A Review on EEG Signal, Methods and Processing Unit

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Abstract— For several years, many efforts have been done to use the electroencephalogram (EEG) as a new communication channel between human brain and computer. This new communication channel is called EEG-based Brain–Computer Interface (BCI). Brain-Computer interfaces (BCIs) are communication systems, which enable users to send commands to computers by using brain activity only; this activity being generally measured by Electroencephalography (EEG).This paper investigates the several methods of feature extraction of EEG signals which provide us to have favourable and desirable BCI systems with higher accuracy and resolution in a short timey.

Key words: EEG, FFT, EM, ARM, TFD, WT

I. ELECTROENCEPHALOGRAPHY (EEG)

An electroencephalogram (EEG) is a test that detects electrical activity in your brain using small, flat metal discs (electrodes) attached to your scalp. Your brain cells communicate via electrical impulses and are active all the time, even when you're asleep. This activity shows up as wavy lines on an EEG recording [5].

Electroencephalography (EEG) is a neuro-imaging technique or recording the brain's electrical potentials, which are commonly used to study the dynamics of neural information processing in the brain, and diagnose brain disorders and cognitive processes[1].Large amounts of EEG data are recorded and it is not possible to analyze EEG datavisually [1]. Therefore, there is a strong demand to extract relevant information from EEG recordings for the proper evaluation and understanding of the desired cognitive processes. The main steps in the process of extracting relevant information from EEG recordings include preprocessing, feature extraction and classification [2]. The measured EEG signal is basically a personal feature and varies betting on the psycho physiological state of an individual. Each of the signal amplitude and dominant frequencies bear changes.

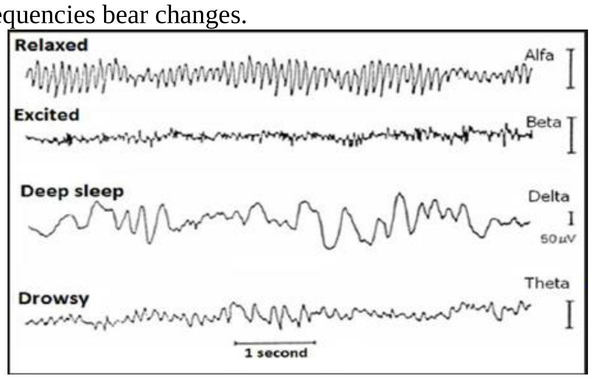

Fig. 1: Distinctive rhythms (waves) of the EEG signal [5].

II. SIGNAL PROCESSING SYSTEM OF EEG

The following are the processing steps of EEG signal feature extraction system describe below:

- Step 1: To collect raw EEG data.
- Step 2: The first half is pre-processing which incorporates acquisition of signal, removal of artifacts, signal averaging, thresholding of the output, tracing of the resultant signal, and eventually, edge detection.
- Step 3: This step incorporates feature extraction from raw EEG data that is supposed to see a feature vector from a regular.

A feature may be a distinctive or characteristic activity, transform, structural part extracted from a phase of a pattern [5]; applied mathematics characteristics and syntax descriptions are the two major subdivisions of the traditional feature extraction model. Feature extraction subject is supposed to settle on the selections or data that is most significant for classification process.

- Step 4: Now the stage is signal classification which may be solved by linear analysis, nonlinear analysis, agglomeration and fuzzy techniques, and neural networks.
- Step 5: This is the last stage of signal process system for getting the output [1].

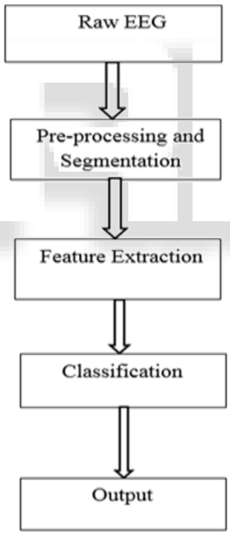

Fig. 2: Signal Processing system for EEG [1]

III. EEG METHODS

The following table shows the strategies of EEG, its analysis strategies and numerous applications.

Method	Analysis Method	Application
FFT	Frequency domain	Narrowband, stationary signals
Wavelet transform	Both time and freq. domain and linear	Transient and stationary signal
Eigenvector	Frequency domain	Signal buried with noise
Time frequency distribution	Both time and domains	Stationary signal
Autoregressive	Frequency domain	Signal with sharp spectral features

Table 1: EEG Methods [1]

IV. FEATURE EXTRACTION OF EEG

In pattern recognition, feature extraction is a special form of dimensionality reduction. When the input data to an algorithm is too large to be processed and it is suspected to be extremely redundant (much data, but not much information) then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

In BCI, there is many classifiers used, that classify the feature extraction of EEG. These classifiers are listed below:

Classifier	Description
Linear Classifier	– It use linear functions to distinguish classes. – Two kinds of linear classifier have been used for BCI design, 1) Linear Discriminant Analysis (LDA) 2) Support Vector Machine (SVM).
Neural Network	1) NN is an assembly of several artificial neurons which enables to produce nonlinear decision boundaries 2) The most widely used NN for BCI is – Multilayer Perceptron vector (MLP). – Learning Vector Quantization (LVQ) Neural Network – Fuzzy ARTMAP Neural Network – Finite Impulse Response Neural Network (FIRNN) – Time-Delay Neural Network (TDNN) – Gamma dynamic Neural Network (GDNN) – RBF Neural Network – Bayesian Logistic Regression Neural Network (BLRNN)
Nonlinear Bayesian Classifiers	1) It introduces two Bayesian classifiers used for BCI: – Hidden Markov Model (HMM). – Bayesian Graphical Network (BGN) 2) All these classifiers produce nonlinear decision boundaries. 3) They are generative, which enables them to perform more efficient rejection of uncertain samples than discriminative classifiers.
Nearest neighbor classifier	1) The classifiers presented in this section are relatively simple. 2) They consist in assigning a feature vector to a class according to its nearest neighbor(s). 3) This neighbor can be a feature vector from the training set as – k Nearest Neighbors (kNN) – Class prototype as in Mahalanobis distance.

