Human Computer Interaction (HCI)

Priyanka Ashok Ugale[#1]

Student, Department of Computer Engineering, SVIT, Nashik.(Pune University)

Nashik, Maharashtra, India

[1]ugalepriya@gmail.com

Abstract -

The field of Human Computer Interaction (HCI) is an interdisciplinary development having roots in computer graphics, operating systems, human factors, ergonomics, cognitive psychology, and others. This term implies that there is a bidirectional communication between the computer and the user where each communication channel may utilize very different techniques and devices for active communication (one channel for user input and one channel for feedback to the user by the com-puter).Current devices for achieving input into the computer mainly require physical or more precisely mechanical operation by the user, e.g. mouse and keyboard. Feed-back from the computer is commonly given by audio/visual elements, e.g. speakersand monitors showing GUIs. However, the limitations in terms of usability and acces-sibility are well understood and have become apparent throughout the course of time.

The main principle in overcoming these limitations is called Multimodal Interaction and there is a lot of ongoing research in this field. For example, current developments in Multimodal Interaction propose a combination of a visual modality with a voice modality for better usability and accessibility. A somewhat unconventional approach to achieving human-computer-interaction involves directly translating thoughts of the user into commands to the computer. In this context the term thought refers to the computer-aided interpretation of neuronal activities of the user. Neuronal activities may be recorded either at certain extremities of the human (arms, legs, etc.) or at the brain itself by analyzing brain waves. In principle, this approach is not limited to input into the computer but moreover may include methods for the computer to give feedback to the user by directly stimulating neurons. A brain- computer interface (BCI) is a system that acquires and analyzes neural (brain) signals with the goal of creating a high bandwidth communications channel directly between the brain and the computer. As such, the goal is to develop a brain-actuated mouse.

Keywords— EEG: Electroencephalogram, Brain wave (EEG) signals are obtained with sensors located on the user's scalp.

EMG: Electromyogram, Muscle movement (EMG) signals are obtained with sensors that are placed on the user's skin.

EKG: Electrocardiogram, recorded from the heartbeats. BCI: Brain computer interface that has direct interface between brain and the computer.

I.INTRODUCTION

A braincomputer interface BCI, sometimes called a direct neural interface or a machine interface (BMI), brainis a direct communication pathway between the brain and an external device. BCIs are often aimed at assisting, augmenting, or repairing human cognitive or sensory- motor functions.

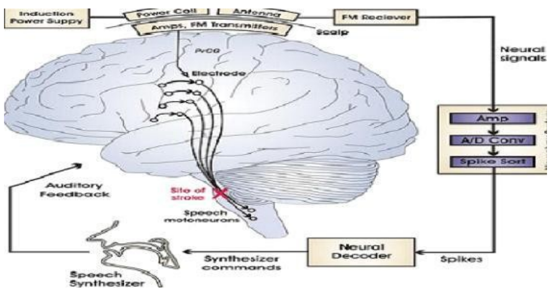

Figure 1.1: Concept Of Brain Computer Interface

Neural interface allows user to take advantage of small electrical signal generated by their bodied that control computer or electrical devices that are attached to their computer. The small electrical can be acquired that recognizes voluntary commands from brain given by the subject itself. Then it triggers appropriate external responses operable without any physical movement.

The response may be speech, writing, or controlling electrical appliance. A brain-computer interface (BCI) is a system that acquires and analyses neural (brain) signals with the goal of creating a high bandwidth communications channel directly between the brain and the computer. Such a channel potentially has multiple uses, for example: bioengineering applications: assist devices for the disabled (e.g. prosthetic aids). Human subject monitoring: sleep disorders, neurological diseases, and attention monitoring, and/or overall "mental state". New paradigm for neuroscience research: real-time methods for correlating observable behavior with recorded neural signals. A penultimate man-machine interface: the Holy Grail. Recent years have seen an increase in research reports aimed at developing and evaluating BCI systems.

A. History

The History of brain computer interfaces (BCIs) starts with Hans Bergers discovery of the electrical activity of human brain and the development of Electroencephalography (EEG). In 1924 Berger was the _rst one who recorded an EEG from human brain. By analyzing EEGs, Berger was able to identify deferent waves or rhythms which are present in a brain, as the Alpha Wave (8 12 Hz), also known as Berger's Wave. Berger's _rst recording device was very rudimentary. He inserted silver wires under the scalp of his patients. Those were replaced by silver foils which were attached to the patients head by rubber bandages later on. More sophisticated measuring devices such as the Siemens double-coil recording galvanometer, which displayed electric voltages as small as one ten thousandth of a volt, led to success. Berger analyzed the interrelation of alternations in his EEG wave diagrams with brain diseases. EEGs permitted completely new possibilities for the research of Human brain activities.

