BRAIN COMPUTER INTERFACE

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ABSTRACT

Brain–computer interfaces (BCIs) enable users to control devices with electroencephalographic (EEG) activity from the scalp or with single-neuron activity from within the brain. EEG has limited resolution and requires extensive training, while single-neuron recording entails significant clinical risks and has limited stability. In this paper we demonstrate that electrocorticographic (ECoG) activity recorded from the surface of the brain can enable users to control a one-dimensional computer cursor rapidly and accurately. It is an area of intense research with almost limitless possibilities. An immediate goal of this paper is to provide a way for people with damaged sensory/motor functions to use their brain to control artificial devices and restore lost capabilities. Recent technical and theoretical advances, have demonstrated the ultimate feasibility of this concept for a wide range of space-based applications. Besides the clinical purposes such an interface would find immediate applications in various technology products also. [1][7]

Keywords : Artificial devices, Electrocorticographic (ECoG), Electroencephalographic (EEG), Single-neuron

I INTRODUCTION

Brain-Machine Interfaces (BMI) or Brain-Computer Interfaces (BCI), also referred to as Neuro-Prostheses, is conceived as technological interfaces between a machine (usually a computer) and the brain of a user. They should permit the use to perform a certain task, usually without implementing any motor action. This implies that neural impulses generated by the user's brain are detected, elaborated and utilized by the machine, approximately in real time, to perform definite tasks. As an example, information can be processed and employed to control mechanical systems (e.g. actuators) or electrical devices (e.g. electronic equipment). 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 logically controlled. Researchers are close to breakthroughs in neural interfaces, meaning we could soon mesh our minds with machines. [1]

In 1969 the operant conditioning studies of Fetz and colleagues at University of Washington School of Medicine in Seattle, showed for the first time that monkeys could learn to control the deflection of a biofeedback meter arm with neural activity. Similar work in the 1970s established that monkeys could quickly learn to voluntarily control the firing rates of individual and multiple neurons in the primary motor cortex if they were rewarded for generating appropriate patterns of neural activity.

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. [2]

II 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 experiments 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.

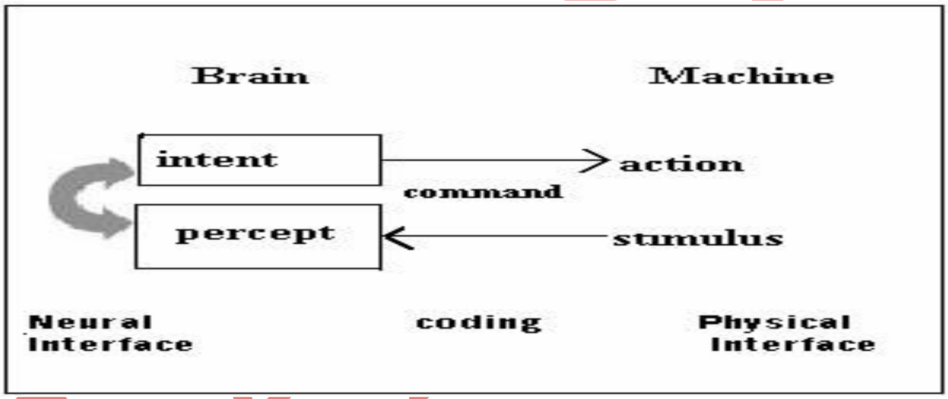

Fig.1 The Organization Of BMI

2.1 Human Brain

It is the organ that allows the person to think, have emotions. The brain is undoubtedly 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 wit h 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.[3]

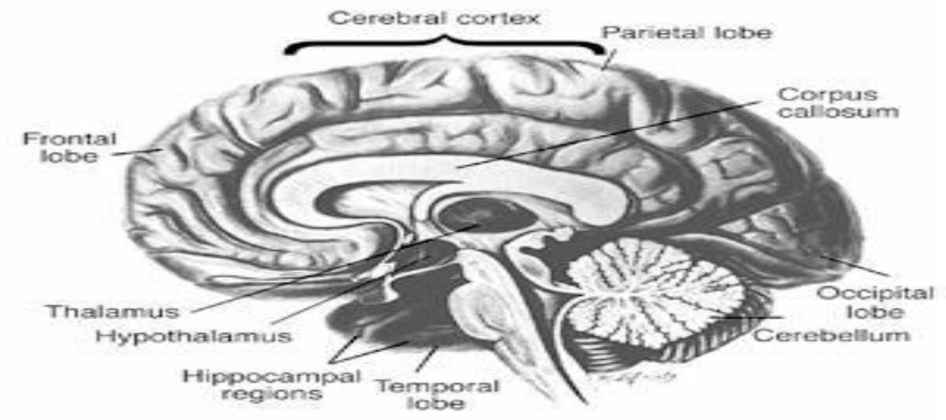

Fig.2 Human Brain

2.2. 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. 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. [3]

III ELECTROENCEPHALOGRAPHY

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.

