Different BCI Methods Used to study Brain Related Disorders: A Review

Mr. Divakar Jha¹, Ms. Sharmila M. Upadhye²
¹MCA Dept, L.B.H.S.S.T’s I.C.A. Bandra E
²T.Y. MCA Student, L.B.H.S.S.T’s I.C.A. Bandra E

Abstract— BrainGate system is used to sense, transmit, analyze and implement the language of neurons into action. The technology used to implement this is Brain Computer Interface (BCI). In this paper various brain related disorders for which BCI is used and that have been implemented by various researchers based on various methodologies used in medical field have been reviewed. Different signal processing methods that are used to study brain related disorders are EEG, QEEG, fMRI, BCI-FES system.

Keywords— BCI, EEG, QEEG, fMRI, BCI-FES, Autism, Schizophrenia, Stroke, Parkinson’s, Meningitis

I. INTRODUCTION

Brain Computer Interface (BCI) is a technology that is used with Brain Gate. BCI is a way for communication between the brain and the external device. It directly measures the brain activity. BCI can be applied with neural prosthesis for people with disabilities like paralysis after stroke or patients with brain disorders like Autism, Alzheimer, Schizophrenia, Neurodegenerative disorder or for emotion recognition. BCI can be used to regain mobility by restoring communication between the brain and the patient’s limbs.

1.1 Objective of Brain Computer Interface

BCI is needed as it can convert the thoughts of people into action using a computer or an external device. Those people those who are down with locked-in syndrome, neurodegenerative disorder, spinal cord injury or Amyotrophic Lateral Sclerosis (ALS) cannot make movements and so for these patients to make their thoughts perform the movement BCI is useful.

II. LITERATURE REVIEW

2.1 Brain computer interfaces for medical applications (by C.C. Postelnicu)

This paper covers the methods that are suitable for signal recording which are as follows EEG (electroencephalography), FMRI (functional magnetic resonance imaging), MEG (magnetoencephalography), PET (positron emission tomography), optical imaging and ECoG (electrocorticography). Based on the recording methods BCI systems are divided into two categories as Invasive BCIs and Non-Invasive BCIs.

2.1.1 BCI System

A BCI system typically composes of a data acquisition system, a signal processing system and commands sent to an application. Here the signal processing block processes all the recorded data and transforms the signals in commands for the application. Also the data processing must be fast so as to provide real-time operation.
Protocols for Invasive BCIs:

Array of electrodes that are connected directly to the neurons records electric signal directly from the brain. The key of controlling robotic arms or neuroprosthesis is recognition of different patterns of signals that are recorded from motor cortex neurons.

Protocols for Non-Invasive BCIs:

Non-invasive BCI systems can be characterized on the basis of what kind of imagery or mental tasks the user must perform in order to drive or evoke the command-related EEG response. The typical BCI paradigms are classified as P300, mu rhythm control, Event Related Synchronization/Desynchronization (ERS/ERD), Slow Cortical Potential (SCP), Short latency Visual Evoked Potential (VEP).

After comparing Invasive and Non-Invasive BCIs it has been concluded in this paper that Invasive BCIs are more suitable for real-time applications that are required for locked-in patients.

2.2. A Step Towards EEG-based Brain Computer Interface for Autism Intervention* (by Jing Fan)

Autism Spectrum Disorder (ASD) or autism is a neurodevelopmental disorder or can be defined as lifelong brain impairment that is characterized by learning difficulties, impaired social interaction, restricted and repetitive behavior, verbal and non-verbal communication.

In this paper, the feasibility of detecting engagement level, emotion states and mental workload of adolescents with ASD using EEG signals while they drive using a VR-based driving simulator are explored. The future goal is to integrate an EEG-based Brain Computer Interface (BCI) into the VR-based driving system for people with ASD.

Emotiv EPOC and NeuroSky Mindwave are EEG devices due to which BCI systems can be available for applications such as video games, neuromarketing, etc.
2.2.1. System Architecture of VR-based driving system

![System Architecture Diagram]

This system architecture describes the five primary modules of the VR-based driving system: VR Driving Module (VDM), Physiological Data Acquisition Module (PDM), EEG Data Acquisition Module (EDM), Gaze Data Acquisition Module (GDM), and Observer-based Assessment Module (OAM). The OAM in the system records behavioral judgment of participants on 0-9 rating scale for three emotional states: enjoyment, frustration, and boredom.

