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Survey of Brain Computer Interaction

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ABSTRACT: A brain computer interface (BCI), often called a mind machine interface (MMI), or sometimes called a brain machine interface (BMI), is a direct communication pathway between the brain and an external device. Over the past decade, researches have begun to explore brain computer interface (BCI) technology which is a new communication option for the people who are paralyzed or 'locked in'. These types of persons prevent from using conventional augmentative communication methods. In BCI, user's communication channels do not depend on peripheral nerves and muscles. Brain computer interface (BCI) systems provide communication and control capabilities to people with severe disabilities. Current BCI's use electroencephalographic (EEG) activity recorded at the scalp or single unit activity which record from within cortex to control cursor movement, select letters or icons. BCI operation depends on effective interaction between two adaptive controllers, the user who encodes his or her commands in the electrophysiological input provided to the BCI, and the BCI which recognizes the commands contained in the input and expresses them in device control. Current BCI's have maximum information transfer rates of 5–25 b/min. BCI technology depends on the development of appropriate applications, identification of appropriate user groups, and careful attention to the needs and desires of individual users.

Keywords: Brain computer interface (BCI), electroencephalographic (EEG), augmentative communication, transfer rates.

I. INTRODUCTION

A. What is BCI?

A brain computer interface (BCI), often called a mind-machine interface (MMI), or sometimes called a brain–machine interface (BMI), is a direct communication pathway between the brain and an external device. A BCI is a communication and control system that does not depend in on the brain's normal output channels. The user's intent is conveyed by brain signals (such as EEG) rather than by peripheral nerves and muscles, it means so keyboard or mouse dependency and these brain signals do not depend for their generation on neuromuscular activity. Furthermore, as a communication and control system, a BCI 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.

B. Early History

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, electro- encephalographic (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 use 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).

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C. Recent interest and activity in BCI

This recent interest and activity focus on the four factors. The first factor is the greatly increased appreciation of both the needs and the abilities of people severely affected by paralysis or 'locked-in' motor disorders such as cerebral palsy, spinal cord injury, brain stem stroke, amyotrophic lateral sclerosis (ALS). 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, which 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. 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. With this new knowledge better methods have come for recording these signals, both in the short and the long term. This new knowledge and technology are guiding and supporting 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 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.

II. BCI SYSTEM BASIC PRINCIPLE

"A BCI uses brain signals to control a device or to adjust the communication between user and device". The system that simply records and analyzes brain signals, without providing the results of that analysis to the user in an online interactive fashion is a BCI. Figure 1 shows the basic design and operation of BCI.

Much popular speculation and some scientific facts have been based on some 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 behaviours that achieve a person's intent, whether it is to walk in a certain direction, speak certain words, or play a certain piece on the piano. During early development and throughout later life, CNS (Central Nervous System) neurons and synapses continually change both to acquire new behaviours and to maintain those already acquired. 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.

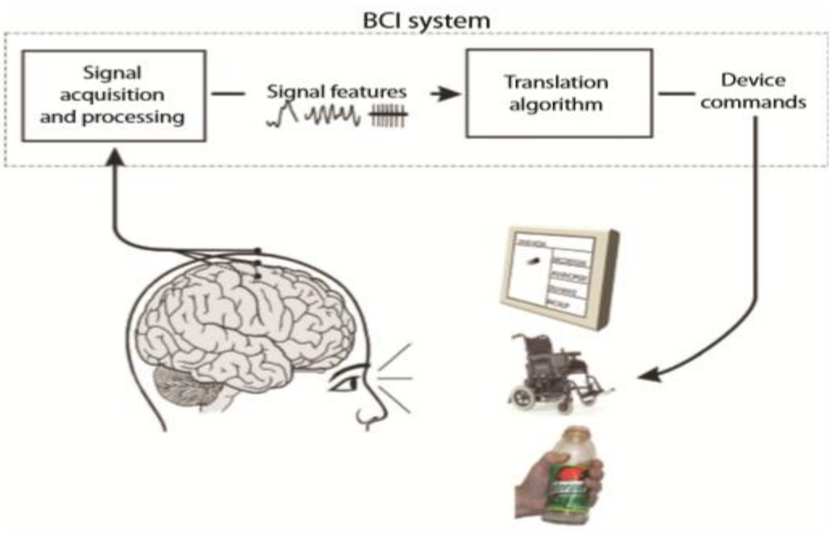

Fig 1. Design and operation of a BCI system.

