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Review Paper on Brain-Computer Interface and Recent Trends

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Abstract--- Although the development in computer hardware and software has been enormous in recent decades, but the development in Human-computer interface (HCI) has been very slow but discontinuous. From punch cards, text console, mouse to recently introduced gesture and voice controls the development is enormous, the recent addition to this is Brain computer interface (BCI). BCI makes uses of changes in brain and Electrical activity of brain to certain actions/thought processes and uses algorithms to interpret the intention of the user, and reports the same to computer. This paper focuses to review this area of HCI and demystify the techniques and concepts used and also give a short report on recent development and research on the same .This technique of BCI not only would be helpful for disabled to gain new strength but also would change the way we interact with machine...FOREVER.

Keywords- -- brain computer interface, HCI, brain waves, electroencephalogy, invasive, non-invasive, OpenBCI.

I. INTRODUCTION

OVER the years the ways we interact with machines have changed completely. Starting with punch cards we have reached now to the infant technology of gesture and voice controls. But the complete game change would take place in the field of HUMAN COMPUTER INTERFACE because of this new technological area of research called as BRAIN COMPUTER INTERFACE. A Brain–Computer Interface (BCI), often called a Mind-Machine Interface (MMI), or sometimes called a direct neural interface or a Brain–Machine Interface (BMI), is a direct communication channel between the brain and an external device. Brain computer interface (BCI) is an upcoming technology which aims to convey people's intentions to the outside world directly from their thoughts, enhancing cognitive capabilities [1]. BCI depends on the electrical activity of the brain that was discovered by Hans Berger in 1924. Later the development of Electroencephalogy (EEG) by the same proved to be very useful in the development of BCI. In this paper we will explore about the basics of brain waves and also the existing technology used in BCI in detail.

A. Electrical activity in brain

Brain is generally divided into cerebrum, the cerebellum, and brain stem. The cerebrum being rich in neurons is the centre of electrical activity in brain. EEG does not record the electrical activity of particular neuron but the average of all the neurons in between the two electrodes. Neuron widely differs in basic shape but their basic structure is same. It contains few biologically important parts and contain high amount of positively charged potassium (K+) ions and low amount of positively charged sodium ions (Na+). While the surrounding as opposite situation .It contains low amount of potassium and high concentration of sodium. This result is concentration gradient. Neuron cell being semipermeable membranes, they allow diffusion of these charges hence create electrical activity in

brain. Its found that diffusion of K+ ions is more easier than Na+, that is its easier for potassium to leak out than sodium to leak in. These diffusion stop at once when the electric potential reaches -70mV and equilibrium is established and is called as resting potential of neuron.

B. Brain Waves

Due to the electric activity in brain and excitation of ions there seems to be the emission of low frequency EM waves called as brain waves. Study of these waves provides us the insights into the functioning of the brains following are the type of waves emitted by the human brain. Starting from delta being the lowest and Gamma being the complex. We can assume them to be a kind of musical notes from low to higher frequency.

B.1. Beta wave (14 to 30 Hz)

Beta waves are associated with normal function of the body. These are important for effective functioning of the body. They are also associated with logical reasoning decision making. They are further divided into three bands low beta, beta high-beta with increasing order of complexity. Normal problem solving thinking action are done during beta wave

B.2. Alpha wave (8 to 13 Hz)

Alpha waves are associated with normal or deep state relaxation. Alpha is the resting of the brain activity. They help in overall coordination. They are the gateway to subconscious mind and form the lower base of self-consciousness. Super learning, where the brain is switched for faster and deeper than in beta is result of alpha state.

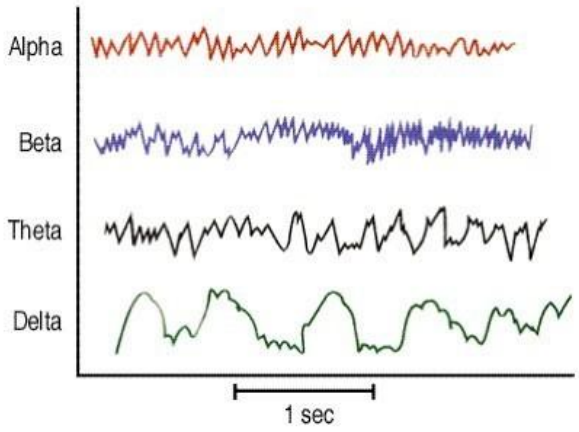

Fig1. Brain Waves

B.3. Theta wave (4 to 8 Hz)

Theta is the border between the conscious and unconscious world these waves are associated with light sleep or deep meditation. The reason for deep spirituality connection and unity comes from these waves. These are lockers of our secrets fears nightmares. Unlike the other waves these are silent and calm it is at the the alpha theta border our brain activity is at its optimal functioning

B.4. Delta wave (0.5 to 4 Hz)

Delta waves have the lowest frequencies as they are generated in sleep, dreamless sleep or very deep sleep. Their domain is the unconscious mind. When stage properly
these waves induce healing process faster as they reduce the neural activity. This is why deep restorative sleep is essential sometimes.

