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Brain Machine Interface through Visually Guided Electrical Brain Responses

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ABSTRACT: **A brain-machine interface is a communication system that does not depend on the brains normal output pathways of peripheral nerves and muscles. It is a new communication link between a functioning human brain and the outside world. These are electronic interfaces with the brain, which has the ability to send and receive signals from the brain. BMI uses brain activity to command, control, actuate and communicates with the world directly through brain integration with peripheral devices and systems. The signals from the brain are taken to the computer via the implants for data entry without any direct brain intervention. BMI transforms mental decisions and reactions into control signals by analyzing the bioelectrical brain activity. While linking the brain directly with machines was once considered science fiction, advances over the past few years have made it increasingly viable. An immediate goal of brain-machine interface study is to provide a way for people with damaged sensory/motor functions to use their brain to control artificial devices and restore lost capabilities. By combining the latest developments in computer technology and hi-tech engineering, paralyzed persons will be able to control a motorized wheel chair, computer painter, or robotic arm by thought alone.**

Key words: **BMI, Callosum, EEG, BCI, ANN, ASIC**

1. INTRODUCTION

When humans see in the UV and IR portions of the electromagnetic spectrum, or hear speech on the noisy flight deck of an aircraft carrier; or when soldiers communicate by thought alone. Imagine a time when the human brain has its own wireless modem so that instead of acting on thoughts, war fighters have thoughts that act. Imagine that one day we will be able to download vast amounts of knowledge directly to our brain! So as to cut the lengthy processes of learning everything from scratch. Instead of paying to go to university we could pay to get a "knowledge implant" and perhaps be able to obtain many lifetimes worth of knowledge and expertise in various fields at a young age. When we talk about high end computing and intelligent interfaces, we just cannot ignore robotics and artificial intelligence. In the near future, most devices would be remote/logically controlled. Researchers are close to breakthroughs in neural interfaces, meaning we could soon mesh our minds with machines. This technology has the capability to impact our lives in ways that have been previously thought possible in only sci-fi movies.

Brain-Machine Interface (BMI) is a communication system, which enables the user to control special computer applications by using only his or her thoughts. It will allow human brain to accept and control a mechanical device as a part of the body. Data can flow from brain to the outside machinery, or to brain from the outside machinery. Different research groups have examined and used different methods to achieve this. Almost all of them are based on electroencephalography (EEG) recorded from the scalp. Our major goal of such research is to create a system that allows patients who have damaged their sensory/motor nerves severely to activate outside mechanisms by using brain signals. Cyber kinetics Inc, a leader in neuro technology has developed the first implantable brain-machine interface that can reliably interpret brain signals and perhaps read decisions made in the brain to develop a fast, reliable and unobtrusive connection between the brain of severely disabled person to a personal computer.

1.1. BRAIN MACHINE INTERFACE: A brain-machine interface (BMI) is an attempt to mesh our minds with machines. It is a communication channel from a human's brain to a computer, which does not resort to the usual human output pathways as muscles. It is about giving machine-like capabilities to intelligence, asking the brain to accommodate synthetic devices, and learning how to control those devices much the way we control our arms and legs today.

These paper lend hope that people with spinal injuries will be able to someday use their brain to control a prosthetic limb, or even their own arm. A BMI could, e.g., allow a paralyzed patient to convey her/his intentions to a computer program. But also applications in which healthy users can benefit from the direct brain computer communication are conceivable, e.g., to speed up reaction times. Initially theses interactions are with peripheral devices, but ultimately it may be interaction with another brain. The first peripheral devices were robotic arms. Our approach bases on an artificial neural network that recognizes and classifies different brain activation patterns associated with carefully selected mental tasks. Using BMI artificial electrical signal can stimulate the brain tissue in order to transmit some particular sensory information.

