An overview on Advanced Research Works on Brain-Computer Interface

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Abstract

A brain–computer interface (BCI) is a proficient result in the research field of human- computer synergy, where direct articulation between brain and an external device occurs resulting in augmenting, assisting and repairing human cognitive. In our overview study past and recent research works on brain computer interface are sincerely explored as well as their productivity in the field of BCI and critical discussions about the proposed research methods for future developments are presented in this paper. Generation of brain-computer interface switch technologies for intermittent (or asynchronous) control in natural environments , developing brain-computer interface by Fuzzy logic Systems , implementation of wavelet theory to drive the efficacies of BCI are few of the advanced and challenging researches on BCI that are still going on and few outcomes are accomplished till now. This paper emphasizes on discussing such and more advanced and recent research trends in BCI modeling and design as the requirements to develop the brain machine interface is also growing day by day for its efficient and faster used in varied technological and scientific uses i.e. like neuropsychological rehabilitation, emotion control, etc. Brief discussions of control theory as well biomedical signal processing technologies has been carried out in this paper for developing brain machine interface system.

Keywords: Brain Computer Interface(BCI),Brain Machine Interface(BMI), Steady State Visual Evoked Potential Concept(SSVEP), Electroencephalogram (EEG) , Neuroprosthesis.

1. INTRODUCTION

The aim is to build an artificial human being capable of doing everything like a human. But, it is like a perception till now. The research work is going on in the field since (1970 – 75) when only an elementary idea was introduced, but still a long period of time, patience and progressive research work is required to see a capable artificial human being. The central unit (CU) of human or the brain is one of the most important and challenging aspect in the field of prosthesis. The response of the signals from different stimuli from outside or inside the body parts are acknowledged, controlled and channelized by the neurons which are the units of brain. To develop a computer interface that can generate lots of information transform via sense or that is able to maintain emotional control, erudite and avid studies and researches are going on to develop such a system.

2.1. CLASSIFIED STUDY OF BRAIN COMPUTER INTERFACE

Since the development of the relationship between the activity of motor cortical neurons and the movement of the upper limb has been progressed throughout the years, strong effort has been given to use motor neurons to control external devices by various researchers in the field of brain-computer interface. The brain-computer interface systems have been developed using a number of different cortical interface modalities, ranging from large-scale recording techniques including electroencephalogram (EEG) and electrocardiographical (ECog) interfaces[1,2,3], down to single-unit recording techniques using microelectrodes, have been done in which monkeys control robot arms through microelectrode cortical interfaces which has been described through BCI technology[4,5]. But these kind of BCI devices could be used in communication-and-control options of practical value mainly for people severely limited in their motor skills and thus had few options of using. To make it widespread, effective changes were needed in the accuracy and speed of BCI devices. From the observation of the linear relationship between the spike rate of motor cortical neurons and Cartesian-space descriptions of hand movement direction [6] multiple versions of BCI prosthetic control algorithms were generated [7,8,9].Mathematical functions(neural network) had been introduced for creating neural population functions from human signals which were simultaneously converted into electrical signals for making proper device. But, the growing developments of neuroprosthetic research clarified that more performance factors were necessary for extracting such algorithms for Brain Machine design. For instance, efficient devices that could provide the performance feedback of animal activity, the ability of the subject to modify better neuronal activity patterns to fit the extraction factors and the using of adaptive algorithms to make the extraction factors more accurate is shown in another research work[48]. The concept of embedded guidance or constraint within human-machine interactive systems was described by "Virtue Fixture", which was introduced by Rosenberg et al[10].The description of this method is constructed by Kragic et al[11]. Though, these researches made an efficient framework for obtaining micro-surgical work environment, practical user assistance by furnishing noble online recognition of task state was still in development as implied by the author[11].

The observation that hand movement direction was encoded in the activity of single motor cortical cells which indicated microelectrode brain-computer interface control of cursors and robots and the directions could be extracted from a population of cells using linear techniques was shown in this work[12].But, such designing procedure needed efficient algorithms. Linear methods for prediction or filtering with some extension into the use of Kalman filters or Bayesian state-based decoding models [13,14] resulted in successful decoding of such algorithms for designing.

The direct[15] and indirect[4,16] approach of controlling of a robotic arm using cortical neurons started after the accomplishment of control of on-screen displays in primates[5] and human[17].The modern sensor integration technique for BCI control of a robot[18] was introduced to increase robot stability .As, it differed from other shared control method, neural prosthetic system faced medical, scientific and engineering challenges for the development of system[19-23].The paper[23] introduced the state-of-the-art in invasive, electrode-based neural prosthetic systems, with particular attention to the advanced signal processing algorithms that enabled the performance as well as the paper produced some important results which indicated that state-of-the-art prosthetic systems could be implemented in an IPP(implantable prosthetic processor) using semiconductor technology, and the challenges of using signal processing technology in improving prosthetic performance, autonomy and robustness within the restrictive constraints of the IPP. Our overview paper on brain-machine interface is also helped by this paper [24].