B. Monkey follows

As almost all experiments which include a certain risk for human lives, the _rst experiments were conducted with animals more precisely on primates. Work groups led by Schmidt, Fetz and Baker found out that monkey could get control over the_rerate of individual neurons in the primary motor cortex, which is responsible for executing voluntary movements after a short period of training time. The _rst wireless intracortial brain-computer interface was build by Philip Kennedy and his colleagues by implanting neurotrophic cone electrodes into monkey brains. Several research groups worked on the real-time reconstruction of more complex motor parameters using recordings from neural ensembles, which are clusters of neurons performing a particular neural computation.\

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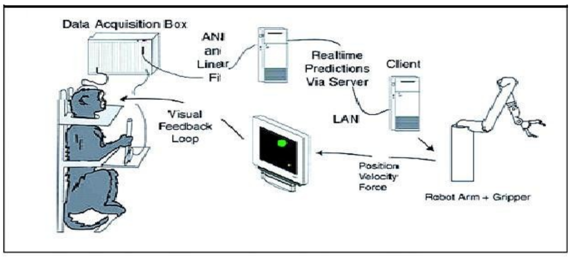

Figure 2.1: Working on Monkey with BCI

C. Human Follows

However, not only monkeys were objects to BCI research but also humans participated in experiments with both invasive (which mean direct contact to the neurons by whatever means) and non-invasive approaches. There have been many experiments using various techniques for reading the brain such as the EEG, MEG, firm or similar methods. Some BCI designs rely on a phenomenon called Cordial Plasticity which states that the location of certain processing functions in the brain can change as the result of experience. This means that this type of design relies heavily on the user adapting to the BCI in order to make it function correctly. From a Human-Computer Interface point of view this is not an acceptable solution. Rather one would expect the BCI to adapt to the user for increased usability.

This approach has been implemented and has proven to be quite successful .One of the _rst persons who bene_t from all the years of BCI research is Matt Nagle. In 2004 an electrode array was implanted into his brain to restore Functionalities he had lost due to paralysis. The system required some training but _nally he was able to control the TV,check emails and do basically everything that can be achieved by using a mouse. He could also open and close a prosthetic hand. Today many researchers at a lot of universities and laboratories are continuing BCI research. However, the present-days achievements are very impressive but there is still a lot of research and studying to be done until the whole potential of Brain- Computer-Interfaces can be tapped.

II.WORKING

As the power of modern computers grows alongside our understanding of the human brain, we move ever closer to making some pretty spectacular science _ctiointo reality. Imagine transmitting signals directly to someone's brain that would allow them to see, hear or feel specie sensory inputs. Consider the potential to manipulate computers or machinery with nothing more than a thought.

It isn't about convenience { for severely disabled people, development of a brain-computer interface (BCI) could be the most important technological break-through in decades. In this article, we'll learn all about how BCIs work, their limitations and where they could be headed in the future. The Electric Brain The reason a BCI works at all is because of the way our brains function. Our brains are filled with neurons, individual nerve cells connected to one another by dendrites and axons. Every time we think, move, feel or remember something, our neurons are at work. That work is carried out by small electric signals that zip from neuron to neuron as fast as 250 mph. [The signals are generated by differences in electric potential carried by ions on the membrane of each neuron.

Although the paths the signals take are insulated by something called myelin, some of the electric signal escapes. Scientists can detect those signals, interpret what they mean and use them to direct a device of some kind. It can also work the other way around. For example, researchers could figure out what signals are sent to the brain by the optic nerve when someone sees the color red. They could rig a camera that would send those exact signals into someone's brain whenever the camera saw red, allowing a blind person to "see" without eyes.

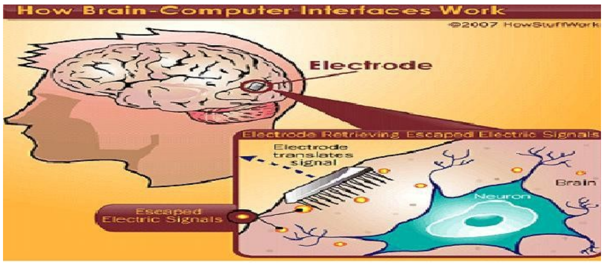

Figure 3.1: How BCI Works.

A. Different interfaces for BCI

Neuroimaging definition Neuroimaging includes the use of various techniques to either directly or indirectly image the Structure, function, or pharmacology of the brain. It is a relatively new discipline within medicine and neuroscience Direct Neural Contact This is the most accurate method of recording potentials occuring in the brain as it has direct contact to every neuron in the brain, e.g. by using nanorobots. Needless to say that this method is highly invasive and impracticable with respect to our current technology. However, with ongoing advances in nanotechnology this method might become reality. Electroencephalography (EEG) This procedure is the _rst non-invasive neuroimaging technique discovered. It measures the Electrical activity of the brain. Due to its ease of use, cost and high temporal resolution this method is the most widely used one in BCIs nowadays.