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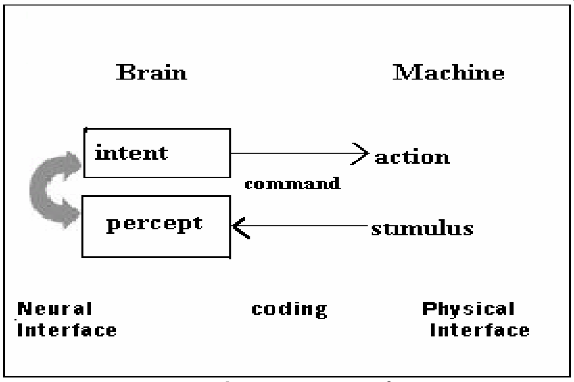

Figure.1. The Organization Of BMI

1.2. THE HUMAN BRAIN: All of it happens in the brain. The brain is undoubtly the most complex organ found among the carbon-based life forms. So complex it is that we have only vague information about how it works. The average human brain weights around 1400 grams. The most relevant part of brain concerning BMI's is the cerebral cortex. The cerebral cortex can be divided into two hemispheres. The hemispheres are connected with each other via corpus callosum. Each hemisphere can be divided into four lobes. They are called frontal, parietal, occipital and temporal lobes. Cerebral cortex is responsible for many higher order functions like problem solving, language comprehension and processing of complex visual information.

The cerebral cortex can be divided into several areas, which are responsible of different functions. This kind of knowledge has been used when with BCI's based on the pattern recognition approach. The mental tasks are chosen in such a way that they activate different parts of the cerebral cortex.

Cortical Area	Function
Auditory Association Area	Processing of auditory information
Auditory Cortex	Detection of sound quality (loudness, tone)
Speech Center (Broca's area)	Speech production and articulation
Prefrontal Cortex	Problem solving, emotion, complex thought
Motor Association Cortex	Coordination of complex movement
Primary Motor Cortex	Initiation of voluntary movement
Primary Somatosensory Cortex	Receives tactile information from the body
Sensory Association Area	Processing of multisensory information
Visual Association Area	Complex processing of visual information
Wernicke's Area	Language comprehension

Table.1 Cortical areas of the brain and their function

1.3. MAIN PRINCIPLE: Main principle behind this interface is the bioelectrical activity of nerves and muscles. It is now well established that the human body, which is composed of living tissues, can be considered as a power station generating multiple electrical signals with two internal sources, namely muscles and nerves. We know that brain is the most important part of human body. It controls all the emotions and functions of the human body. The brain is composed of millions of neurons. These neurons work together in complex logic and produce thought and signals that control our bodies. When the neuron fires, or activates, there is a voltage change across the cell, (~100mv) which can be read through a variety of devices. When we want to make a voluntary action, the command generates from the frontal lobe. Signals are generated on the surface of the brain. These electric signals are different in magnitude and frequency.

By monitoring and analyzing these signals we can understand the working of brain. When we imagine ourselves doing something, small signals generate from different areas of the brain. These signals are not large enough to travel down the spine and cause actual movement. These small signals are, however, measurable. A neuron depolarizes to generate an impulse; this action causes small changes in the electric field around the neuron. These changes are measured as 0 (no impulse) or 1 (impulse generated) by the electrodes. We can control the brain functions by artificially producing these signals and sending them to respective parts. This is through stimulation of that part of the brain, which is responsible for a particular function using implanted electrodes.

1.4. ELECTROENCEPHALOGRAPH:
Electroencephalography (EEG) is a method used in measuring the electrical activity of the brain. The brain generates rhythmical potentials which originate in the individual neurons of the brain. These potentials get summated as millions of cell discharge synchronously and appear as a surface waveform, the recording of which is known as the electroencephalogram. The neurons, like other cells of the body, are electrically polarized at rest. The interior of the neuron is at a potential of about –70mV relative to the exterior. When a neuron is exposed to a stimulus above a certain threshold, a nerve impulse, seen as a change in membrane potential, is generated which spreads in the cell resulting in the depolarization of the cell. Shortly afterwards, repolarization occurs.

The EEG signal can be picked up with electrodes either from scalp or directly from the cerebral cortex. As the neurons in our brain communicate with each other by firing electrical impulses, this creates an electric field which travels though the cortex, the dura, the skull and the scalp. The EEG is measured from the surface of the scalp by measuring potential difference between the actual measuring electrode and a reference electrode. The peak-to-peak amplitude of the waves that can be picked up from the scalp is normally 100 µv or less while that on the exposed brain, is about 1mV. The frequency varies greatly with different behavioral states. The normal EEG frequency content ranges from 0.5 to 50 Hz.
Frequency information is particularly significant since the basic frequency of the EEG range is classified into five bands for purposes of EEG analysis. These bands are called brain rhythms and are named after Greek letters. Five brain rhythms are displayed in Table.2. Most of the brain research is concentrated in these channels and especially alpha and beta bands are important for BCI research. The reason why the bands do not follow the greek letter magnitudely (alpha is not

the lowest band) is that this is the order in which they were discovered.