B.5. Gamma waves

Gamma waves are the fastest waves and correspond to multiprocessing or simultaneous processing .These are also associated with generation of ideas, language processing, memory processing. Expanded consciousness is due to presence of gamma waves.

II. OVERVIEW OF BCI

BCI is mainly used for assisting people with sensory motor function disability. The field of BCI research and development has been focused on neuroprosthetics applications for that. This aims at restoring damaged hearing, sight and movement Neuroprosthetics is an area of neuroscience concerned with neural prostheses. We can use artificial devices to replace the function of nervous system which is not proper and brain related problems as well as sensory organs. The most widely used neuroprosthetic device is the cochlear implant which, as of 2006, had been implanted in approximately 100,000 people worldwide. There are many other neuroprosthetic devices which aim to restore the vision, including retinal implants. The difference between BCI and neuroprosthetics are: neuroprosthetics connect nervous system to a device whereas BCI connects the brain to a computer system. However, neuroprosthetics and BCIs are mainly focusing on to achieve the same goal such as restoring sight, hearing, movement, ability to communicate, and even cognitive function. Both use similar experimental methods and surgical techniques [2]. But our main focus lies in exploiting BCI as an method of user interface. Due to thought processes by the user various electro-neural activities are triggered which will result in emission of appropriate brain waves. Using devices like EEG or embedded electrodes these activities are captured. These captured signals have varying amount of noise, using appropriate methods noises are cancelled and useful feature among the signal is extracted. That is apart from regular pattern of brain waves useful pattern is sorted out. By using algorithm to predict the meaning of the signal proper machine understandable output is generated which is fed into machine that will manipulate the environment in real time.

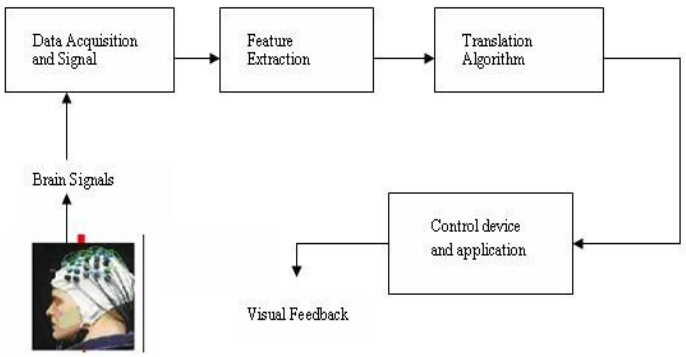

Fig 2. Generic BCI feedback loop

III. Types of BCI

A. Invasive BCI

Here electrodes are directly inducted into the brain so they can draw the highest quality signals. Usually electrodes are introduced inside the brain .these systems are used in case of paralytic or sensory disability. In vision science direct brain implants have been used to treat non conginetal ie acquired blindness. One of the first scientists working with bci to restore blindness was a private researcher named willia dobell who implant this first prototype in to jerry he inserted single array of

bci containing 68 electrodes into jerrys visual cortex and succeeded in producing sensation of light.Although the signal quality we get is high but there is the risk of infections and scars.

B. Partial Invasive BCI

These are BCI devices implanted into the skull but they exist externaly under skull rather than inside grey matter.

signal strength obtained by this system is bit weaker compared to invasive bci but to the advantage they produce better resolution signals than non-invasive bci. Electrocorticography (ECoG) uses the same system but the electrodes are embedded in thin plastic rod that is placed beneath the cortex. Due to this, they also prove to be threat due to infection. Light reactive imaging BCIs are still in research. These would involve implanting laser inside the skull which would work on the neuron firing associated wavelength and reactance.

