

Brain-Computer Interface: Application and Challenges

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Abstract

The continual advancement of technology and computing has resulted in the creation of various innovative, remarkable works and products that continue to alter people's perceptions of reality around the world. The introduction of an emerging field of technology, Brain-Computer Interface (BCI), has changed the way people interact with computers. The major goal of BCI researchers is to create a link that allows direct communication between the brain and the computer. BCI has a wide range of uses and possibilities, from allowing disabled people to communicate with the outside world to improving military intelligence and countering terrorism in countries. BCI implementation, on the other hand, is still limited to research and laboratories, and it is not yet operational in actual real world use. This paper discusses the fundamentals of BCI, as well as its applications and the problems that have prevented its advancement and development in time and public systems use.

Keywords: Computer Interaction, Bci, Neural, Emerging Technology, Communication, Challenges, Invasive, Application

Introduction

A brain-computer interface (BCI) is a system that measures central nervous system (CNS) behavior and converts it into artificial output that replaces, restores, enhances, supplements, or enhances healthy CNS output, consequently changing the CNS's ongoing interactions with its environment. (Hill & Wolpaw, 2016). Humans are now able to interact directly with the human brain because of advances in neuroscience and brain imaging technology. Brain-computer interface (BCI) is a form of communication between a brain and a technology that allows signals from the brain to influence some external activity, such as the movement of an artificial limb. The interface allows for direct communication between the brain and the controlled object. (Rouse, 2011).

Brain-Computer Interfaces (BCIs) are interaction methods that provide users' communication and control channels that are not dependent on the brain's typical output channels of peripheral nerves and muscles. (Wolpaw et al., 2000). The preceding definition concentrates on two key points: communication and control. The majority of researchers are interested in how BCI can help people with severe motor and sensory problems interact and control computers as if they were an extension of their bodies. The need for human physical intervention (muscle control) to initiate a command to the computer distinguishes BCI from standard input devices (such as mouse, keyboard, touchpad, and so on).

BCI technology is intended to scan brain waves, interpret them into commands, and then send those commands to a computer (s). Following that, the

computer(s) will generate an output based on the commands. The rate of BCI research has increased over time, and new inventive methodologies and applications have been created to propel the notion forward. BCI research isn't just for people; it's also for animals. A monkey was able to control a robotic arm and move a screen pointer in 2008. (Ramadan et al., 2015). Invasive, Semi-Invasive, and Non-Invasive Signal Acquisition Techniques are used to collect or capture signals from the brain. Invasive BCI approaches include significant surgery to install particular signal reading devices to the brain.

Signals can be captured from a single location (single unit) or from numerous locations (multiple units). These devices capture the best quality brain impulses, but they can cause scar tissue, which can lead to brain injury or death. Devices are mounted to the head on top of the human brain in semi-invasive BCI procedures. Although the signal strength is not as strong as with an invasive BCI, there is a lower danger of scar tissue formation. Electrodes are placed on the scalp to record EEG data in non-invasive BCI. Low-cost devices are used in non-invasive BCI approaches, however the signal strength is extremely weak.

Despite the rapid advancement of BCI research, the tools required to successfully deploy it remain restricted, and overcoming its hurdles will necessitate a great deal of expert assistance.

Related Work

BCIs generally aid communication for people with severe motor disabilities who are unable to communicate in any other way, but they may also aid communication and rehabilitation for people who

are healthy or have less serious movement abnormalities such as training tasks, feedback analysis, accessibility, concentration, weariness, stimulation, and suffering, BCI research can benefit from breakthroughs in cognitive neuroscience (Allison, 2009; Allison et al., 2007). A broad BCI system is presented by Li et al. (2009), which includes data collecting, pre-processing, feature extraction, and translation algorithms (See Figure 1).

