science brain implants have been utilized to treat not at birth acquired blindness. A private researcher named Willia Dobell who implanted this first prototype in to jerry, he inserted single array contains 68 electrodes into jerry's visual cortex and succeed in producing sensation of brightness. Although the signal quality we acquire is high but there is the danger of infections.

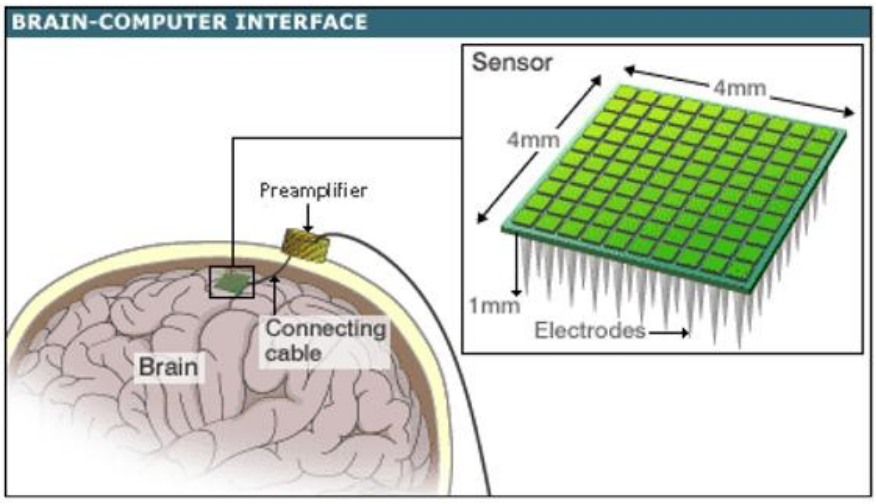

Figure 5. Invasive data acquisition [4]

4.2. Partial Invasive BCI

These are BCI devices implanted into the skull but they exist superficially under skull rather than deep inside. Signal power fetched by this system is bit weaker as compared to Invasive BCI but to the benefit they create better resolution signals than Non-Invasive BCI.

Electrocorticography (ECOG) uses the similar system but the electrodes are fixed in thin plastic rod that is placed beneath the cortex. Due to this, they also confirm to be threat due to infection. Light reactive imaging BCIs would involve im- planting laser in the head which would work on the neuron firing related reactance.

4.3. Non-Invasive BCI

In Non-Invasive BCI, no Invasive methods areused. Figure 6used No electrodes are inserted here in the cortex, instead array of electrodes are placed on the skull such as to catch the electric activity outwardly (Figure 6). Though they have the smallest amount of signal clarity when communicating with the brain but it is measured the safest as compared to the other kinds. This has been winning situation in giving the kinetic skills and restore partial actions [1]. Non invasive technique involves scanning machines or sensors on the skull and needs no implantation and is free from threat and inside scars.

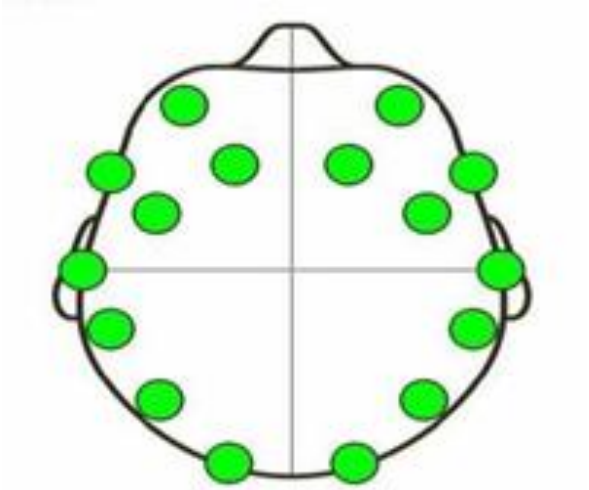

Figure 6. Positions of EEG 16 sensors [5]

Magnetic Imaging, Neuro Imaging EEG are used to get the brain wave signals. But due to ease of EEG, it is selected widely for non- invasive BCI Research/applications. Advanced EEG contains very stylish sensor that fetch very small electrical excitation. Computer software not only detects the electric activity but records them also. Signals from EEG passed through different algorithms and software for noise dele-tion and feature extraction. Extracted signals then accepted through recognized databases and machine learning algorithm to understand the command, then output command passed to target machine or hardware.

5. Application of BCI

- In Medical Area for motor sensory disabled people BCI would benefit as their inability to move or talk can be cancel out by BCI to robotsand talking algorithm Also by means of invasiveBCI it's been attempted to give sight to a blindusing surrounded electrodes and camera.
- Entertainment Video games will harvest the benefits of BCI, united with virtual reality one will be able to present game APIs to build reality games.
- Military application In an actual fight the incidents of the soldier cannot be copied by ma- chines. In that case soldier, while in simulation with BCI, the movements and judgment of soldier can be utilized to control robots/drones where the soldier sits securely fighting in simulation.

- Space Exploration Simulation with BCI this technology can be valuable in searching of deep space.

6. Conclusion

BCI is a very capable branch of Human Machine Interaction which if succeeds not only will change the mode we interact with machines but will also be a main hope for people with disability. Also with the raise in BCI it would be the duty of scientific society to address the confidentiality issue of method. But, for sure BCI will become a game changer in computer interaction with machines and also change our entertainment and spiritual experience too.

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