A Survey on Brain Computer Interface Applications Built Using EEG

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***Abstract*— Brain-Computer Interface (BCI) uses brain's neural activity to interact with others or to control machines, prosthetic limbs, or robots without any direct physical movements. Electroencephalography (EEG) measures the electrical signals generated by the neurons in the brain, by placing electrodes along the scalp. BCI helps disabled individuals by providing a new channel of communication with the environment and offers a feasible way to control artificial limbs. BCI is an interdisciplinary research topic that combines various others fields like Human-Computer Interaction (HCI), medicine, signal-processing, psychology, neurology, and machine learning.**

***Index Terms*— Electroencephalography, BCI2000, P300 speller, Ipsilateral Cortical Physiology, Discrete Wavelet Transform, Support Vector Machine, Wavelet-common spatial pattern, Random forest classifier, Ternary Search Tree.**

I. INTRODUCTION

Brain Computer Interfaces help people with motor neuron disease, ALS, paralysis and other handicapped victims to interact with a computer and hence open up a new way to communicate with the world. EEG is a medical procedure that is used to measure the brain's spontaneous electrical activity over a period of time, recorded using multiple electrodes placed on the scalp. EEG signals can be captured in many areas of the brain, by placing electrodes at the corresponding locations specified by the 10-20 Electrode System. Most applications generally focus on the spectrum of EEG, that is, the type of waves that can be observed in EEG signals occurring at various frequencies. These frequency bands are named alpha (8-12Hz), beta (13-30Hz) etc. and each band corresponds to a state of mind. The EEG spectrum is usually obtained by the application of Discrete Fourier Transforms to the time domain EEG signals. We are proposing a single channel EEG based BCI application that is simple and cost effective.

II. EXISTING SYSTEMS

BCI2000: These systems work on a variety of brain signals, processing methods, and applications. Data shows that they satisfy two main concerns regarding BCI systems, i.e. online and real-time operation .Different BCI systems and other psycho physiological experiments can be implemented as they reduce labor and cost.

BCI using a Simplified Functional Near-Infrared Spectroscopy: Near-infrared spectroscopy (NIRS) uses an optical technique to measure localized cortical brain activity. This work describes the principles of operation, the construction, and the implementation of an fNIRS-BCI application, 'Mindswitch' that harnesses motor imagery for control of a switch. Analysis is performed online and feedback is presented. The switching application presents a basic 'on/off' option to the user, where selection of either state by thinking takes 1 min.

EmotivEpoc: A commercial EEG headset mainly aimed for applications like BCI Games. The 12 channel headset is ergonomic and wireless and comes with software that can be used to analyze real time EEG signals, also provides a developer kit to facilitate programmers to build applications using EEG data.

P300 Speller: This is a standard speller/typing application for people with locked-in syndrome. A 6x6 character matrix is displayed to the patient and each row and column is flashed while he/she focuses on the character that needs to be selected. The flashing of the rows and columns are randomized and at the end of 15 flashes the P300 signals of each flash is calculated and one character with the highest P300 value is selected.

III. LITERATURE SURVEY

EEG based BCI for restoration of hand control [1] presents a novel BCI, the IpsiHand, which combines advances in neurophysiology, electronics, and rehabilitation to help people suffering from stroke and traumatic brain injury (TBI) that causes long-term, loss of motor control due to brain damage on the opposing side of the body. The conventional therapies are ineffective in rehabilitating the upper-limb function after a stroke. Brain computer interfaces (BCIs), devices that tap directly into brain signals, show promise in providing rehabilitation. A device for rehabilitation was developed that makes use of recent developments in electronics, neurophysiology and physical therapy into a BCI prosthetic hand. Signals associated with hand movements are observed in cortex ipsilateral to the hand. With this knowledge, these intent-to-move signals can be recorded from the cortex to control a prosthetic hand that opens and closes. The objective was to directly recouple the brain's motor signals of a hand with hand motion in order to reduce the lifetime cost of brain injury, improve outcomes of recovery, and improve quality of life for those affected by stroke or TBI. Signal was acquired using 10-20 standard EEG electrode system. Signal features associated with opening and closing of the hand was identified and control signals from the electrode location were extracted. The control signal is communicated to a linear actuator for mechanical output (opening/ closing of the robotic hand). When tested on healthy subjects it was found that hand movement correlates with EEG signals from the contralesional hemisphere and the motor-driven orthosis could be controlled using these signals.

Maximum Entropy Method (MEM) was used for spectral estimation instead of Fast Fourier Transforms since MEM has higher spectral resolution and better fitting of sharp spectral features for a time-limited signal.