Band	Frequency [Hz]
Delta	0.5- 4
Theta	4- 8
Alpha	8- 13
Beta	13- 22
Gamma	22-30

Table.2.Common EEG frequency ranges

The alpha rhythm is one of the principal components of the EEG and is an indicator of the state of alertness of the brain.

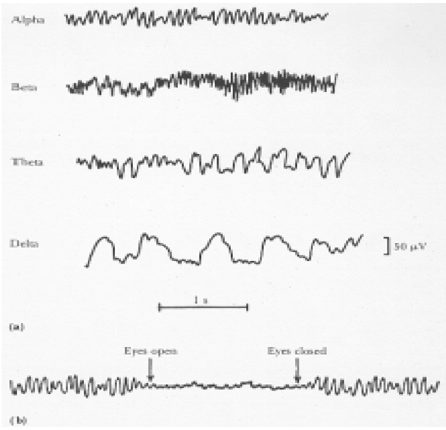

Figure 2. Examples of alpha, beta, theta and delta rhythms.

The average human brain weights around 1400 grams. The brain can be divided into four structures: cerebral cortex, cerebellum, brain stem, hypothalamus and thalamus. The most relevant of them concerning BCIs is the cerebral cortex. The cerebral cortex can be divided into two hemispheres. The hemispheres are connected with each other via corpus callosum. Each hemisphere can be divided into four lobes. They are called frontal, parietal, occipital and temporal lobes. Cerebral cortex is responsible for many "higher order" functions like problem solving, language comprehension and processing of complex visual information. The cerebral cortex can be divided into several areas, which are responsible of different functions. These areas can be seen in Figure. These kinds of knowledge have been used when with BCIs based on the pattern recognition approach. The mental tasks are chosen in such a way that they activate different parts of the cerebral cortex.

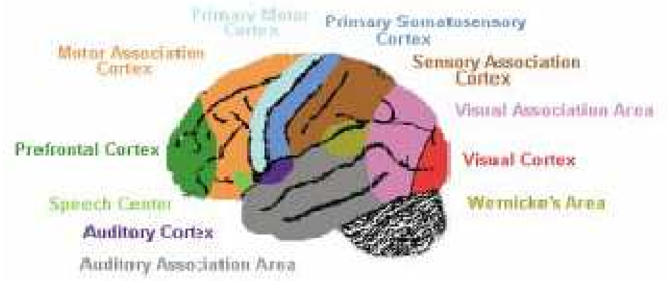

Fig 3. Functional areas of the brain

1.5. Electrode Placements: In order to make patient's records comparable over time and to other patient's records, a specific system of electrode placement called International 10-20 system is used. The system is for 21 electrodes. The distance between the specific anatomic landmarks (nasion and inion, see Figure 2.7) is measured after which the electrodes are placed on the scalp using 10 and 20 % interelectrode distances. Each electrode position has a letter (to identify the underlying brain lobe) and a number or another letter to identify 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. As can be seen in Figure 2.7 midline (or zero) electrodes are flanked up by electrodes numbered 3 on the left and 4 on the right.

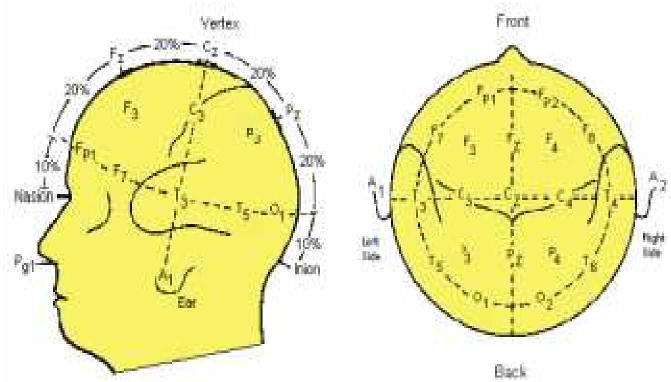

Fig 4. The international 10-20 electrode system: side and top views

1.6. BMI APPROACHES: What are the thoughts the user thinks in order to control a BMI? An ideal BMI could detect the user's wishes and commands directly. However, this is not possible with today's technology. Therefore, BMI researches have used the knowledge they have had of the human brain and the EEG in order to design a BMI. There are basically two different approaches that have been used. The first one called a pattern recognition approach is based on cognitive mental tasks. The second one called an operant conditioning approach is based on the self-regulation of the EEG response.

