



Future of EEG Based Hybrid Visual Brain Computer Interface Systems in Rehabilitation of People with Neurological Disorders

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Abstract

Brain-computer interfaces (BCIs) are technologies that make it possible for humans to control external devices merely using their cortical potentials rather than normal output pathways such as muscles or peripheral nerves. BCIs present a hope towards restoration of independence for people affected by neurological disorders or disable individuals. Hybrid visual BCI (V-BCI) i.e. BCIs those are using two or more types of visual evoked potential for its operation, are providing promising results than other all BCI systems types. Over past two decades research and development in hybrid V-BCI systems have grown tremendously. Recently lot of efforts has been placed to make laboratory validated hybrid V-BCI systems to work in real life applications for disables. In this paper we argue on possible futuristic applications of hybrid V-BCI systems and its clinical relevance. We will present existing restrictions of hybrid V-BCI technology and its futuristic expectations.

Keywords: V-BCI systems, EEG, Neurological Disorders ,etc

1. Introduction

Brain-Computer Interfaces (BCI) created as a tool for assisting the disabled as well as healthy humans of society by mapping of individual intentions onto directive commands in professional and daily tasks [1]. Performing tasks such as controlling external devices by measuring and analyzing cortical activity is possible in electroencephalogram (EEG) based brain-computer interface (BCI). Compared to other neuroimaging methods, electroencephalography (EEG) is widely used because of its high temporal resolution, high portability, few risks to users and relative low cost [2]. BCIs that utilize visual evoked potentials (VEPs) for its operation attain popularity in last few years than other BCI types because of their higher communication rate, ease of usability and less/negligible training time [3]. Most prominent BCIs based on VEPs are P300 based BCI and SSVEP based BCI. However conventional BCI have several limitations and “Ideal BCI System”

properties are difficult to obtain using conventional BCI. Hence to overcome these limitations a novel approach is proposed by combining conventional BCI system with other interface systems called hybrid BCI [4]. A study of combination of conventional BCI with other physiological/external signals is out of the scope of this paper, so hereafter hybrid BCI term refers to the BCI systems where one or more neurological signals are combined [5]. Various hybrid systems combine two or more cortical potentials based BCI’s either in sequential or simultaneous ways. These hybrid systems overcome limitations of conventional BCI systems to some extent. Such as hybrid systems are having higher communication rate, accuracy, robustness and response time as compared to conventional single cortical potential based BCI systems [6]. Although much promising results are achieved by Hybrid BCIs in some research studies, still hybrid BCIs are in naïve stage of development. In very short period, BCI community has made

considerable progress in research in hybrid BCIs with significant diversity in development of hybrid BCIs [7]. Hybrid BCI systems that use visual evoked potentials for their operation hereafter called as hybrid visual BCI are providing promising results than other Hybrid BCI systems types [8]. So, probable future of Hybrid V-BCI systems must be analyzed to work towards systematic development of these systems. Here in this paper we are recognizing the potential applicable areas of hybrid V-BCI systems and advancement of in such domains using Hybrid V-BCI.

2. Future of Hybrid V-BCI

Hybrid V-BCI systems have tremendous potential to develop effective and efficient futuristic task oriented BCI applications. Term task oriented defines applications where user's intentions towards performing online task with real time feedback system and include:

- 1) BCI based primary interface where users are explicitly performing task using their brain potentials, such as prosthetic movement using modulation of brain potentials.
- 2) An application where BCI does not provide primary interface but directly supports users performing task. Such as, a system that predicts user's performance while Driving by directly monitoring user's brain signals [9].

In future developers will probably find success in developing task oriented hybrid V-BCIs with possibility of automatic controlling of environmental conditions, where user is intended to perform task. Future hybrid V-BCI systems will turn into prevalent in daily life activities by analyzing cortical potentials for extended time periods with advanced adaptive computing algorithms, artificial intelligence, incorporation of pervasive computing, sensor technologies and brain sensing in multi-aspects [10]. Users wearing brain sensors regularly for specific purposes increase the possibility of hybrid V-BCI systems in "opportunistic" applications. Opportunistic BCI are BCI which do not directly supports user performing task but provide many benefits without any overhead. Let an example of opportunistic BCI as, a pervasive application that automatically adjust local environmental factors (such as dietary suggestions, lightning color, entertainment, music and so on) where user is performing task to enhance

or alter user's mental condition or mood [9]. Opportunistic BCI will likely to require collection of brain data in large scale and analyzing data over longer period of time.

2.1. Direct Control

Earlier traditional conventional BCI applications were focused towards direct control of external devices or environment by manipulation of cortical activity (i.e. prosthetics devices, wheelchair, computer screen navigation, game control and so on). Hybrid V-BCI proved its significance toward improvement of performance and user conformability over conventional BCI in such applications [11]. In future, there will be likely demand of using hybrid V-BCI in direct control mode in entertainment and quality of life applications. In clinical applicability view, patients with neurological disorders are greatly benefited from use of hybrid V-BCI for consciously control of devices in their surrounding environment and for their own movements. From the entertainment view, ability to control objects directly using their brain would be fascinating to humans, for example telekinesis [12]. There are numerous factors that affect success of direct control.

1) Abilities of brain functioning and its limitations: Although, human brain is capable of various fascinating complex tasks such as motor control, emotion control and so on, it is also apparent that human brain has certain limitations like multilimb control [11]. Let a frictional example where a human is capable of control additional four mechanical limbs together with his own limbs, a concept demonstrated in spider-man movie. Take advantages of such benefits (multilimb control) may require multitasking, which is tedious and difficult to humans.