Table 2: BCI classifier [13]

Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately [3]. When performing analysis of complex data one of the major problems stems from the number of variables involved. Analysis with a large number of variables generally requires a large amount of memory and computation power or a classification algorithm which over fits the training sample and generalizes poorly to new samples. Feature extraction is a general term for methods of constructing combinations of the variables to get around these problems while still describing the data with sufficient accuracy [1].

V. LITERATURE SURVEY

The following table shows various papers published in different years, and the comparative analysis of all the papers has been studied below:

Author	Published Journal, Year	Methods and Technique
Mdbelal Bin Heyat	IJARCSSE, 2015	Recording of ECG signal is done by analog & digital form. The EEG signal recording is based on 10/20 system .EMG signal recording is done in step wise setup.
Nazlar Ghassemzadeh	IJABBR, 2016	BCI techniques of feature extraction
Nandish M	IJEIT, 2012	Neural Network techniques used for feature extraction. Data division algorithm used for implementation.
F Lotte	JNE,2007	BCI classifiers and their properties
R saab	IEEE EMBS, 2005	DWT used for detection of coupling of EEG signal
Remigiusz J. Rak	MMS, 2012	BCI methods and its classifications. Also discussed about the methods of brain activity detection.
Oliver Faust	Elsevier,2015	computer-aided seizure detection and epilepsy diagnosis using wavelet

Amjed S. Al-Fahoum	Hindawi Publishing Corporation,2014	Feature extraction of EEG signal using Linear Analysis wrt frequency and time domain

Table 3: Comparative analysis of different papers.

In this article author mentioned EEG based Brain Computer Interface (BCI) systems feature extraction such as Principle Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), Mutual Information theory (MI), Empirical Mode Decomposition (EMD), High–order frequency component, Wavelet Transform, Common Spatial Pattern (CSP), and Complex Band Power (CBP).[4].

A variety of methods have been widely used to extract the features from EEG signals, among these methods are Time frequency distributions (TFD), Fast Fourier Transform (FFT), Eigenvector Methods (EM), Wavelet Transform (WT), and Auto Regressive Method (ARM), and so on. The purposes of this paper, therefore, shall be discussing some conventional methods of EEG feature extraction methods, comparing their performances for specific task, and finally, recommending the most suitable method for feature extraction based on performance. [1].

Bioelectric potentials are generated to nerve transmission, heart activity, heartbeat, muscle activity etc. The bioelectric signal produced in patient body is coordinated activity of large group of cells. Electroencephalography (EEG), Electrocardiography (ECG), and electromyography (EMG) systems measure brain, heart, Muscle activity [8].

This paper presents an approach to measure coupling, or synchrony, between various parts of the brain, critical for motor and cognitive processing, using wavelet coherence of EEG signals. This highlight the benefits of the wavelets approach by exploring how a single time-frequency coherence map can be controlled to yield various time and/or frequency resolutions [6].

The EEG was recorded bipolarly from left and right central and parietal regions and was sampled at 128 Hz. In the feedback sessions, the EEG from both central channels was classified on-line with a neural network classifier, and the success of the discrimination between left and right movement imagination was given within 1.5s by means of a visual feedback. By averaging over all training and over all feedback sessions, the EEG data discovered a significant desynchronisation (ERD) over the contralateral central area and synchronization (ERS) over the ipsilateral side. The ERD/ERS patterns over all sessions displayed a relatively small intra-subject variability with slight differences between sessions with and without feedback [9].

In this scheme, the discrete wavelet transform is applied on EEG signals and the relative wavelet energy is calculated in terms of detailed coefficients and the estimate coefficients of the last decomposition level. The extracted relative wavelet energy features are distributed to classifiers for the classification purpose [3].

Autoregressive models are often used to provide these estimates. The order of the autoregressive model has varied widely among studies. Through analyses of both simulated and actual EEG data, the present study examines the effects of model order on sensorimotor rhythm measurements and BCI performance. The results show that resolution of lower frequency signals requires higher model orders and that this condition reflects the temporal distance of the model coefficients [10].

A brain-computer interface aims at restoring communication and control in severely disabled people by identification and classification of EEG features such as Event-Related Potentials (ERPs). The aim of this study is to compare different modalities of EEG recording for extraction of ERPs. The first comparison evaluates the performance of six disc electrodes with that of the EMOTIV headset, while the second evaluates three different electrode types (disc, needle, and large squared electrode). The evaluation of comfort by participants revealed an increasing discomfort with the EMOTIV headset starting with the second hour of use [11].

This paper is designed to introduce the reader to how to diagnose sleep disorder with Electroencephalogram (EEG) Signals. Sleep disorder, is a medical disorder of the sleep patterns of a person or animal. Some sleep disorders are serious enough to interfere with normal physical, mental and emotional functioning. [12].

VI. Conclusion

Electroencephalogram (EEG) is a non-invasive technique for diagnostic of brain disorders. An automatic EEG analyzing system is made possible with the advancement in the field of signal processing. Applying signal processing at the preprocessing and feature extraction stage in combination with artificial intelligence and soft computing at classification stage, differentiation of disorder is possible with high classification rates. This paper reviewed various feature extraction methods and classification techniques, giving a clear insight of EEG analyzing problem.

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