In the first approach the subject concentrates on a few mental tasks. Concentration on these mental tasks produces different EEG patterns. The BCI (or the classifier in

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particular) can then be trained to classify these patterns. In the second approach the user has to learn to self-regulate his or her EEG response, for example change the beta rhythm amplitude. Unlike in the pattern recognition approach, the BMI itself is not trained but it looks for particular changes (for example higher amplitude of a certain frequency) in the EEG signal. This requires usually a long training period, because the entire training load is on the user.

2. BMI BLOCK DIAGRAM & DESCRIPTION

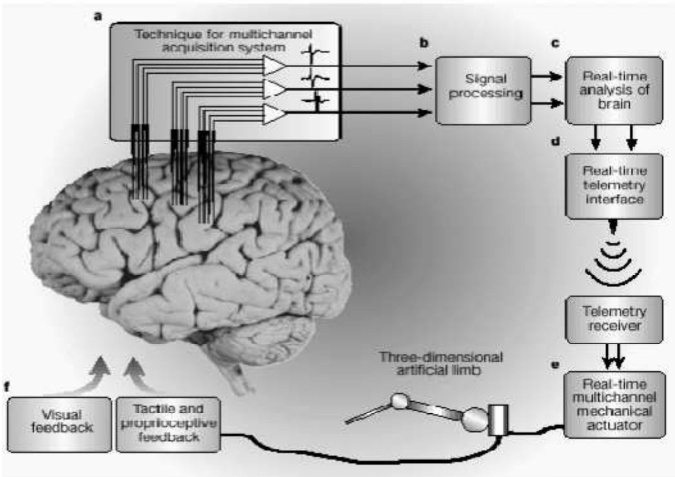

Fig 5. Block diagram of BMI System

2.1. Block description: The BMI consists of several components: 1.the implant device, or chronic multi-electrode array, 2.the signal recording and processing section, 3.an external device the subject uses to produce and control motion and 4.a feedback section to the subject. The first component is an implanted array of microelectrodes into the frontal and parietal lobes—areas of the brain involved in producing multiple output commands to control complex muscle movements. This device record action potentials of individual neurons and then represent the neural signal using a rate code.

The second component consists of spike detection algorithms, neural encoding and decoding systems, data acquisition and real time processing systems etc. A high performance DSP architecture is used for this purpose. The external device that the subject uses may be a robotic arm, a wheel chair etc. depending upon the application. Feedback is an important factor in BCI's. In the BCI's based on the operant conditioning approach, feedback training is essential for the user to acquire the control of his or her EEG response. However, feedback can speed up the learning process and improve performance.

2.2. BMI COMPONENTS: A brain-machine interface (BMI) in its scientific interpretation is a combination of several hardware and software components trying to enable its user to communicate with a computer by intentionally altering his or her brain waves. The task of the hardware part is to record the brainwaves– in the form of the EEG signal – of a human subject, and the software has to analyze that data. In other words, the hardware consists of an EEG machine and a number of electrodes scattered over the subject's skull. The EEG machine, which is connected to the electrodes via thin wires, records the brain-electrical activity of the subject, yielding a multi-dimensional (analog or digital) output. The values in each dimension (also called channel) represent the relative differences in the voltage potential measured at two electrode sites. The software system has to read, digitize (in the case of an analog EEG machine), and preprocess the EEG data (separately for each channel), "understand" the subject's intentions, and generate appropriate output. To interpret the data, the stream of EEG values is cut into successive segments, transformed into a standardized representation, and processed with the help of a classifier.

There are several different possibilities for the realization of a classifier; one approach – involving the use of an artificial neural network (ANN)– has become the method of choice in recent years.