The proposed EEG-based BCI for the VR-based driving system consists of three main modules: Signal Preprocessing module, Feature Generation module, and Classification module.

2.2.2. Working of the three modules

Signal Preprocessing module is fed with raw EEG signals to remove outliers, correct EOG and EMG artifacts and enhance the signal-to-noise ratio. The transformation of the time series signals into a group of meaningful features for Classification module is done by Feature Generation module. Classification module detects the engagement level, emotional states and mental workload of the participant.
The above figure states the Classification accuracies based on the experiments performed on the ASD patients. These results after the experiments suggest that EEG-based BCI could be used in the VR-based driving system to enhance the human computer interaction, and to improve the system efficiency through individualized system adaptation based on multimodal sensory data and performance data. The main aim is to explore the use of EEG signals towards an adaptive closed-loop system for better driving skill training for individuals with ASD.

2.3. Application of BCI-FES System on Stroke Rehabilitation* (by Shenglong Jiang)

Reductions in blood flow to the brain of sufficient duration and extent lead to stroke, which results in damage to neuronal networks and the impairment of sensation, movement or cognition. Brain Computer Interface can be used to speed up the brain plasticity of stroke survivors. Event-related desynchronization (ERD) or event-related synchronization (ERS) feature could be used to detect the motor intention of stroke patients.

BCI system can cause aversion in patient due to monotonic task, whereas Functional electric stimulus (FES) is an efficient proprioceptive feedback. If FES is incorporated with BCI it could reduce muscle spasticity and joint flexibility. When BCI-FES system are combined, it uses BCI system to detect motor intention of stroke patient, and trigged FES when motor intention is detected.
The above figure shows the BCI-FES system that detected EEG data of subjects by EEG amplifiers (Nuamps Express), NeuroScan 4.5 and Matlab software.

Off-line and Online training procedures were performed on the stroke patients and healthy subjects before the official rehabilitation treatment for stroke survivors.

In the off-line training when the subjects implement the motor imagery task the EEG data is recorded every 2s. The motor imagery modes of subjects are classified using common spatial pattern (CSP) and support vector machine (SVM). In 8mins of off-line training 8s idle state and 8s MI task is switched at random. Using SVM the probability density distribution of idle state and motor imagery task is separated.

Setting the decision value affects the motor intention efficiency in the online treatment.
The above figure shows the online BCI-FES rehabilitation treatments experiment procedure. In the online procedure the BCI detects the motor intention by classified decision value and when the task value increases than the decision value it is regarded as the patient wants to move.

In this study, the BCI-FES stroke rehabilitation system was studied and the motor intention classification model was optimized by classified decision value. The success rate of the online experiment was higher than the offline experiment due to different detection method of motor intention and at the same time the feedback effect of the FES stimulates motor cortex neurons which learn new body control method. The BCI-FES system rehabilitation efficiently activated impaired motor related cortex of stroke survivors. The ERD power of motor related cortex were improved significantly, it proved that intact brain neurons were activated to compensate impaired cortex areas by brain plasticity. The BCI-FES system could effectively induced the rehabilitation of impaired brain areas of stroke survivors.

2.4. QEEG Analysis during Bicycle Riding For Parkinson's Patient (by Lattika Tiawongsuwan)

Parkinson's disease is a neurological movement disorder which is caused by the death of cells in substantia nigra (a region of the midbrain) which results in not enough dopamine in these areas. The motor symptoms of Parkinson’s disease are movement related which include shaking, rigidity, slowness of movement and postural instability.

The aim of this study was to investigate the effect of bicycle riding to the brain activity by observing the absolute power and coherence revealed by the quantitative electroencephalogram (QEEG). The QEEGs of before biking, during biking and after biking were observed. The result showed that the brain activity of during biking will increase both absolute power and coherence when compared with before biking and after biking.

QEEG is the mapping of the brain that show the function of the brain and the result is shown in the topographic mapping of scalp.

