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A STUDY ON BRAIN–MACHINE INTERFACE (BMI)

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ABSTRACT

A brain–machine interface (BMI), sometimes called a mind-machine interface (MMI), or sometimes called a direct neural interface (DNI), synthetic telepathy interface (STI) or a brain–machine interface (BMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions.

The field of BCI research and development has since focused primarily on neuroprosthetics applications that aim at restoring damaged hearing, sight and movement. Thanks to the remarkable cortic al plasticity y of the brain, signals from implanted prostheses can, after adaptation, be handled by the brain like natural sensor or effector channels.

KEYWORDS: Brain-Machine interface, Mind Machine Interface, direct neural interface (DNI), synthetic telepathy interface (STI).

INTRODUCTION

Early speculation

Electrical signals produced by brain activity were first recorded from the cortical surface in animals by Richard Caton in 1875 (Caton, 1875) and from the human scalp by Hans Berger in 1929 (Berger, 1929).

In the 75 years since Berger's first report, electroencephalographic (EEG) activity has been used mainly for clinical diagnosis and for exploring brain function. Nevertheless, throughout this period, scientists and others have speculated that the EEG or other measures of brain activity might serve an entirely different purpose, that they might provide the brain with another means of conveying messages and commands to the external world. While normal communication and control necessarily depend on peripheral nerves and muscles, brain signals such as the EEG suggested the possibility of non-muscular communication and control, achieved through a brain–computer interface (BCI).

Recent interest and activity

Despite long interest in this possibility, and despite isolated demonstrations (e.g., Vidal, 1973; 1977) it has only been in the past two decades that sustained research has begun, and only in the past 10 years that a recognizable field of BCI research, populated by a rapidly growing number of research groups, has developed. This recent interest and activity reflect the confluence of four factors.

The first factor is the greatly increased appreciation of both the needs and the abilities of people severely affected by motor disorders such as cerebral palsy, spinal cord injury, brain stem stroke, amyotrophic lateral sclerosis (ALS), and muscular dystrophies. Modern life-support technology (e.g., home ventilators) now enables the most severely disabled people to survive for many years. Furthermore, it is now clear that even people who have little or no voluntary muscle control, who may be totally "locked-in" to their bodies, unable to communicate in any way, can lead lives that are enjoyable and productive if they can be provided with even the most minimal means of communication and control (Simmons et al., 2000; Maillot et al., 2001; Robbins et al., 2001).

The second factor is the greatly increased understanding of the nature and functional correlates of EEG and other measures of brain activity, understanding that has come from animal and human research. In tandem with this new knowledge have come better methods for recording these signals, both in the short and the long term. This new knowledge and technology are guiding and supporting increasingly sophisticated and effective BCI research and development.

The third factor is the availability of powerful low-cost computer hardware that allows complex real-time analyses of brain activity, which is essential for effective BCI operation. Much of the online signal processing used in present-day BCIs was impossible or prohibitively expensive until recently.

The fourth factor responsible for the recent surge in BCI research is new recognition of the remarkable adaptive capacities of the central nervous system (CNS), both in normal life and in response to damage or disease. This recognition has generated great excitement and interest in the possibility of engaging these adaptive capacities to establish new interactions between brain tissue and computer-based devices, interactions that can replace or augment the brain's normal neuromuscular interactions with the world.

WHAT IS A BMI AND WHAT IT IS NOT

A BMI is a communication and control system that does not depend in any way on the brain's normal neuromuscular output channels. The user's intent is conveyed by brain signals (such as EEG) rather than by peripheral nerves and muscles, and these brain signals do not depend for their generation on neuromuscular activity. (Thus, e.g., a device that uses visual evoked potentials to determine eye-gaze direction is not a true BMI, for it relies on neuromuscular control of eye position, and simply uses the EEG as a measure of that position.)

Furthermore, as a communication and control system, a BMI establishes a real-time interaction between the user and the outside world. The user receives feedback reflecting the outcome of the BC'Is operation, and that feedback can affect the user's subsequent intent and its expression in brain signals.

For example, if a person uses a BCI to control the movements of a robotic arm, the arm's position after each movement is likely to affect the person's intent for the next movement and the brain signals that convey that intent. Thus, a system that simply records and analyzes brain signals, without providing the results of that analysis to the user in an online interactive fashion, is not a BCI. Figure 33.1 shows the basic design and operation of any BCI.

THE FUNDAMENTAL PRINCIPLE OF BCI OPERATION

Much popular speculation and some scientific endeavors have been based on the fallacious assumption that BCIs are essentially "wire-tapping" or "mind-reading" technology, devices for listening in on the brain, detecting its intent, and then accomplishing that intent directly rather than through muscles.