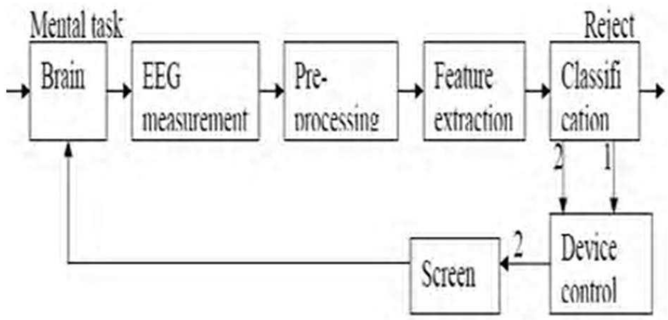

Figure 6.BMI components

A BMI based on the classification of two mental tasks. The user is thinking task number 2 and the BCI classifies it correctly and provides feedback in the form of cursor movement. Now the BMI components are described as follows

2.3. IMPLANT DEVICE: The EEG is recorded with electrodes, which are placed on the scalp. Electrodes are small plates, which conduct electricity. They provide the electrical contact between the skin and the EEG recording apparatus by transforming the ionic current on the skin to the electrical current in the wires. To improve the stability of the signal, the outer layer of the skin called stratum corneum should be at least partly removed under the electrode. Electrolyte gel is applied between the electrode and the skin in order to provide good electrical contact.

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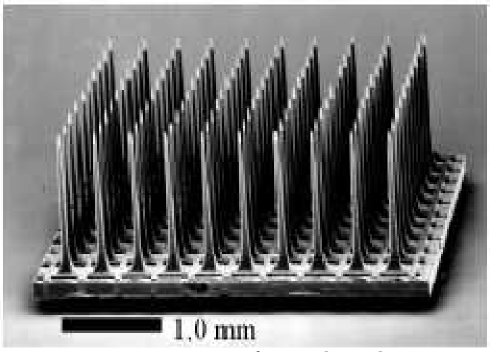

Figure 7.An array of microelectrodes

Usually small metal-plate electrodes are used in the EEG recording. Neural implants can be used to regulate electric signals in the brain and restore it to equilibrium. The implants must be monitored closely because there is a potential for almost anything when introducing foreign signals into the brain.

There are a few major problems that must be addressed when developing neural implants. These must be made out of biocompatible material or insulated with biocompatible material that the body won't reject and isolate. They must be able to move inside the skull with the brain without causing any damage to the brain. The implant must be chemically inert so that it doesn't interact with the hostile environment inside the human body. All these factors must be addressed in the case of neural implants; otherwise it will stop sending useful information after a short period of time.

There are simple single wire electrodes with a number of different coatings to complex three-dimensional arrays of electrodes, which are encased in insulating biomaterials. Implant rejection and isolation is a problem that is being addressed by developing biocompatible materials to coat or incase the implant. One option among the biocompatible materials is Teflon coating that protects the implant from the body. Another option is a cell resistant synthetic polymer like polyvinyl alcohol. To keep the implant from moving in the brain it is necessary to have a flexible electrode that will move with the brain inside the skull. This can make it difficult to implant the electrode. Dipping the micro device in polyethylene glycol, which causes the device to become less flexible, can solve this problem. Once in contact with the tissue this coating quickly dissolves. This allows easy implantation of a very flexible implant. Three-dimensional arrays of electrodes are also under development. These devices are constructed as two-dimensional sheet and then bent to form 3D array. These can be constructed using a polymer substrate that is then fitted with metal leads. They are difficult to implement, but give a much great range of stimulation or sensing than simple ones.

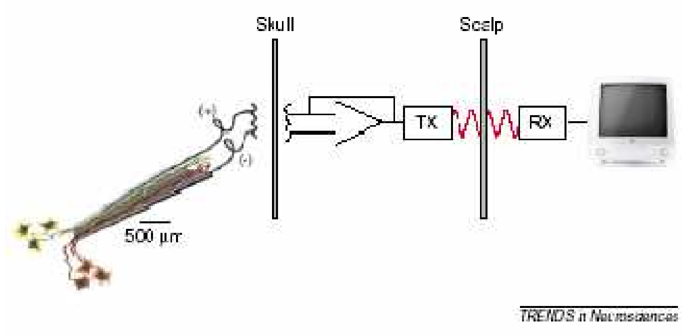

Figure 8. Block diagram of the neurotrophic electrodes for implantation in human patients.

A microscopic glass cone contains a neurotrophic factor that induces neurites to grow into the cone, where they contact one of several gold recording wires. Neuritis that are induced to grow into the glass cone make highly stable contacts with recording wires. Signal conditioning and telemetric electronics are fully implanted under the skin of the scalp. An implanted transmitter (TX) sends signals to an external receiver (RX), which is connected to a computer.