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Electrophysiological signals reflecting brain activity which record from scalp or from within brain and process to measure specific signal features that reflect user's intent. These features translated into commands that operate a device such as word processing program, wheelchair etc.

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. Thus, BCI use is a skill that both user and sys- tem 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.

A. Brain signals that can or might be used in a BCI

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 future.

There are many alternative recording methods for electrical signals; The electrical fields produced by brain activity can be recorded from the scalp (EEG), from the cortical surface (ElectroCorticoGraphy activity, (EcoG)), or from within the brain (local field potentials (LFPs)) or neuronal action potentials (spikes)). These three alternatives are shown in Fig.2. Each recording method has advantages and disadvantages. EEG recording is easy and non-invasive, but EEG has limited topographical resolution and frequency range. EcoG 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. Intra cortical 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 are not yet resolved.

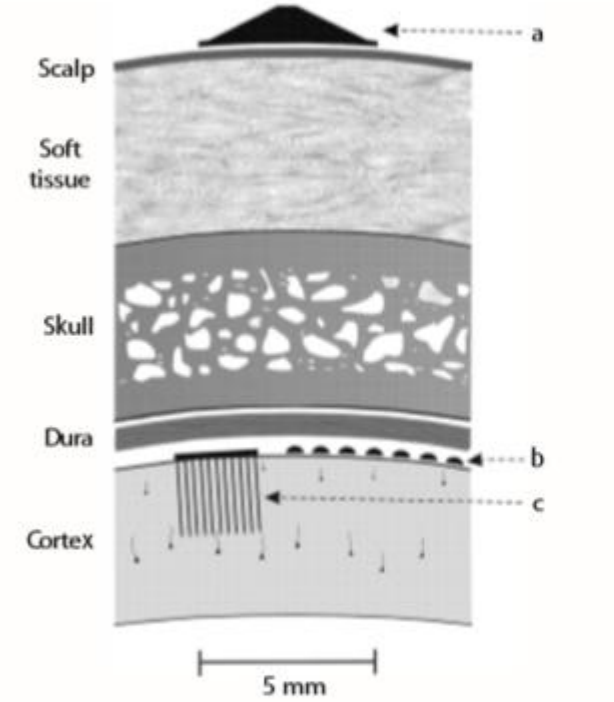

Fig 2. Recording sites for electrophysiological signals used by BCI system.

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B. EEG-based BCIs

Three different kinds of EEG-based BCIs have been tested in humans. They differ in the particular EEG features that serve to convey the user's intent. A P300-based BCI. It uses the P300 component of the event related brain potential, which appears in the EEG about 300ms after presentation of a salient or attended stimulus. The P300 BCI system described by Don chin's group flashes letters or other symbols in rapid succession. The letter or symbol that the user wants to select produces a P300 potential. By detecting this P300 potential, the BCI system can determine the user's choice. This BCI method appears able to support operation of a simple word processing program that enables users to write words at a rate of one or a few letters per minute. Improvements in signal analysis may substantially increase its capacities. At the same time, the effects of long term usage of a P300 based BCI on its communication performance remain to be determined: P300 size and reliability may improve with continued use so that performance improves, or P300 may habituate so that performance deteriorates.

C. Signal processing

A BCI records brain signals and processes them to produce device commands. This signal processing has two stages. The first stage is feature extraction, the calculation of the values of specific features of the signals. These features may be relatively simple measures such as amplitudes or latencies of specific potentials (e.g., P300), amplitudes, or frequencies of specific rhythms (e.g., sensor motor rhythms). To support effective BCI performance, the feature extraction stage of signal processing must focus on features that encode the user's intent, and it must extract those features as accurately as possible. 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. Translation algorithms may be simple or more complex (e.g., neural networks. 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. Finally the translation algorithm should have the capacity to at least accommodate, and at best encourage, improvements in the user's control. The translation algorithm should take advantage of this improvement to increase the speed and/or precision of cursor movement control. This need for continual adaptation of the translation algorithm to accommodate spontaneous and other changes in the signal features is in accord with the fundamental principle of BCI operation (i.e., the continuing dependence on system/user and user/ system adaptation), and has important implications. First, it means that new algorithms cannot be adequately evaluated simply by offline analyses. They must also be tested online, so that the effects of their adaptive interactions with the user can be assessed. This testing should be long term as well as short term, for important adaptive interactions may develop gradually. Second, the need for continual adaptation means that simpler algorithms, for which adaptation is usually easier and more effective, have an inherent advantage. Simple algorithms (e.g., linear equations) should be abandoned for complex alternatives (e.g., neural networks) only when online as well as offline evaluations clearly show that the complex alternatives provide superior performances.

