Brain Computer Interface

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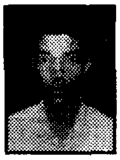

S.Y.B.Tech. (Textiles)

Swapnil V. Vasaikar : I want to pursue an M.B.A degree after completing my B.Tech. in textiles. First I would like to gain some technical experience, and finally set up a factory based on my knowledge and experience.

Abstract

Being fully awake and alert but trapped in a body that is unable to move or speak must be very frightening and frustrating. The main difficulty that is they are not able to express themselves. This is often the situation for patients in the late stages of Lou Gehrig's disease (Amyotrophic Lateral Sclerosis or ALS). Now there is new hope that computers may be able to help these patients to communicate by, in a way, "Reading their minds." The interface relies on the biosignal originated from brain waves. These are sent to computer for processing by the means of a Brain Computer Interface (BCI) such as *simple word processing, moving robotic limbs, playing video games* through the use of a brain computer interface (BCI).

These requirements have resulted in experiments that rely highly on directional attention patterns and selection among stimuli presented simultaneously or very close together in time. Absence of a detailed understanding of the complex physiological and psychological means of producing the responses, experimenters depend on response traces in the Electroencephalogram (EEG). The EEG with surface-mounted electrodes provides a minimally invasive way to detect brain activity. Many experimenters cite its shortcomings stemming from the extreme reduction of billions of simultaneous electrical events to a few traces, and the attenuation of weak signals by the skull. Some experimenters suggest surgical implantation and single-neuron sensing as supporting more reliable detection. Such techniques have low relevance for BCI applications in normal individuals. BCI technology is beginning to provide severely disabled individuals with alternative communication options.

1. Introduction

Less than a decade ago, hardly anyone could have predicted that attempts to build direct functional interfaces between brains and artificial devices, such as computers and robotic limbs, would have succeeded so readily, and in the process would lead to the establishment of a new era in neuroscience. The last 6 years have witnessed a rapidly-growing body of research and technique development involving detecting human brain responses and putting these techniques to appropriate uses to help people with debilitating diseases or who are disabled in some way - the so-called "Brain-Computer Interface" (BCI).

The chief difference between BCI techniques and those studied in more common human-computer interface (HCI) tasks lies in not relying on any sort of muscular response, but only detectable signals representing responsive or intentional brain activity.

The first experimental demonstration by Mikhail A. Lebedev in 1999, showed that ensembles of cortical neurons could directly control a robotic manipulator. Since then, a continuous stream of research papers has kindled an enormous interest in BCIs among the scientific community and the lay public. This interest stems from the considerable potential of this technology for restoration of motor behaviors in severely handicapped patients. Indeed, BCI has been primarily conceived as a potential new therapy to restore motor control in severely disabled patients, particularly those suffering from devastating conditions such as amyotrophic lateral sclerosis (ALS), spinal cord injury, stroke and cerebral palsy. As this technology advances and the risks of invasive brain recordings decrease, BCIs might also hold promise for amputees. In addition to the systems controlling upper limb prostheses, BCIs dedicated to the restoration of locomotion and speech are likely to emerge.

2. What is Brain-Computer Interface (Bci) ?

A BCI is a computer device that helps a person operate a computer by using systems that measure brain waves rather than using his or her hands. Changes in the brain waves are then converted to an output perceivable by the human mind.

2.1 How it Works ?

The schematic sketch of BCI is shown in fig.1.

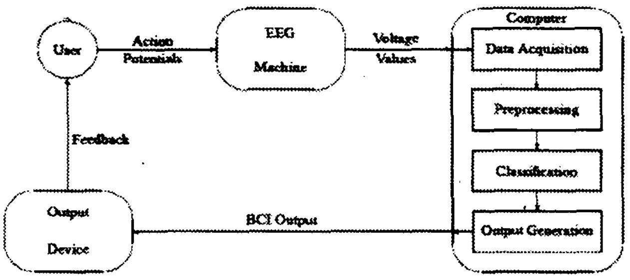

Fig.1. Schematic sketch of a BCI

Here, is a BCI user. When he thinks something, certain types of signals/waves are generated in his brain called "Brain Waves". These waves are given to an Electroencephalogram (i.e. EEG) machine. This machine produces equivalent potential values of these brain waves, which are further given to computer. In the computer various software algorithms sort the brain waves and finally the output device gives the output.

The output device may be a Robotic limb, Thought controlled wheelchair, etc.

3. Types of BCI

There are two types of BCI -

- Invasive BCIs
- Non-invasive BCIs

The first feature that distinguishes BCIs is whether they utilize Invasive (i.e. Intra-cranial) or Non-invasive (i.e. Extra-cranial) methods of electrophysiological recordings.

3.1 Invasive BCIs

Invasive method consists of electrodes implanted intra-cranially. This methodology provides neural signals of best quality and has a potential for further improvement, although it carries a risk of surgical procedure.