2.4. Signal Processing Section:

2.4.1. *Multichannel Acquisition Systems:* Electrodes interface directly to the non-inverting opamp inputs on each channel. At this section amplification, initial filtering of EEG signal and possible artifact removal takes place. Also A/D conversion is made, i.e. the analog EEG signal is digitized. The voltage gain improves the signal-to-noise ratio (SNR) by reducing the relevance of electrical noise incurred in later stages. Processed signals are time-division multiplexed and sampled.

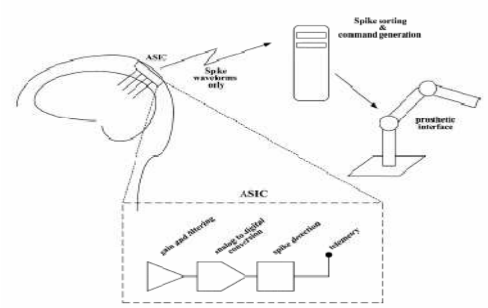

Figure 9: A BMI under design.

2.4.2. Spike Detection: Real time spike detection is an important requirement for developing brain machine interfaces. Incorporating spike detection will allow the BMI to transmit only the action potential waveforms and their respective arrival times instead of the sparse, raw signal in its entirety. This compression reduces the transmitted data rate per channel, thus increasing the number of channels that may be monitored simultaneously. Spike detection can further reduce the data rate if spike counts are transmitted instead of spike waveforms. Spike detection will also be a necessary first step for any future hardware implementation of an

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autonomous spike sorter. Figure shows its implementation using an application-specific integrated circuit (ASIC) with limited computational resources. A low power implantable ASIC for detecting and transmitting neural spikes will be an important building block for BMIs. A hardware realization of a spike detector in a wireless BMI must operate in real-time, be fully autonomous, and function at realistic signal-to- noise ratios (SNRs). An implanted ASIC conditions signal from extra cellular neural electrodes, digitizes them, and then detects AP spikes. The spike waveforms are transmitted across the skin to a BMI processor, which sorts the spikes and then generates the command signals for the prosthesis.

2.4.3. Signal Analysis: Feature extraction and classification of EEG are dealt in this section. In this stage, certain features are extracted from the preprocessed and digitized EEG signal. In the simplest form a certain frequency range is selected and the amplitude relative to some reference level measured. Typically the features are frequency content of the EEG signal) can be calculated using, for example, Fast Fourier Transform (FFT function). No matter what features are used, the goal is to form distinct set of features for each mental task. If the feature sets representing mental tasks overlap each other too much, it is very difficult to classify mental tasks, no matter how good a classifier is used. On the other hand, if the feature sets are distinct enough, any classifier can classify them. The features extracted in the previous stage are the input for the classifier.

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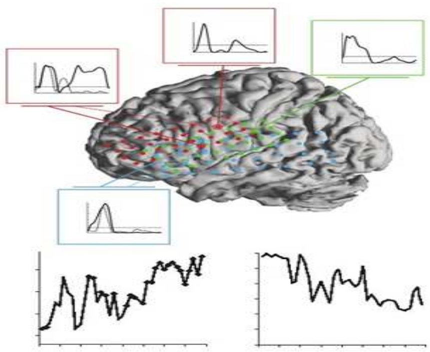

Fig 10: Various Signals

The second stage is a translation algorithm that translates these features into device commands. Features such as rhythm amplitudes or neuronal firing rates are translated into commands that specify outputs such as cursor movements, icon selection, or prosthesis operation. Translation algorithms maybe simple (e.g., linear equations), or more complex (e.g., neural networks, support vector machines).To be effective, a translation algorithm must ensure that the user's range of control of the chosen features allows selection of the full range of device commands.

2.5. Implementation of BMI: An implantable, Brain Machine Interface, has been clinically tested on humans by American company Cyberkinetics. The Brain Gate device can provide paralyzed patients a mode of communication through the translation of thought into direct computer control. The technology driving this breakthrough in the brain machine interface field has a myriad of potential applications, including the development of human augmentation and commercial purposes

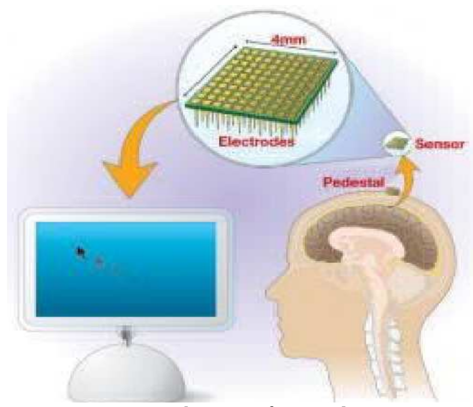

Fig 11.Brain Machine Interface Implementation

The Brain Gate Neural Interface Device is a BCI that consists of an internal neural signal sensor and external processors that convert neural signals into an output signal under the users own control. The sensor consists of a tiny chip with one hundred electrode sensors each that detect brain cell electrical activity. The chip is implanted on the surface of the brain in the motor cortex area that controls movement. The computers translate brain activity and create the communication output using custom decoding software