This misconception ignores the central feature of the brain's interactions with the external world: that the motor behaviors that achieve a person's intent, whether it be to walk in a certain direction, speak certain words, or play a certain piece on the piano, are acquired and maintained by initial and continuing *adaptive changes* in CNS function. During early development and throughout later life, CNS neurons and synapses continually change both to acquire new behaviors and to maintain those already acquired (Salmoni et al., 1984; Ghez and Krakauer, 2000). Such CNS plasticity underlies acquisition of standard skills such as locomotion and speech and more specialized skills as well, and it responds to and is guided by the results achieved.

For example, as muscle strengths, limb lengths, and body weight change with growth and aging, the CNS adjusts its outputs so as to maintain the desired results.

BCI Operation

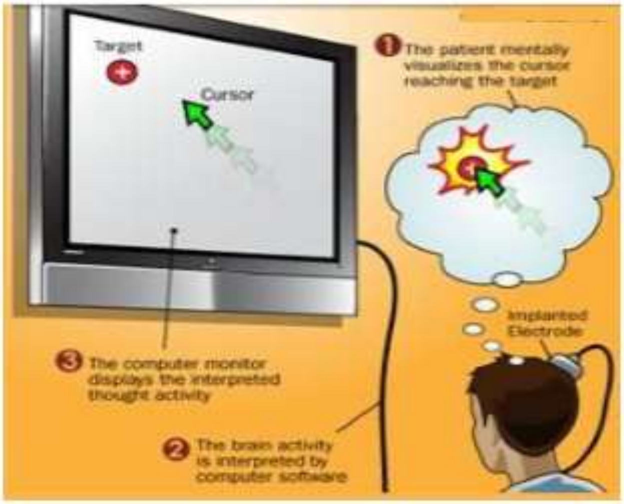

Fig-3.1 BCI OPERATION

This dependence on initial and continuing CNS adaptation is present whether the person's intent is accomplished in the normal fashion, that is, through peripheral nerves and muscles, or through an artificial interface, a BCI, that uses brain signals rather than nerves and muscles. BCI use depends on the interaction of two adaptive controllers: the user, who must generate brain signals that encode intent; and the BCI system, that must translate these signals into commands that accomplish the user's intent

BCI System

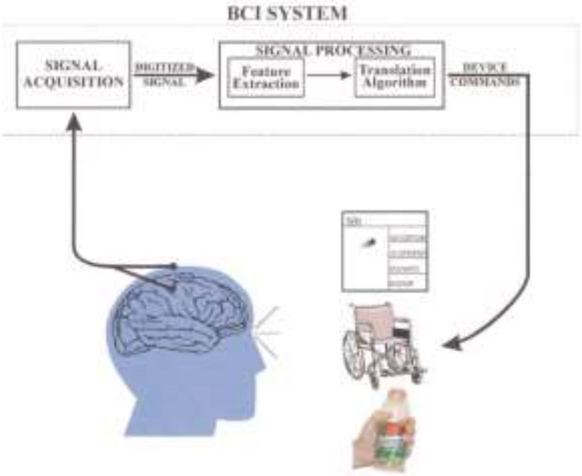

FIG 3.2 BCI SYSTEM

Thus, BCI use is a skill that both user and system must acquire and maintain. The user must encode intent in signal features that the BCI system can measure; and the BCI system must measure these features and translate them into device commands. This dependence, both initially and continually, on the adaptation of user to system and system to user is the fundamental principle of BCI operation; and its effective management is the principal challenge of BCI research and development.

ARCHITECTURE

BCI is a brand new branch of pattern recognition. The general architecture of BCI systems is shown below.

Architecture

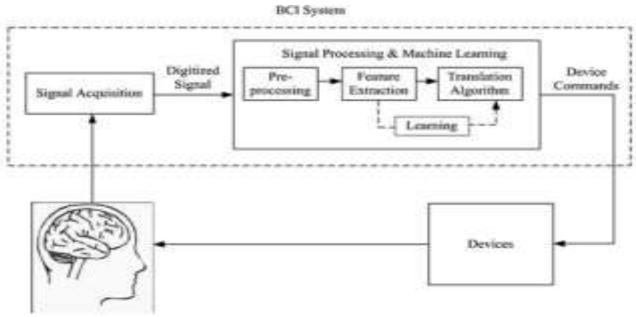

FIG-4 of ARCHITECTURE

Data acquisition: Brain signals are first acquired using sensors. Such as using EEG Neuro headset or electrode cap placed on the scalp to acquire and measure these signals.

Preprocessing: Improving the SNR by removing what could reduce the quality of the signal like “Noise” and “artifacts”. Many signal components are noisy, For Example: The user’s intent generates signals that are not associated with brain patterns, also the hardware used to acquire the brain signals. Examples of artifacts are signals generated by eye or muscle activity, which are recorded simultaneously with the brain signals. Preprocessing methods such as spatial filtering and temporal filtering can improve signal quality by greatly reducing noise and artifacts.