The purpose of this study to assess the effect of cycling by using QEEG to evaluate brain function during bicycle riding. The primary goal of this study is to interpret QEEG to assess the effect of bicycle riding on brain activity that improve motor performance of Parkinson's disease. And the secondary goal of this study is developing the neurorehabilitation system for Parkinson's disease by using stationary bicycle combine with virtual reality to create a more appealing and motivational way to exercise for Parkinson's disease.

The main focus of this cycling exercise is to improve motor performance, reduce the fall and also have progress on brain function of Parkinson's patients. In this paper the absolute power and coherence of topographic mapping before biking, during biking and after biking was observed also increase in during biking both absolute power and coherence that improve brain activity is found.

2.5. Development of a Binary fMRI-BCI for Alzheimer Patients (by Giulia Liberati)

AD patients those who have lost the ability to communicate verbally may benefit from a brain-computer interface (BCI) that could allow them to convey basic thoughts and emotions.
The aim of developing a brain-computer interface for the communication of basic mental states, a classical conditioning paradigm with affective stimuli was used, that evaluates the possibility to discriminate between affirmative and negative thinking in an fMRI-BCI setting for Alzheimer patients.

In this study the feasibility of an auditory classical conditioning paradigm within an fMRI-based BCI setting is evaluated. The main goal was to assure whether the brain activations relative to congruent and incongruent word-pairs, respectively evoking affirmative (“yes”) and negative (“no”) responses, that could be classified using a linear Support Vector Machine (SVM) after the conditioning process.

The classification analysis was performed using a linear SVM by selecting the fMRI signals from each voxel within insula, ACC and amygdala as input vector, these are areas that are highly involved in emotional processing.

From the classification data analysis it comes to conclusion that combining voxel extraction from insula, amygdala and ACC leads to higher classification accuracy compared to these brain region are considered individually. The only exception is given by classification in the insula which lead to higher accuracy in AD patients.

After the study it can be concluded that fMRI system cannot be used in everyday life rather some more portable systems such as near-infrared spectroscopy based BCIs (NRIS-BCIs) or EEG with source localization could be used for online classification of mental states.

III. METHODOLOGY

3.1. Electroencephalography (EEG)

The vigorous action as well as the electrical activity of brain are measured and recorded using electroencephalography.

EEG signals are measured through the electrodes that are connected to the scalp of the patient and wires hooked to a computer. The computer records the brains electrical activity on the screen or on paper as wavy lines. EEG can detect changes over millisecond. EEG is used to diagnose brain related disorders or problems which include coma, epilepsy, loss of consciousness or dementia. It is also used to find out if the brain is dead.

3.2. Quantitative Electroencephalography (QEEG)

The analysis of the digitized EEG is known as quantitative electroencephalography. QEEG is also referred as Brain Mapping. Using a computer the QEEG processes the recorded electrical activity from a multi-electrode recording.

Algorithms used to process multi-channel data are Fourier and the processed EEG is converted into color maps of brain functioning called brain maps.

To track the changes in the brain and to evaluate brain function that is due to interference of neurofeedback or medication. EEG and QEEG information can be translated.

3.2. BCI-FES System

Functional Electrical Stimulation (FES) is used to create muscle contraction in paralyzed individuals’ limbs to produce functions like walking, bladder voiding and grasping. FES does this using low energy electrical pulse.
BCI integrated with FES system can help a patient with spinal cord injury to regain grasp control.

3.3. fMRI

Functional magnetic resonance imaging uses MRI for measuring and mapping brain activity by detecting the changes related to the blood flow. It is a non-invasive neuroimaging technique. The goal of fMRI is to detect the correlation with specific cognitive states that is induced in the subject.

IV. CONCLUSION

In this paper the different methods to study the brain related disorders are presented. Most of the brain related disorders are being studied upon like patients with Alzheimer, schizophrenia, autism, Parkinson’s disease. To study different disorders different methods were used like EEG, QEEG, fMRI and BCI-FES. We suggest that these methods can be used to study other brain related disorders like meningitis. Meningitis which is an infection that affects protective membranes that covers brain and spinal cord. Some of the effects of meningitis are same as for the brain disorders which are mentioned above like epilepsy, paralysis or cerebral palsy, speech problems, etc. To help patients with these problems the mentioned BCI methods can be applied.

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