3. BMI FOR HEALTHY USERS

A New Brain machine interface research and development projects envisioned healthy subjects as end users. Researches have demonstrated BCI's intended to let healthy users navigate maps while their hands are busy. Game companies such as Neurosky and emotive advertise games that allow people to move a character with conventional handheld controls and control special features through a BMI. However, some BCIs allow walking or turning by imagining foot or hand movements and these might offer new frontiers of usability for all users. As with other interfaces, research should address which mental activities seem most natural, easy and pleasant for different users in different situations.

3.1. INDUCED DISABILITY: Healthy users might communicate via BCIs when conventional interfaces are inadequate, unavailable, or too demanding. Surgeons, mechanics, soldiers, cell phone users, drivers, and pilots can experience induced disability when hand or voice communication is infeasible. BMI's might help them request tools, Access data or perform otherwise difficult, distracting or impossible tasks. Expert Gamers often use many keys at once.

3.2. EASE OF USE IN HARDWARE: Bluetooth, the ubiquitous wireless Internet and related technologies facilitate wireless BCIs. BCIs might eventually become more convenient and accessible than cell phones, watches, remote controls, or car dashboard interfaces. BCIs could also help people, who retype words or sentences by letting them instead select, drag,

REFERENCES

[1]. B. Graimann, B. Allison, and G. Pfurtscheller, “Brain–Computer Interfaces: A Gentle Introduction”.

[2]. Md. Mahfuzur Rahman, Md. Mahmudul Hasan, Md. Mizanur Rahman, Md. Siam Hasan, Md. Mansurul Alam, “Brain computer interface”, Bangladesh University of Engineering and Technology.

[3]. S. Soman, S. Sen Gupta, P. Govind Raj, “Non invasive Brain Computer Interface for controlling user desktop”, available at www.cdacnoida.in/ASCNT-2012/ ASCNT- 2012/UC/6.pdf

[4]. B. Graimann, B. Allison, and G. Pfurtscheller, “Brain–Computer Interfaces: A Gentle Introduction” Md. Mahfuzur Rahman, Md. Mahmudul Hasan, Md. Mizanur Rahman, Md. Siam Hasan, Md. Mansurul Alam, “Brain computer interface”, Bangladesh University of Engineering and Technology.

[5]. S. Soman, S. Sen Gupta, P. Govind Raj, “Non invasive Brain Computer Interface for controlling user desktop”, available at www.cdacnoida.in/ASCNT-2012/ ASCNT- 2012/UC/6.pdf

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Professor **HARIKRISHNA MUSINADA** received Bachelor of Engineering and M.Tech degrees in ECE from Marathwada University, Aurangabad and JNTU-Hyderabad. He is currently Professor in ECE Department of RVR Institute of Engineering & Technology, Hyderabad and pursuing Ph.D degree at Department of ECE OU-Hyderabad. He has 8 Research papers into his credit published in various International Journals, Magazines and Conference Proceedings. He is an active life member of professional bodies like Indian Society for Technical Education **(MISTE),** Institution of Electronics and Telecommunication Engineers **(MIETE)**, Society of EMC Engineers (INDIA) - **SEMCE (I).** Secured **Best Teacher Award** in the course of teaching and inspiring many students in the academics. He has conducted many conferences, workshops, short term courses and was convener for many technical symposiums in the Engineering colleges he worked. He was Co-Chairman to one of the technical sessions of **2nd International Conference** on Innovations in Electronics and Communication Engineering (ICIECE) organized by ECE Department of Guru Nanak Institutions Technical Campus (GNITC) on 9-10 August, 2013 in association with IETE, ISTE, CSI and BESI. He is an Associate Editor for International Journal of Pure Research in Engineering and Technology (**IJPRET**) and Governing Body Member for International Journal of Ethics in Engineering and management Education (**IJEEE**). His currently research interests include Mixed Signal VLSI design, Bio Technology with Signal Processing.