It is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain.[1] In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals. In neurology, the main diagnostic application of EEG is in the case of epilepsy, as epileptic activity can create clear abnormalities on a standard EEG study

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.[4][5]

IV 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 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. [6]

V 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 intent ions, 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.

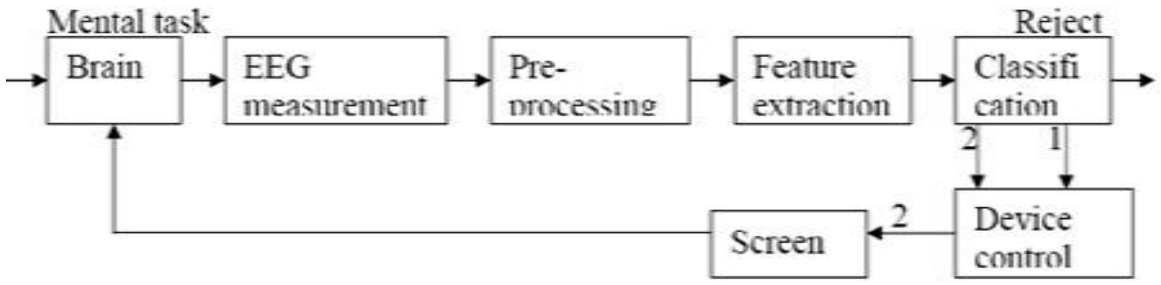

Fig3. A BMI based on the classification of two mental tasks. The user is thinking task number 2 and the BCI classifies it correctly and provides feedback in the form of cursor movement.

5.1 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. [6] [7]

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.

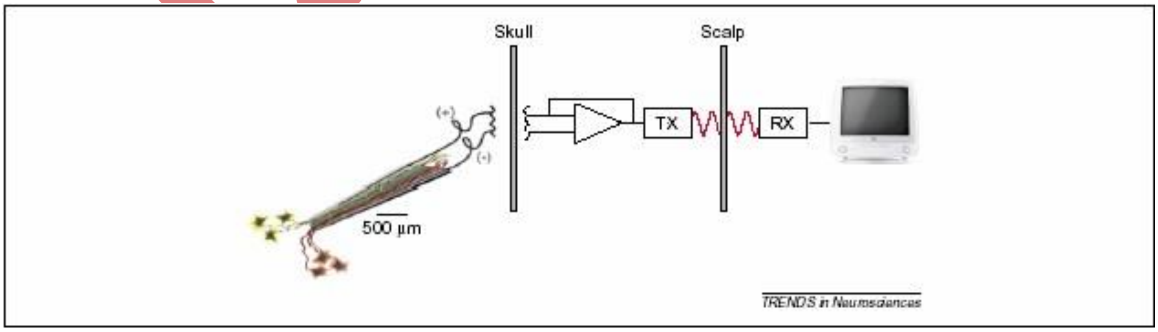

Figure 5: Block diagram of the neurotrophic electrodes for implantation in human patients.

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. Neurites 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.

5.2 Signal Processing Section

5.2.1 Multi-channel Acquisition Systems

Electrodes interface directly to the non-inverting op-amp 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.

5.2.2 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 autonomous spike sorter. Figure 6 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.

5.2.3 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.

The classifier can be anything from a simple linear model to a complex nonlinear neural network that can be trained to recognize different mental tasks. Nowadays real time processing is used widely. Real-time applications provide an action or an answer to an external event in a timely and predictable manner. So by using this type of system we can get output nearly at the same time it receives input. Telemetry is handled by a wearable computer. The host station accepts the data via either a wireless access point or its own dedicated radio card. [3][4]

5.3 External Device

The classifier's output is the input for the device control. The device control simply transforms the classification to a particular action. The action can be, e.g., an up or down movement of a cursor on the feedback screen or a selection of a letter in a writing application. However, if the classification was ―nothing‖ or ―reject‖, no action is performed, although the user may be informed about the rejection. It is the device that subject produce and control motion. Examples are robotic arm, thought controlled wheel chair etc [10]

5.4 Feedback

Real-time feedback can dramatically improve the performance of a brain–machine interface. Feedback is needed for learning and for control. Real-time feedback can dramatically improve the performance of a brain–machine interface. In the brain, feedback normally allows for two corrective mechanisms. One is the 'online' control and correction of errors during the execution of a movement. The other is learning: the gradual adaptation of motor commands, which takes place after the execution of one or more movements.