Subject Independent BCI [2] uses machine learning to reduce the calibration time (30 minutes) required to assess an individual's brain signature before using a Brain Computer Interface. It proposes a subject independent zero-training BCI that enables both experienced and novice BCI subjects to use BCI with no prior calibration. The study revealed that with 83 subjects' EEG data that a distribution of different alpha band features in combination with a number of common spatial patterns (CSPs) is highly predictive for all users.

Different forms of regression and classification algorithms were used to predict the movement imagination data of unseen subjects. An ensemble consisting of subject dependent CSP filters and their matching classifiers was constructed.
The results showed that BCI-naïve users could start using real-time BCI with no calibration with a very moderate performance loss.

The EEG Mouse [3] uses a wireless EEG headset (NeuroSky) is used to control the mouse cursor on a computer screen. EEG data was got using the headset and wavelets were extracted from it and the data got were given as inputs to few machine learning algorithms to generate decision rules to control the cursor. A preprocessing system is employed and it uses a single channel, Discrete Wavelet Transform is made use of as properties of dilation and translation allows extraction from every component. SVM and NN's are used in the classification of data. MATLAB NN and MySVM software are used for most of the machine learning training and experiments. The pre-processing system removes redundant EEG data. DWT being better fit for discrete data optimizes the analysis performance. SVM and NNs provide excellent classification performance.

BCI using Alpha Waves [4] describes the development and testing of a BCI system that uses alpha waves to control external devices. Alpha waves are triggered by the movement of the eye i.e. through voluntary closure of the eye. Alpha waves are of the frequency 8-12Hz.Since there are various waves of different frequencies low pass and high pass filters are made use of to filter out unwanted frequencies. Peak to Peak Detection is enforced through Fast Fourier Transform methods.

This is different from the other related works because it does not use machine learning. A threshold is used for the alpha waves, if the signal crosses the threshold (concentration/relaxation or blinking of the eye causes spikes in alpha wave) an action is performed.

Analysis of Real Time EEG signals [5] talks about acquisition and preprocessing of real time EEG signals using dry electrode placed on forehead. Transmission of EEG signals happen through wireless mode to the local acquisition server and is stored in the computer. Common, average and current source density references are explained. Surface Laplacian Filters were found to be best suitable for EEG analysis as they increase topological specificity and helps in filtering volume-conduction effects. The classification algorithms can be categorized into linear classifiers, neural networks, nonlinear Bayesian classifiers, nearest neighbor classifiers and classifier combinations.

A wireless EEG Headset (NeuroSky) was used to acquire EEG signals and the paper mainly describes the processing of raw EEG data.

Present algorithms being incorporated in the design of Brain-Computer Interface (BCI) systems that uses Electroencephalography (EEG) is described in the Study of Algorithms for EEG based BCI [6]. Wavelet-Common Spatial Pattern (W-CSP) algorithm is used to extract features from the EEG data and FLD classifier to classify those features.

Novel feature extraction algorithm - in which the new concept of fuzzy Region Of Interest (ROI) is used. A semi supervised support vector machine - Two stage feature extraction- Normalized and non-normalized CSP feature.

The drawback of P300 brain computer interface system in practice is its typing speed which could take a few minutes to type each character of a target word. In this work [7], they have proposed a BCI system through which a whole word can be typed with much higher word typing speed and accuracy. They integrated a custom-built smart dictionary to give word predictions. The user can select one out of the given predictions to complete word typing. This reduces word typing time. For classification they have adopted a new classifier, called Random Forest (RF) instead of Support Vector Machine (SVM) which is widely used.

After the user types the first few letters, the dictionary module gives suggestions to the user. Finally, the user only needs to select one of the suggestions. This system consists of two sections: the first section is a matrix of 6×5 with characters. When the user starts typing the characters, the first section is shown to a user and the user spells few initial characters of a desired word. The typed initial characters are used to search the dictionary for a matching word. When the number of suggested words is less than a pre-specified threshold the searched words are displayed as suggestions. Finally, the user is asked to select one out of those suggestions. The dictionary module is a Ternary Search Tree (TST). TST is a special prefix tree data structure that can find all keywords for a given prefix. Partial matches can easily be searched.

IV. CONCLUSION

A detailed literature survey regarding the existing methods of EEG data acquisition, pre-processing and classification have been mentioned; also various EEG signals such as alpha waves and P300 have been discussed. After reviewing the above mentioned papers the following conclusions were arrived at the following implementation decisions:

- Building our own EEG acquisition system using monitoring electrodes and a custom amplification and filtering circuit.
- Support Vector Machine and Neural Networks when used for classification provides a better solution.
- Fast Fourier Transforms is chosen over Maximum Entropy Method based on time complexity.

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