III. APPLICATIONS

Initially BCI technology developed as a communication device for the physically challenged or locked-in users. However, the scope of research has increased to include non-medical applications; even first commercial products are available for home use. As a result, new disciplines such as gaming and Human Computer Interaction enter the BCI community, and new researches are introduced. Now a days BCI also help in non-medical applications. Below are some non medical BCI applications.

A. Device control

One of the driving forces behind the development of BCIs was the desire to give users who lost full control of his/her limbs access to devices and communication systems. Under these conditions, users can already benefit from a device even if it has limited speed, accuracy and efficiency. For healthy users that have full muscular control, a BCI currently cannot act as a competitive source of control signals due to its limitation in bandwidth and accuracy. However, it is possible, that healthy users could also benefit from either additional control channels or hands-free control. Examples include drivers, divers, and astronauts who need to keep their hands on the steering wheel, to swim, or to operate equipment. Brain-based control paradigms are developed for these applications in addition to, for instance, voice control.

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B. User state monitoring

The future generation user-machine interfaces need to understand user's current state and user's intentions. These future implementations of user machine require systems to gather and interpret information on mental states such as emotions, attention, workload, fatigue, stress, and mistakes. Another application field is the use of BCIs as a research tool in neuroscience research. Compared to slower, lab based functional imaging methods it can monitor the acting brain in real time and in the real world and thus help to understand the role of functional networks during behavioural tasks.

C. Evaluation

Evaluation applications can be used in an online fashion and an offline fashion. Neuro marketing and neuroergonomics are two evaluation examples. Neuroergonomics has a clear link to Human Computer Interaction: it evaluates how well a technology matches human capabilities and limitations. For An example is the recent research on cell phone use during driving: brain imaging results show that even hands free or voice activated use of a mobile phone is as dangerous as being under the influence of alcohol during driving. The body of evidence in this area is mainly based on fundamental neuroscientific studies and will be benefit from a transition to more applied studies. The societal impact is rated low; it is merely a tool that adds to current evaluation tools but has no direct contribution to solving societal issues.

D. Training and education

As we know most aspects of training are related to the brain and its plasticity. Measuring this plasticity and changes in the brain can help to improve training methods in general and an individual's training schedule. With respect to the latter, indicators such as learning state and rate of progress are useful for automated training systems and virtual instructors. Currently, this application area is in a theoretical phase with limited experimental evidence.

E. Gaming and entertainment

The entertainment industry is often front runner in introducing new concepts as everybody know; among others in human-computer interaction for consumers (recent examples are 3D movies at home and gesture-based game controllers) that recent technology to interact with the TV though hand motions. Over the past few years, new games have been developed that are exclusively for use with a EEG headset by companies like Neurosky, Emotiv, Uncle Milton, MindGames, and Mattel. The first application of non medical BCIs may actually be in the field of gaming/entertainment where the first stand-alone examples came to the market in 2009 and a broadening to console games may follow soon. As per the research the successful applications will be based on state monitoring and not on the user directly controlling the game.

F. Safety and security

EEG alone or combined EEG could support the detection of abnormal behaviour and suspicious objects. In an envisioned scenario an observer or multiple observers are watching CCTV recordings or baggage scans to detect deviant (suspicious or criminal) behaviour or objects. EEG and eye movements might be helpful to identify potential targets that may otherwise not be noticed consciously. Also, images may be inspected much faster than normal. It is already known that eye fixations as well as event related potentials in the EEG reflect what is relevant, and that brain signals indicate relevant pictures in a rapidly presented stream of images up to 50 images per second. Other applications in this area include using EEG in lie detection and person identification, but both are under fierce debate.

IV. CONCLUSION

A brain computer interface is a communication and control channel that does not depend on the brain's normal output. Current BCI's record electrophysiological signals using non invasive or invasive methods. Non invasive BCI's use scalp recorded EEG rhythms or evoked potentials, while invasive BCI's use single unit activity recorded within cortex or EEG recorded. They have maximum information transfer rates of 5–25 b/min and are being used to control cursor movement or to select letters or icons.

Like other communication and control systems, BCI's have inputs, outputs, and translation algorithms that convert the former to the latter. BCI operation depends on the interaction of two adaptive controllers, the user's brain, which produces the input (i.e., the electrophysiological activity measured by the BCI system) and the system itself, which translates that activity into output. With further increases in speed, accuracy, and range of applications, BCI technology could become applicable to larger populations and could there by engage the interest and resources of private industry.

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