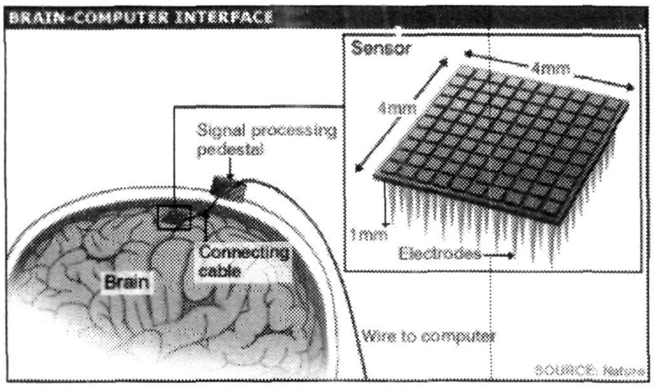

Fig.2. INVASIVE BCIs

3.2 Non Invasive BCIs

Non-invasive systems primarily exploit electroencephalograms (EEGs) to control computer cursors or other devices. This technique is based on the recordings of EEGs from the surface of the head. There is no risk of surgical procedure. It provides solutions to the paralyzed people for simple communications with the outside world. However, neural signals have a limited bandwidth. Their typical transfer rate is currently 5–25 bits/s.

4. Brain Waves

Brain waves are patterns of electrical brain activity. Brain cells can communicate with each other by electricity and chemicals called **Neurotransmitters**. Brain wave depends on thoughts and mental activities.

4.1 Electroencephalogram (EEG)

EEG records Brain Potential by placing Electrode Cap over the scalp.

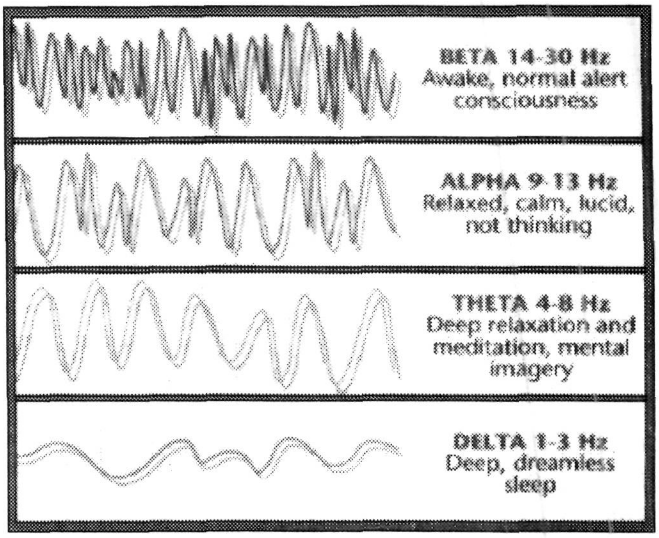

Fig.3. Classification of Brain Waves

For this test, tiny metal discs called *electrodes* are painlessly stuck to the scalp with gel or paste. These electrodes can pick up the electrical impulses of the brain, which pass through the skull. This electrical activity is very weak, so the signal is then amplified by an EEG machine.

The EEG machine then displays the recorded brain electrical activity on a computer screen or paper tracing. Brain waves measured by EEG do not represent a particular thought or movement, but rather represent a summary of the brain's electrical activity at a recording point on the scalp. You could compare an EEG recording to being able to look at an ocean and identify that there are big or little waves and determine what direction they are coming from, but not being able to pick out one individual wave. Brain waves can be altered by thoughts of planned action (such as thinking of moving a hand), without actually moving the hand itself.

While using a brain-computer interface (BCI), users can learn to self modulate brain activity to perform a simple computer activity, such as spelling, answering yes or no questions, or moving a cursor on a computer monitor. Recent research has shown that recording from Electrocorticogram (ECoG) can provide increased accuracy in these tasks when compared to using an Electroencephalogram (EEG). To measure and characterize responses to motor imagery, patients were asked to imagine facial movements. Online testing gives patients feedback of important brain signal characteristics, allowing voluntary modulation of brain activity to move a cursor to a target on the computer screen. The two modalities (motor and auditory) were each used independently to control movement in the horizontal direction. Once sufficient accuracy is achieved for each modality, the patients were provided with the task of controlling auditory and motor responses simultaneously for cursor control in two dimensions. For example, the auditory component could control vertical cursor movement, and the motor component could horizontal cursor movement.

5. Current Brain-Computer Interface Techniques

5.1 Technique: P300 Evoked Potential Detection

Farwell [Farwell and Donchin, 1988] describes a technique for detecting the P300 component of a subject's event-related brain potential (ERP) and using it to select from an array of 36 screen positions. The P300 component is a positive-going ERP in the EEG with a latency of about 300ms following the onset of a rarely-occurring stimulus the subject has been instructed to detect. The EEG was recorded using electrodes placed at the Pz (parietal) site. Electro-oculogram (EOG) data was also recorded from each subject via electrodes placed above and below the right eye. The "odd-ball" paradigm was used to elicit the P300, where a number of stimuli are presented to the experimental subject who is required to pay attention to a particular, rarely-occurring stimulus and respond to it in some non-motor way, such as by counting occurrences. Detecting the P300 response reliably requires averaging the EEG response over many presentations of the stimuli.