C. Non Invasive BCI

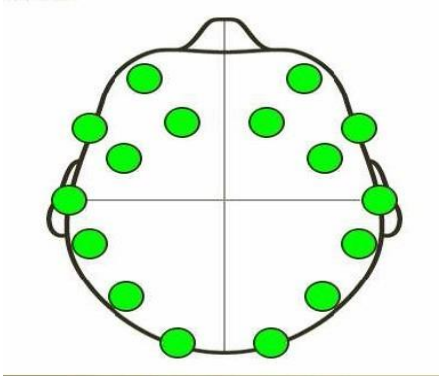

Fig 3 position of EEG sensors used

No electrode is embedded here either in grey matter or cortex, instead array of electrodes are placed around skull such as to catch the electric activity externally. Though they have the least signal clarity when communicating with the brain but it is considered the safest when compared to the other types. This has been successful in giving the kinetic abilities and restore partial movements.Non invasive technique involves mounting scanning devices or sensors around the skull and require no operation and is free from health threat.

IV. Non Invasive BCI (NIBCI)

For NIBCI techniques like magnetic Imaging, neuroimaging, EEG are used to get the brain wave signals. But due to ease of use and non-harmful nature of EEG, it is chosen widely for non-invasive BCI Research/applications.EEG was developed by Hans in 19th century.Conventional EEG uses array of sensor to pick up the electric activity and is amplified nearly 10000 times and then sent to galvanometer for detection. But now advanced EEG contains very sophisticated sensor that pickups very minute electrical excitation. And galvanometer is replaced by sophisticated computer modules that not only detect the electric activity but is also recorded and simplified. This signal from EEG is passed through various algorithms and softwares for noise cancellation and salient feature extraction. Extracted signals are passed through previously known databases and machine learning algorithm to interpret the command and the output command is passed to target hardware.

V. OpenBCI -an open source community approach to BCI

OpenBCI is a palm-sized board meant to make mind controlled devices a little less sci-fi and a little more accessible. The heart of any EEG system are its 3 parts an EEG sensor, an amplifier and a computer for interpreting signals. The heart of OpenBCI is its EEG amplifier that is based on Texas instruments ADS1299 chip. They provide a re-programmable microcontroller. And all the algorithms and software used is open source licensed and also the board is under open hardware license. The board is priced under 300$ and is under rapid development having its own community of hackers and developers around it. The founders of this initiative want OpenBCI to be a whole platform for BCI communication using opensource technologies so that community as whole be benefited.

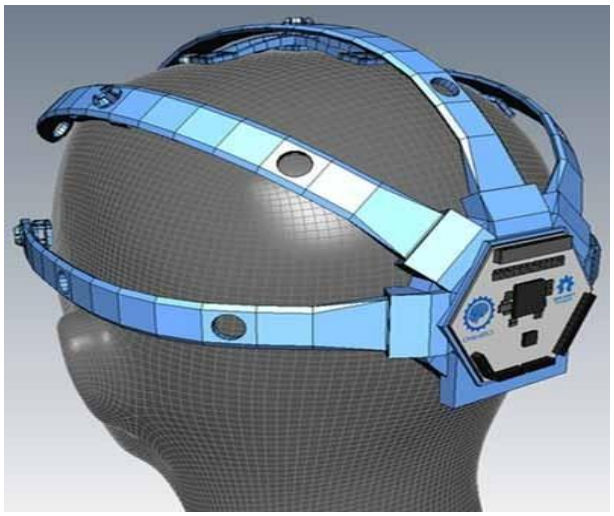

Fig4. OpenBCI wearable sensors and onbaord computer

VI. Application of BCI

A. Medical industry

For people with motor-sensory disability BCI would boon as their inability to move or speak can be nullified by BCI to robots and speaking algorithm. Hence the development in BCI would directly affect the development of this weaker part of society to grow independent. Also using invasive BCI its been tried to provide sight to blinds using embedded electrodes and cameras.

B. Entertainment

Videogames will be the most important field of entertainment that will reap the benefits of BCI , combined with virtual reality we will be able to provide game makers APIs to build super reality games.

C. Military application

In an actual fight the experience of the soldier can not be duplicated by machines.In that case soldier,while in simulation using BCI ,the voluntary movements and decision of soldier can be used to guide robots/drones while the soldier sits safely playing simulation.

D. Space Exploration

When Combined with simulation this technology can be useful in exploration of deep space.

VII. Ethical Issues

With raise in BCI the issue of privacy would haunt the user, As this would be mean that anyone would be able to hack into the target's brain easily. And also it would provide significant way for government to spy on its subject using BCI devices (which NSA already is said to be doing with internet data), Which in case of corrupt government would cease the opportunity of citizen to uprise against the government. Hence privacy would be a major issue with raise in BCI

VIII. Conclusion

BCI is a very promising branch of HCI which if succeeds not only will change the way we interact with machines but will also be a major hope for people with disability. Also with the raise in BCI it would be the duty of scientific community to address the privacy issue of method. But , for sure BCI will be a game changer in the way we interact with computer and machines and also change our entertainment industry.

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