Now, the development of an IPP, which could coexist and bi-directionally communicate with living brain tissue is described by an interdisciplinary multi-laboratory effort in [25].The prospect of helping disabled patients by translating neural activity from the brain into control signals for prosthetic device is highly dependent on plan movement maximum likelihood(PMML) algorithm[26]. This work constructed a lucid platform of working by adjoining both PMML algorithm along with a noble adaptive point process algorithm improving the overall performance of a neural prosthetic system. The improvement of tracking the switching of plan activity by which an accurate plan estimation could be decided into movement decoding is one of the important outcome of this work done by Santhanam and Shenoy[26]. The movement of a prosthetic hand controlled by an electroencephalogram (EEG)-based motor imagery BCI is presented in[27].The architecture of a brain machine interface based on the concepts of reinforcement learning, co-adaption and shaping is introduced and demonstrated in [28]. New and effective methods for training the RLBMI, which is constructed of two intelligent system loop based computational BMI(Brain Machine Interface) architecture capable of facilitating both prosthetic control for the user and adapt to the learning of the systems such that they act symbiotically is shown in this work and the training of this RLBMI using multiple models [49] for rapidly learning VFE for a patient's acquisition of prosthetic control is also presented in[28].. Though the RL-BMI model presented in this paper could be modified as an environmental model to estimate future states and rewards [50] to learn from both experience and model prediction of possible environmental interactions and thus facilitating faster learning, which was only indicated as future work in this paper.

Further studies and research works have been incorporated on the advancement of brain-computer interface and in 2006 it entered in a new dimension by introducing electrode arrays implanted in monkey dorsal pre-motor cortex, of a many-fold higher performance BCI than previously reported[29]. A fast and accurate key selection system, capable of operating with a range of keyboard sizes, is possible (up to 6.5 bits per second, or 15 words per minute, with 96 electrodes), was shown by this work, which gave the effective idea of increasing clinical viability of human-brain.

In this paragraph some recent research outcomes on Brain Computer Interface is shown. The subject's emotional states and their interpretation by perceiving the knowledge of influence to construct a BCI recognition algorithm and recollecting the memory states and generating new emotions in BCI is considered in this paper [30]. Another advanced EEG based brain computer model is presented in a work [31]. In this work [31], if a person thinks of a motor activity, it works. Mainly, the system was incorporated by acquisition and analysis of brain signals via EEG equipment, development of a classification system using AI techniques and also by propagating the subsequent control signals to Lego-robot via parallel port. It is depicted in this paper [32]. Detection and automated interpretation of attention-related or intention-related brain activity has a great significance for many military and civilian applications. This interpretation of brain activity could provide information about a person's intended movements, imagined movements, or attentive focus, and thus could be very useful for the optimization or replacement procedure of motor-based communication between a person and a computer or other output devices. This work is illustrated in [33]. After few years, newer researches came in this field of study. The phase detection technique and its studies on visually-evoked potential based BCI is shown in this paper [34].A steady state visual evoked potential concept (SSVEP) was drawn on BCI to provide higher information transfer rate than other BCIs by promoting a high frequency to elicit the SSVEP based BCI. To eliminate the frequency limitations of BCI, the technique of combining several frequencies to drive a single visual stimulus was used [35, 36].By implementing discrete Fourier transform, the SSVEP phase could be easily obtained which is shown in [37-39].

Sufficient knowledge and critical discussions about brain computer interface also needs a historical state of approach for discussion. Different bibliometric studies on BCI is very efficiently shown in this paper [40]. The first paper on BCI-research was published by J.J.Vidal in 1973[41]. After two decades, pioneer BCI research by J. Wolpaw was published in 1990 [42] and 1991 [43].Since then, the no of research works had grew substantially augmenting to 92 in 2003, to 171 in 2006, to 217 in 2007, and 280 in 2008.

Now, the success of SSVEP BCI required few modifications and development for enhancing its transcendence of working as well as its workability i.e. like implementation of visual stimuli. To solve the high frequencies for SSVEP responses, a new method for enabling reliable visual stimuli over 20Hz on a classical LCD screen has been used in [44].

The combinations of wavelet entropy (WE) and band powers (BP) for feature extraction in BCI system proved to be a very good method for the feature extraction. Linear Discriminant Analysis (LDA) was used for classification and mutual information (MI) was used for the evaluation technique. This work is shown in[45]. Though this paper produced an effective algorithm, basic communication and control to people with severe motor disabilities its real world implementation as well as the convenience and reliability of its use were still to be accomplished as a future research work. The control of FES-based neuro-prosthesis with a high degree of accuracy and robustness is another research work and it is depicted in a paper[46].An SSVEP-based BCI speller system using two EEG sensor modalities: water-based and gelbased surface electrodes is illustrated in this[47].

2.2. CONCLUSION

During the last few decades, lot of clinical and research works have been carried out which points towards the future development of the study of human-computer interaction. Our overview study is an effort to visualize the recent as well as past research works based on brain machine interface as much as possible. The proposed methods, their outcomes as well as critical discussions about the works for constructing newer ideas for future developments of this field and attaining state of art model structure are explored sincerely in this paper. This overview study is not intended to be an exhaustive survey on this topic, though a sincere effort has been made to cover all the recent works as much as possible and any omission of other works is purely unintentional. Future works aims at making smarter prosthesis, by better integrating the state of art- neuroscience with innate implementation of art-engineering, medicine, computer and social science.

3.REFERENCES

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