Signal processing: the translation algorithm

The first part of signal processing simply extracts specific signal features. the next stage, the translation algorithm, translates these signal features into device commands orders that carry out the user’s intent. this algorithm might use linear methods (e.g. classical statistical analyses (jain et al., 2000) or nonlinear methods (e.g. neural networks). whatever its nature, each algorithm changes in dependent variables (i.e. signal features) into dependent variables (i.e. device control commands).effective algorithms adapt to each user on 3 levels. first, when a new user first accesses the BCI the algorithm adaptsto that user’s signal features. If the signal feature is murhythmamplitude, the algorithm adjusts to the user’s range of mu-rhythm amplitudes; if the feature is P300amplitude, it adjusts to the user’s characteristic P300 amplitude; and if the feature is the firing rate of a single cortical neuron, it adjusts to the neuron’s characteristic range offering rates. A BCI that possesses only this first level of adaptation, i.e. that adjusts to the user initially and never again, will continue to be effective only if the user’s performance is very stable. However, EEG and other electrophysiological signals typically display short- and long-term variations linked to time of day, hormonal levels, immediate environment, recent events, fatigue, illness, and other factors. Thus, effective BCIs need a second level of adaptation: periodic online adjustments to reduce the impact of such spontaneous variations. A good translation algorithm will adjust to these variations so as to match as closely as possible the user’s current range of signal feature values to the available range of device command values. While they are clearly important, neither of these first two levels of adaptation addresses the central fact of effective

BCI operation: its dependence on the effective interaction of two adaptive controllers, the BCI and the user’s brain. The third level of adaptation could respond to this increase by rewarding the user with faster communication. It would thereby recognize and encourage the user’s development of greater skill in this new form of communication. On the other hand, excessive or inappropriate adaptation could impair performance or discourage further skill development. Proper design of this third level of adaptation is likely to prove crucial for BCI development. Because this level involves the interaction of two adaptive controllers, the user’s brain and the BCI system, its design is among the most difficult problems confronting BCI research.

The output device

For most current BCIs, the output device is a computerscreen and the output is the selection of targets, letters, oricons presented on it (e.g. Farwell and Donchin, 1988;Wolpaw et al., 1991; Perelmouter et al., 1999; Pfurtschelleret al., 2000a). Selection is indicated in various ways (e.g. the letter flashes). Some BCIs also provide additional, interimoutput, such as cursor movement toward the item prior to itsselection (e.g. Wolpaw et al., 1991; Pfurtscheller

et al.,2000a). In addition to being the intended product of BCI operation, this output is the feedback that the brain uses to maintain and improve the accuracy and speed of communication. Initial studies are also exploring BCI control of aneuroprosthesis or orthes is that provides hand closure to people with cervical spinal cord injuries (Lauer et al.,2000; Pfurtscheller et al., 2000b). In this prospective BCI application, the output device is the user's own hand.2.3.5. The operating protocol Each BCI has a protocol that guides its operation. This protocol defines how the system is turned on and off, whether communication is continuous or discontinuous, whether message transmission is triggered by the system(e.g. by the stimulus that evokes a P300) or by the user, the sequence and speed of interactions between user and system, and what feedback is provided to the user. Most protocols used in BCI research are not completely suitable for BCI applications that serve the needs of people with disabilities. Most laboratory BCIs do not give the user on/off control: the investigator turns the system on and off. Because they need to measure communication speed and accuracy, laboratory BCIs usually tell their users what
messages or commands to send

Brain Signals That Can or Might Be Used In A BCI

In theory, brain signals recorded by a variety of methodologies might be used in a BCI. These methodologies include: recording of electrical or magnetic fields; functional magnetic resonance imaging (fMRI); positron emission tomography PET); and infrared (IR) imaging.

In reality, however, most of these methods are at present not practical for clinical use due to their intricate technical demands, prohibitive expense, limited real-time capabilities, and/or early stage of development. Only electrical field recording is likely to be of significant practical value for clinical applications in the near future surface (electrocorticographic activity, (EcoG)), or from within the brain (local field potentials (LFPs)) or neuronal action potentials (spikes)). These three alternatives are shown in Fig. 33.2. Each recording method has advantages and disadvantages. EEG recording is easy and non-invasive, but EEG has limited topographical resolution and frequency range and may be contaminated by artifacts such as electromyographic (EMG) activity from cranial muscles or electrooculographic (EOG) activity.