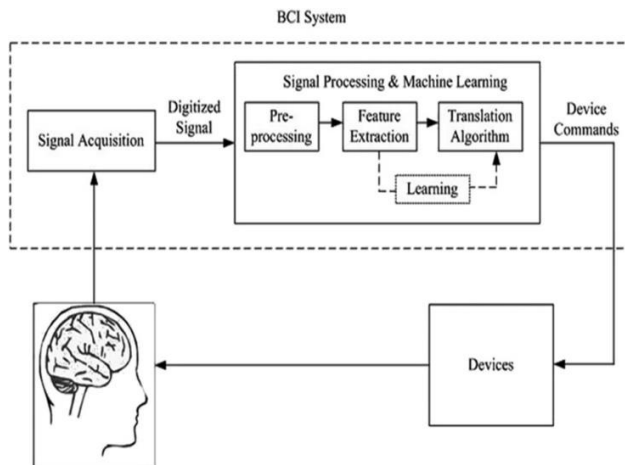


Figure 1: A BCI system's basic layout and process.
From (Papanastasiou et al., 2020)

Moreover, such behavioural benefits were demonstrated to be sustained after a 2-year follow-up, suggesting that these children could continue to effectively manage their brain activity (Arns et al., 2009; Gani et al., 2008). Friedrich et al. (2014) developed an innovative game for autistic children which included social interactions, provided neural and body-based responses, and highlighted the role of using neurofeedback and neurofeedforward training to reinforce their neurophysiological and peripheral physiological behavior in social situation

According to Al-Nafjan et al. (2017), mainstream adoption of Brain-Computer Interface will take more than 10 years, according to the Gartner Hype Cycle study for Emerging Technologies 2016. People with less severe disabilities, and also healthy individuals, are more interested in BCI as a way to improve cognitive skills including memory, communication, emotion and concentration, as well as for entertainment (Ramadan et al., 2015).

According to Lotte and Jeunet (2015), a complete training framework must be established to educate anyone on how to achieve BCI control and to examine the impact of current BCI training procedures on BCI performance and illiteracy/deficiency in order to push BCI dependability to the next level.

BCI technologies require expertise to deal with significant brain signal fluctuation and face challenges such as poor BCI signal intensity, low data transfer rate, and high error percentage (Rao et al., 2012; Ramadan et al., 2015). Because long periods of use have been found to create cognitive tiredness, the system's accuracy is hindered by the subjects' inability to maintain stable mental states between sessions.

Applications of Brain-Computer Interface

A BCI system's main aim is to allow the user to perform a list of functions by sending signals to an external device. For researchers, BCI is an intriguing interaction field because successful implementation will provide solutions to previously intractable problems. The following are common application of BCI technology applications.

Medical Applications of BCI

1. **Verbal Communication:** One of the primary applications of BCI is the restoration of oral communication to people who have a disability like locked-in syndrome (total paralysis and speech impairment) and amyotrophic lateral sclerosis (ALS). Researchers have conducted a wide range of experiments, from using simple logical spelling functionalities to the use of onscreen keyboards that support spelling.
2. **Neural Prosthetics:** Another key applications of BCI technology is the restoration of movement to individuals with motor disabilities. Experiments such as virtual hand control have been carried out to gain a better understanding of how integrating electrical simulations into a BCI system can be used to enable movement. Cortical signals were used to control a hand, re-establishing the linkage between the brain and a paralyzed hand (Moore, 2003).
3. **Vision:** Another BCI application is the use of cameras to restore vision to the blind. This can be achieved by connecting an external camera that uses BCI technology to the brain. Thus, the user can send signals to the camera and the camera becomes an extension of their body by responding to these signals and providing output in the form of vision. BCI application is the use of camera systems to help the blind see again. This can be accomplished by connecting a peripheral camera to the brain that employs BCI technology. As a result, the user can send signals to the camera, and the camera responds to these signals by providing information in the form of vision.

Environmental Applications of BCI

1. **Multi-tasking:** BCI technology can be further extended to healthy individuals that need to perform several tasks at the same time. An example is a mother who is driving and also needs to look after her baby. With BCI, the mother can control the car without direct contact and take care of the baby effectively without accidental risk. BCI technology can be advanced to healthy individuals that need to perform multiple tasks at once. As an example, consider a mother who is driving while also caring for her baby. With BCI, the mother can control the car without making direct contact and effectively care for the baby without putting herself in danger.
2. **Gaming:** BCI can be utilized for entertainment purpose and video games in which the user can use their thoughts to control their game character.
3. **Virtual World Control:** In virtual reality, BCI can be used to communicate and interact with virtual objects. BCI was used in a virtual maze, and users were able to navigate the maze by making decisions about which way to turn (Moore, 2003).