However, in practice EEGs are highly susceptible to noise and thus require a significant amount of user training in order to be operable in a BCI. Luckily, recent research at the Fraunhofer Society has shown that this problem can be overcome by using neural networks to shift the learning overhead from the human to the computer. Magnetoencephalography (MEG) Though similar to the EEG in that it is a non-evasive technology the MEG is a much newer and more accurate technology. Instead of measuring the electrical activity in the brain this technology records magnetic fields produced by it. The main drawbacks of this technology are its high requirements in equipment. Using MEG requires a room _lled with super-conducting magnets and giant super-cooling helium tanks surrounded by shielded walls. Functional Magnetic Resonance Imaging (fMRI) This technique measures the hemodynamic response (blood ow and blood oxygenation) related to neural activity in the brain by the use of MRI (Magnetic Resonance Imaging formerly known as Magnetic Resonance Tomography MRT). The fact that there is a correlation between neural activity and the brains hemodynamic makes the fMRI a neuro imaging tool. In contrast to the MRI which studies the brains structure this method studies the brains function. As this method requires MRI technology it needs very special equipment and thus is quite costly.

B. BCI Input and Output

One of the biggest challenges facing brain-computer interface researchers today is the basic mechanics of the interface itself. The easiest and least invasive method is a set of electrodes { a device known as an electroencephalograph (EEG) attached to the scalp. The electrodes can read brain signals. However, the skull blocks a lot of the electrical signal, and it distorts what does get through. To get a higher-resolution signal, scientists can implant electrodes directly into the gray matter of the brain itself, or on the surface of the brain, beneath the skull. This allows for much more direct reception of electric signals and allows electrode placement in the specific area of the brain where the appropriate signals are generated. This approach has many problems, however. It requires invasive surgery to implant the electrodes, and devices left in the brain long-term tend to cause the formation of scar tissue in the gray matter. This scar tissue ultimately blocks signals. Regardless of the location of the electrodes, the basic mechanism is the same: The electrodes measure minute differences in the voltage between neurons. The signal is then amplified and altered. In current BCI systems, it is then interpreted by a computer program, although you might be familiar with older analogue encephalographs, which displayed the signals via pens that automatically wrote out the patterns on a continuous sheet of paper. In the case of a sensory input BCI,the function happens in reverse. A computer converts a signal, such as one from avideo camera, into the voltages necessary to trigger neurons.The signals are sent to an implant in the proper area of the brain, and if ev-erything works correctly, the neurons _re and the subject receives a visual image corresponding to what the camera sees. Another way to measure brain activity is with a Magnetic Resonance Image (MRI). An MRI machine is a massive, complicated device. It produces very high-resolution images of brain activity, but it can't be used as part of a permanent or semi permanent BCI. Researchers use it to get benchmarks for certain brain functions or to map where in the brain electrodes should be placed to measure a specific function. For example, if researchers are attempting to implant electrodes that will allow someone to control a robotic arm with their thoughts, they might _rst put the subject into an MRI and ask him or her to think about moving their actual arm. The MRI will show which area of the brain is active during arm movement, giving them a clearer target for electrode placement.

III. ADVANTAGES AND DISADVANTAGES

A.Advantages

1. Easy to use The user can will a cursor to move until it reaches a specific character on a virtual keyboard on a computer screen, and then select it to compose an instruction. By creating command sequences (i.e. by thinking) the user can, for example, read a web page, play computer games, turn on appliances and even guide a wheelchair. The virtual keyboard can also be used to write messages. All of this can be achieved after just a short training period, so it is very easy to use.
2. Compact, suitable for deployment in natural environments The neural network is capable of learning the brain patterns of the individual who is using it. This learning process is important as no two individuals have the same reaction. At the same time, each user can adapt his own way of thinking to get the best out of the machine. The ABI can currently distinguish reliably between threemental tasks chosen by the user for example, moving a hand, visualizing a rotating cube or mental arithmetic.
3. Bene_cial for physically impaired people While ABI is concerned immediately with helping disabled people live a better life, other uses could soon be developed, for example in the medical diagnosis of brain disorders and psychological research. It could also help tackle health and safety issues by monitoring levels of alertness. Later versions could be used for general education and entertainment.
4. Excellent performance BCI shows excellent performance in extreme conditions like electromagnetic _elds, ambient noise and people moving and talking in the vicinity. -Expressing Commands Messages and commands are expressed not by muscle contractions but rather by signals generated in the brain. - Speed and accuracy Greater speed and accuracy is achieved that is, information transfer takes place at higher rates.

B. Disadvantages

1. 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.

2. 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. Revetments 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.

3. 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 BCIs still require a wired connection to the equipment, and those that are wireless requirethe subject to carry a computer that can weight around 10 pounds. Like all technology, this will surely become lighter and more wireless in the future.

C. Application

Apart from being a non-conventional input device for a computer we have found three main application Fields for BCIs and BCI related devices which are more or less controversial: _ Medical applications
_ Human enhancement
_ Human manipulation

IV. CONCLUSIONS

Depending on the use case each technology has its pros and cons, but when wanting to type letters VEP is still the fastest and most e_cient method. In the case of more analogue control ERS/ERD is more applicable. Of course, there are many more techniques and application scenarios than shown in this paper, but these somehow show the basics. These can be combined in order to increase precision and functionality. Future applications will probably leverage a more detailed picture of brain waves and there is also a trend towards implants so that very specific signals can be altered. Also, implants are of good use if the EEG is too weak e. g. as a result of a cerebral apoplexy.

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