EOG has better topographical resolution and frequency range, but requires implantation of electrode arrays on the cortical surface, which has as yet been done only for short periods (e.g., a few days or weeks) in humans. Intracortical recording (or recording within other brain structures) provides the highest resolution signals, but requires insertion of multiple electrode arrays within brain tissue and faces as yet unresolved problems in minimizing tissue damage and scarring and ensuring long-term recording stability. The ultimate practical value of each of these recording methods will depend on the range of communication and control applications it can support and the extent to which its limitations can be overcome.

Brain Signals That Can Or Might Be Used In A BCI

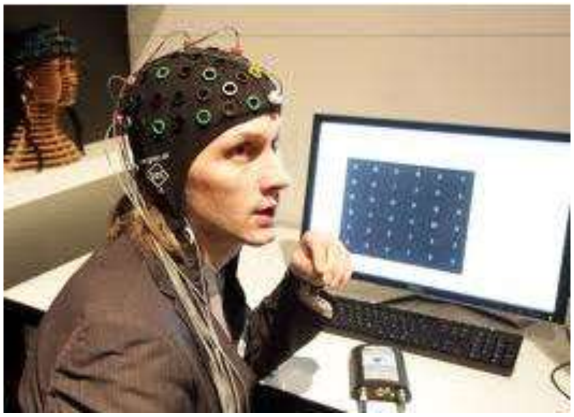

Fig-4.3 Brain Signals That Can Or Might Be Used In A Bci

PRESENT-DAY BCIS

Human BCI experience to date has been confined almost entirely to EEG studies and short-term ECoG studies. Intracortical BCI data come mainly from animals, primarily monkeys. The available human data indicate that EEG-based methods can certainly support simple applications and may be able to support more complex ones. Invasive methods appear able to support complex applications, but the issues of risk and long-term recording stability are not yet resolved users to write words at a rate of one or a few letters per minute.

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. For example, suppose that the feature is the amplitude of a 8– 12 Hz mu rhythm in the EEG over sensorimotor cortex; that the user can vary this feature over a range of 2–10_V; and that the application is vertical cursor movement. In this case, the translation algorithm must ensure that the 2– 10_V range allows the user to move the cursor both up and down.

Present-Day BCIS

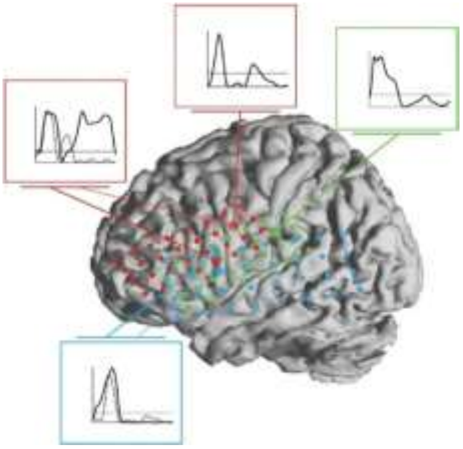

Fig-5PRESENT-DAY BCIS

Furthermore, the algorithm must accommodate spontaneous variations in the user’s range of control (e.g., if diurnal change, fatigue, or another factor changes the available voltage range) (e.g., Ramoser et al., 1997). Finally the translation algorithm should have the capacity to at least accommodate, and at best encourage, improvements in the user’s control.

For example, if the user’s range of control improves from 2–10 to 1–15_V, the translation algorithm should take advantage of this improvement to Increase the speed and/or precision of cursor movement control.

FUTURE WORK

It is possible that the interaction between the brain and the computer be in the opposite direction from the computer to the brain, instead of measuring electrical signals it can send signals to the brain similar to the signals transmitted by the optic nerve to the brain to recognize the picture, Using a camera capable of generating and transmitting electrical signals to the brain directly helps the human vision without the using eyes.

CONCLUSION

The possibility that EEG activity or other electrophysiological measures of brain function might provide new non-muscular channels for communication and control (i.e., BCIs) has been a topic of speculation for many years. Over the past 15 years, numerous productive BCI research and development programs have been initiated. These endeavors focus on developing new augmentative communication and control technology for those with severe neuromuscular disorders, such as ALS, brain stem stroke, and spinal cord injury. The immediate objective is to give these users, who may be totally paralyzed, or “locked-in,” basic communication capabilities so that they can express their desires to caregivers or even operate word-processing programs or neuroprostheses. Current BCIs determine the intent of the user from ectrophysiological signals recorded non-invasively from the scalp (EEG) or invasively from the cortical surface (ECoG) or from within the brain (neuronal action potentials).These signals are translated in real-time into commands that operate a computer display or other device. Successful operation requires that the user encode commands in these signals and that the BCI derive the commands from the signals. Thus, the user and the BCI system need to adapt to each other both initially and continually so as to ensure stable performance. This Dependence on the mutual adaptation of user to system and system to user is the fundamental principle of BCI operation.

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