2) Technical limitations: Non-invasive EEG based V-BCI systems are focused on brain's cortex activity only. Use of brain activities at brain stem and spinal cord is not possible using this technology [13]. This imposes further limitations on applicability of BCI in real life environment.

3) Cortical potentials type: Different types of neural signals signify different brain activities. None of these types of signals fully represent whole brain function. Further, present signal processing algorithms are capable of extract relevant information from little segment of the EEG signal

[14]. Also brain is dynamic, adaptive and nonstationary.

4) Alternative technologies: In direct control scenario, the main alternative for healthy humans is using their own hands to operate devices). To date, the technologies for directly controlling devices using brain signals provide relatively low bandwidth and low signal-to-noise ratios. As a result, it is a nontrivial problem to enhance control for healthy individuals through the incorporation of brain signals into direct control BCIs [14]. For this to occur, the ability to analyze neural signals to add information above and beyond that more easily obtained through other channels (e.g., manual input) will need to be achieved.

2.2. Indirect Control

One of the factors that will affect future hybrid V-BCI is inclusion of brain signals in system that could provide information which is not readily accessible from other channels. For example, cortical potentials those are related with human perceptions like comprehension, anger, frustration, attention or error associated signals combination. Indirect control in applications is a control system where user is not engaged directly in task execution. For example, in hybrid V-BCI systems, automatic adjustment of visual stimulus features such as color, frequency, intensity based on strength of cortical potentials evoked in brain in different environmental conditions [15]. In this example application indirectly accesses strength of evoked potentials in human brain and to optimize them further in subsequent task operations, it adjusts external visual stimulus properties, but it will not directly involve in task operations or task control. Mostly success of such applications depends on specificity, robustness and signal detection timeliness. At present there is very restricted applicability of indirect control systems. In future, extensions of hybrid V-BCI systems for indirect controlling of other environmental factors than merely direct task control are needed, to further extend boundaries of Hybrid V-BCI applications in larger context [16].

2.3. Communications:

BCI systems have largest impact on communication domain. Previous BCI based communications enables populations of clinical sector such as "locked-in" patients with neurological disorders with slight movement capabilities and small control

over devices like prosthetics [17]. These systems have very limited purposes and great benefits to clinical populations rather than healthy populations [20]. Future hybrid V-BCI technologies will make revolutionary advances such as approaching towards communication basis, speech generation and capability to convey meaning among two or more parties [18]. Future of hybrid V-BCI will leverages communications-definite technologies with incorporation of other technologies, like pervasive computing and internet of things [19]. Particularly, hybrid V-BCIs would potentially support to communication domain through three models:

1) Bandwidth among the computer and the human should be increased and bandwidth effectiveness must be enlarged [21].

2) Context information comprehensions must be enhanced or predicted [22].

3) New ideas formation must be supported [23].

2.4. Brain-Process Modification:

Futuristic hybrid V-BCI systems may allow capabilities to users to dynamically alter or modify their own brain states or processes. Present technologies like neurofeedback already permit users to regulate their individual brain function to conquer an extra enviable brain state [24 - 27]. Incorporation of analytical approaches and sensor technologies to existing BCI system based neurofeedback can increase its potential benefits. Certain mental disorders like depression, can be treatable by allowing individuals to modulate their own brain states using highly developed neurofeedback system with hybrid V-BCI [28 - 33]. Further unimaginable achievements such as stoppage of neural degradation by ailment or delay age related adaptations can be achieved through allowing user to enter in particular brain state. Current neural stimulation require invasive operations, which can be replaced by non-invasive neural stimulation techniques like magnetic fields, infrared light, direct current, or ultrasound in future [34 - 38]. There could be possibility of putting user in desired brain state using neural stimulation to perform relevant task. However it requires precise determining individual optimal neural goals and strong ethics consideration [39, 40].

2.5. Neurorehabilitation

In addition to above applications, Hybrid V-BCI system has ability to control prosthetic devices to assist people who have damaged their motor function due to neurological disorders [41]. Improving quality of life of clinical patients and encouraging the neuro-

functional recovery using valuable use of damaged brain areas is made possible using neurorehabilitation. Classification of BCI based muscular movement training strategies into two categories is proposed in [42].

1) In first strategy, patients were trained to evoke stronger brain activity in brain with external visual stimulus to organize motor functioning [43]. In EEG based neurorehabilitation, stroke patients skilled to produce particular brain activity patterns such as ERD/ERD signals and BCI is used to collect and analyze these EEG signals to generate control commands and feedback [44].

2) In second strategy, BCI output is used as command signal to devices such as prosthetics to assist movement of patients resulting in improved motor control [45]. This is based on hypothesis that improved motor control using external devices in patients' results in enhanced CNS plasticity [46].

Conclusion

EEG based hybrid V-BCI demonstrated its abilities to provide motor control capabilities for people with sever motor disabilities. This non-invasive hybrid V-BCI systems success will depend on further development in their convenience and ease in daily life use, safety, long term use reliability and applicability in maximum number of tasks. hybrid V-BCI systems will be able to induce activity dependent CNS plasticity in patients with neurological disorders using neurorehabilitation. Progress in our understanding of this relation will allow us to predict the amount of the applications of hybrid V-BCI technology in rehabilitation protocols.

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