The experiment presented a 36-position array of letters, plus common typing characters and controls (e.g. space, backspace), made to flash in a random sequence first by rows and then columns. Each trial consisted of a complete set of six columns or row flashes. Trials contaminated with muscular or EOG response were rejected and additional trials presented until data were collected from a block of 30 good trials, during which subjects were to fixate on a particular position, and count the number of times it flashed while a control message was elsewhere on the screen. After each block the fixated letter (one of B-R-A-I-N) was added to the screen so that subjects were conscious of slowly spelling out the word "BRAIN" through a succession of five blocks. It takes 93.6 seconds of presentation per character, an effective communication rate range of 0.01 to 0.8 characters-per-second, respectively.

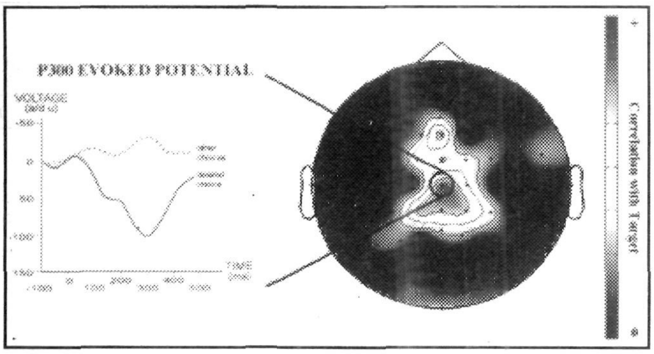

Fig.4. P300 Evoked Potential Detection

5.2 Technique: EEG - Mu Rhythm Conditioning

Wolpaw [Wolpaw et al 1991], McFarland [McFarland et al 1993], and colleagues describe subject's abilities to move a cursor toward a target on a computer screen by manipulating their mu- rhythm, a detectable pattern in a great majority of individuals in the EEG 8-12Hz frequency range, centered about 9.1 Hz.

The 8-12 Hz activity over the central sensorimotor cortex – present in nearly all adults is called the *mu rhythm*. According to (LaCourse and Wilson 1995), mu waves are almost constantly present when the subject is relaxed and disappear when the subject moves a hand or a finger of the contra lateral side, i.e. mu waves disappear over the left brain hemisphere when the right hand is moved and vice versa. In addition, humans can learn to modify the amplitude of the mu rhythm after prolonged training (on the order of weeks or months) with the help of mental activities alone. This is the starting point of the system described in (Wolpaw *et al.* 1991). Their idea is to take that amplitude – measured by only one pair of electrodes – and translate it into (one-dimensional) cursor movement.

6. Discussion

The brain-computer interface provides new ways for individuals to interact with their environment. The computer will continue to be a necessary component as long as detecting a brain response reliably remains a complex analytical task. In most cases, the brain response itself is not new, just the means of detecting it and applying it as a control. However, the necessary feedback associated with experimental trials frequently resulted in improved, or at least changed performance.

All current experiments ally brain responses with one or more of the five senses, most often vision, for stimulating subjects. This emphasis results in experiments that rely on highly directional attention patterns and selection among stimuli presented simultaneously or very close together in time. Absent a detailed understanding of the complex physiological and psychological means of producing the responses, experimenters depend on response traces in the EEG to detect particular occurrences. While the EEG with surface-mounted electrodes provides a minimally invasive way to detect brain activity, many experimenters cite its shortcomings stemming from the extreme reduction of billions of simultaneous electrical events to a few traces, and the attenuation of weak signals by the skull.

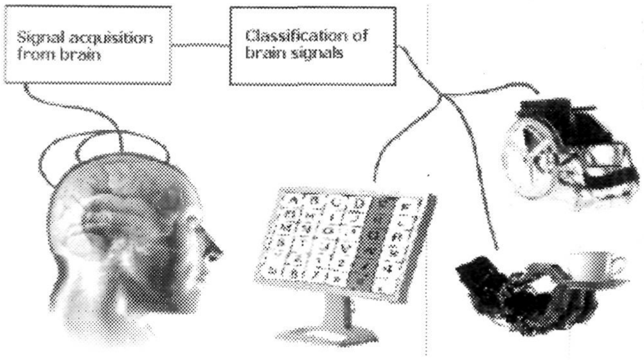

Fig.5. Application of BCI

7. Conclusion

BCI technology is beginning to provide severely disabled individuals with alternative communication options. Modulation of scalp recorded EEG has improving performance in a variety of settings. Standard BCI training protocols can be used in a similar fashion. Appropriate studies can be designed and conducted to test the efficacy of the methods. Experimenters see BCI techniques as offering much potential for useful applications for individuals with reduced capabilities for muscular response. They cited communicating with others (writing, making their needs known) and manipulating devices (computer, television set, wheelchair) as important targets for brain-computer control.

By reaching these milestones, future BCIs will be able to drive and control revolutionary prostheses, which will help a severely disabled to live a healthy life.

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