Other Applications of BCI

BCI can be used to wake up people like tired drivers or students. The electroencephalogram's delta signal denotes consciousness, and hence its precise interpretation can be used for alerting. Military Intelligence and Counter-Terrorism are two further applications.

Challenges of Brain-Computer Interface Technology

One of the most difficult challenges in developing brain-computer interaction technology has been the development of non-invasive devices and surgical methods. In the conventional Brain-computer model structure, the brain accepts and controls an embedded mechanical device as a natural part of its representation of the body. The majority of current research is centered on the potential of non-invasive brain-computer interaction (Desney, 2010).

The following challenges hinder the future advancement and integration of Brain-Computer Interface.

1. **Information Transfer Rate:** With a transmission rate of 2 – 25 bits per minute, the transfer speeds between the human nervous system and the interacting computer are still too low for substantial real-time applications, after more

than a decade of thorough and rigorous research. This makes precise device control more difficult. After the user has had extensive training, the maximum transfer rates are obtained. This slow data transfer rate impedes the advancement of BCI technology and makes it less acceptable in comparison to today's touch-based, button-based, voice-recognition-based, and gesture-based interfaces. By optimising selection approaches and combining prediction processes, researchers are attempting to uncover new ways to speed up communication (Moore, 2003).

2. **Error Rate:** The chance of more errors emerging during the communication is proportionally affected by the low information transfer rate. The diversity of brain impulses aids this mistake rate even more, because of persistent tiredness and medications, the inconsistency is more obvious among seriously disabled people. Devising techniques to limit and prevent errors during interaction is critical to BCI's successful deployment.
3. **Autonomy:** The capacity to restore communication and control channels to those with physical disabilities is the driving force behind BCI use. The existing BCI level strongly encourages communication, however control is a little fuzzy. All brain impulses are accepted as input by the system, but how does the user indicate his or her desire to control the system? During scientific testing, caretakers aid the impaired user in placing the EEG headsets so that the user can communicate with the system. As a result, the disabled user is not really the sole controller of the system. Another concern is that the disabled seem unable to turn the system off and on (i.e., BCI systems are mostly system-initiated). To tackle this problem, researchers are looking into using hybrid methodologies and using biometric interfaces.
4. **Signal Rate:** Recent studies and research have revealed that collecting information from the brain is a time-consuming process with low signal quality. As a result, in order to enhance the signal, intrusive BCI techniques are required. However, this makes BCI inappropriate for usage in business contexts. Signal amplifiers are employed with non-invasive and semi-invasive procedures. Some of these signal amplifiers perform admirably, while others fall short and cause inaccurate brain signal interpretation. As a result, new tools that

can read signals more efficiently are needed for greater BCI progression.

5. **Signal Classification:** Different sorts of impulses are sent to different parts of the brain. Electroencephalogram (EEG), electromyogram (EMG), and electrocardiogram are examples of such signals (ECG). High interference makes accurate capture and classification of these signals difficult (brain variability). However, to address this issue, clustering algorithms are provided, as well as computational intelligence algorithms and methodologies, to ensure more precise signal classification.
6. **Cognitive Load:** BCI experiments are currently only available in laboratories, making it difficult to determine how real-world deployment of the technology would alter its efficacy. BCI users in the real world will have to cope with more complex events and emotional responses that cannot be simulated in a research lab setting.

Conclusion

The application of BCI in the real world will enable people with severe and motor disabilities to communicate and control their surroundings more easily. Moreover, there is still room for development and enhanced innovation in this research area.

Human beings' fantasy about the ability to interact and communicate with machines, and now it is not going to be just fantasy but reality. Brain-computer interface is the ability of computers to enhance both physical and mental abilities. The ability of the computer to interface directly with the human brain is achieved directly through the use of sensors that can monitor some of the physical processes that occur within the brain that correspond with certain forms of thought.

The computer's ability to directly interface with the human brain is easily achieved through the use of sensors that can monitor most of the physical processes that occur within the brain that conform with certain forms of thought. It is gradually becoming a reality. Brain-computer interface is going to make it possible for the blind to see, the deaf to hear, and the physically impaired to function normally.

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