In the BMIs based on the operant conditioning approach, feedback training is essential for the user to acquire the control of his or her EEG response. The BMIs based on the pattern recognition approach and using mental tasks do not definitely require feedback training. However, feedback can speed up the learning process and improve performance. Cursor control has been the most popular type of feedback in BMIs. Feedback can have many different effects, some of them beneficial and some harmful. Feedback used in BMIs has similarities with biofeedback, especially EEG biofeedback.

VI ADVANTAGES

Depending on how the technology is used, there are good and bad effects.

In this era where drastic diseases are getting common it is a boon if we can develop it to its full potential.

i. Also it provides better living, more features, more advancement in technologies etc.
ii. Linking people via chip implants to super intelligent machines seems to a natural progression – creating in effect, super humans.

iii. Linking up in this way would allow for computer intelligence to be hooked more directly into the brain, allowing immediate access to the internet, enabling phenomenal math capabilities and computer memory.

iv. By this humans get gradual co-evolution with computers.

VII CHALLENGES

Although we already understand the basic principles behind BMIs, they don't work perfectly. There are several reasons for this.

i. Connecting to the nervous system could lead to permanent brain damage, resulting in the loss of feelings or movement, or continual pain.

ii. Virus attacks may occur to brain causing ill effects. The brain is incredibly complex. To say that all thoughts or actions are the result of simple electric signals in the brain is a gross understatement. There are about 100 billion neurons in a human brain. Each neuron is constantly sending and receiving signals through a complex web of connections. There are chemical processes involved as well, which EEGs can't pick up on.

iii. The signal is weak and prone to interference. EEGs measure tiny voltage potentials. Something as simple as the blinking eyelids of the subject can generate much stronger signals. Refinements in EEGs and implants will probably overcome this problem to some extent in the future, but for now, reading brain signals is like listening to a bad phone connection. There's lots of static.

iv. The equipment is less than portable. It's far better than it used to be -- early systems were hardwired to massive mainframe computers. But some BMIs still require a wired connection to the equipment, and those that are wireless require the subject to carry a computer that can weigh around 10 pounds. Like all technology, this will surely become lighter and more wireless in the future.[8][12]

VIII DISADVANTAGES

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ii. Virus attack may occur to brain causing ill effect.[9]

IX APPLICATIONS

The BMI technologies of today can be broken into three major areas:

i. Auditory and visual prosthesis
- Cochlear implants
- Brainstem implants
- Synthetic vision
- Artificial silicon retina

ii. Functional-neuromuscular stimulation (FNS): FNS systems are in experimental use in cases where spinal cord damage or a stroke has severed the link between brain and the peripheral nervous system. They can use brain to control their own limbs by this system

iii. Prosthetic limb control

- Thought controlled motorized wheel chair.[8]
- Thought controlled prosthetic arm for amputee.
- Various neuroprosthetic devices

X FUTURE EXPANSION

A new thought-communication device might soon help severely disabled people get their independence by allowing them to steer a wheelchair with their mind. Mind-machine interfaces will be available in the near future, and several methods hold promise for implanting information. . Linking people via chip implants to super intelligent machines seems to a natural progression –creating in effect, super humans. These cyborgs will be one step ahead of humans. And just as humans have always valued themselves above other forms of life, it is likely that cyborgs look down on humans who have yet to 'evolve'.

Will people want to have their heads opened and wired? Technology moves in light speed now. In that accelerated future, today‘s hot neural interface could become tomorrow‘s neuro trash. Will you need to learn any math if you can call up a computer merely by your thoughts? Thought communication will place telephones firmly in the history books. [8][11]

XI CONCLUSION

BMI's will have the ability to give people back their vision and hearing. They will also change the way a person looks at the world. Someday these devices might be more common than keyboards. The computer can actually take a look inside the user's head to observe their mental state. While brain-based spelling is a reality today, unfortunately, it is rather slow. Thus, it seems that practical application of BCI technology in the area of translation would require a dramatic increase in this communication rate. Along with the spelling of words using brain signals the Identifying, recognizing emotions or feelings through brain signals is the next big thing.[12][13]

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