

Brain-Computer-Interface: A Survey on Feature Extraction Techniques for Brain Signal

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ABSTRACT: This article address to the various feature extraction techniques as Auto Regressive, Band Powers, Cross-Correlation, Fast Fourier Transformations, Hjorth Parameters, Independent Component Analysis, Phase Locking Value, Power Spectral Density, Principal Component Analysis, Time Frequency Representation, Wavelet Packet Decomposition, Wavelet Transformation, and their comparative discussion with their advantages and disadvantages in modern application areas.

KEYWORDS: Blind Source Separation, B-Spline Clint, Power Spectral Density, Wavelet Packet Tree, Time Frequency Grid.

I. INTRODUCTION

Scientists in this modern era analyze that the application of a Brain-Computer-Interface is to diagnose and quantify features of brain signals that indicate what the user wants the BCI to do, to translate these computations in real time into the specified device commands, and to provide concurrent feedback to the user. The brain signal characteristics used for this purpose are called signal features. [1] Feature extraction is the process of distinguishing the pertinent signal characteristics from extraneous content and representing them in a compact and meaningful form, amenable to interpretation by a human or computer. [2]

II. RELATED WORK

In the realm of signal processing techniques feature extraction is an important process in which distinguishing the pertinent signal characteristics from extraneous content and representing them in a compact and meaningful form. In 2012 Jonathan Wolpaw, and Elizabeth Winter Wolpaw [3] published the core concept of feature extraction in his book "Brain-Computer Interfaces: Principles and Practice". Another article published in 2014 by M. Rajya Lakshmi, Dr. T. V. Prasad, and Dr. V. Chandra Prakash [4] which shows various feature extraction techniques in details such as Independent Component Analysis, Principal Component Analysis, Wavelet Transformation, Auto Regressive, Wavelet Packet Decomposition, and Fast Fourier Transformations. However Independent Component Analysis and Principal Component Analysis techniques have less significance in the above referenced article.

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III. FEATURE EXTRACTION TECHNIQUES

The following figure (Fig.1) represents all the feature extraction techniques disused in this survey article in abundance theoretical description.

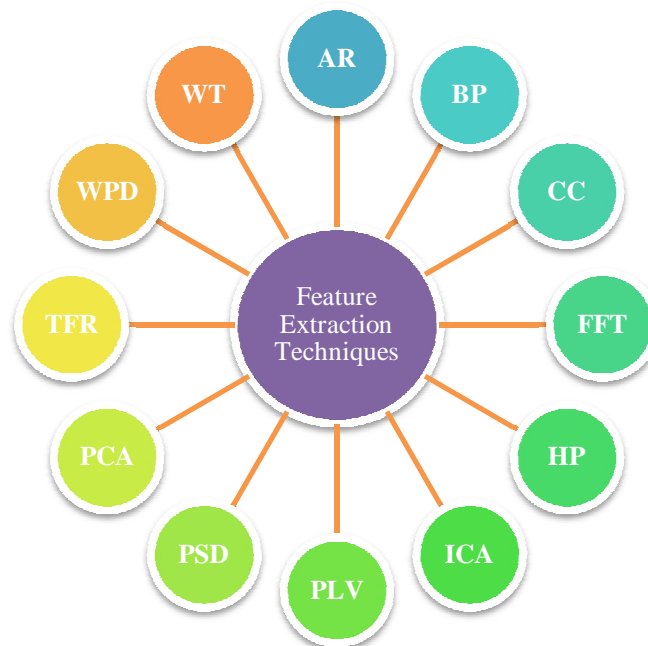


Fig.1

A. AUTO REGRESSIVE [AR]

AR technique is used for feature extraction in time domain analysis. By using short duration of data records this method provides better frequency resolution and reduces the spectral loss problems. It is the most often used method for non-stationary signals such as EEG where parameters are given to the model. [5] The difficulty lies in establishing the parameter model property. Various auto regressive methods are used in feature extraction such as Adaptive AR, Bilinear AAR, and Multivariate AAR.

B. BAND POWERS [BP]

BP technique is used for feature extraction by estimating the power distribution of the EEG in predefined frequency bands. [6] Band Power used and demonstrated that for each subject, different frequency components in the α and β band were found which provided best variation between left and right side movement imagination.

C. CROSS-CORRELATION [CC]

CC technique of feature extraction uses in the case of EEG measurements the cross-correlation coefficients between the EEG activities may be calculated to obtain some information from comparing different locations and different frequency bands. [7]

D. FAST FOURIER TRANSFORMATIONS [FFT]

FFT technique used to extracts the signal features by transforming the signals from time domain to frequency domain. FFT works well for stationary signals and, linear random processes. [8] It cannot measure both time and frequency. In this frequency analysis the signals are divided into one second windows overlapping a half second window. This half second overlapping results in large amount of data for the training of the classifier that forms classes.

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E. HJORTH PARAMETERS [HP]

HP technique described three parameters that characterize the temporal dynamics of EEG signal. These parameters can be measured in the time domain, as opposed to the other features, which are measured in the frequency domain. These parameters are capable of discriminating between different mental states. The first parameter is Activity which is a measure of the mean power of the signal. It is measured as the standard deviation. Second parameter is Mobility which represents the mean frequency in the signal. [9] The mobility can be computed as the ratio of the standard deviation of the slope and the standard deviation of the amplitude. The third parameter is Complexity which tries to capture the deviation from the sine wave. It is expressed as the number of standard slopes actually seen in the signal during the average time required for one standard amplitude, as given by the mobility.

F. INDEPENDENT COMPONENT ANALYSIS [ICA]

ICA technique in feature extraction makes the components that are independent to each other, and from the components essential features were extracted. An essential application of ICA is Blind Source Separation problem means identifying the independent signals and noise separation from original signals. [10] Blind Source Separation is also referred to as Cocktail party problem that means separation of a number of independent components from a set of uncontrollable records.

G. PHASE LOCKING VALUE [PLV]

PLV is a statistic feature extraction technique that can be used to explore task induced changes in long range synchronization of neural activity from EEG data. It is important to keep in mind a few properties of the PLV statistic before diving in further. PLV statistic is a time course, means that for every time point in your EEG data, you can extract a measure of connectivity. This quantity can be used to observe transient changes in connectivity without predefining a time window of analysis. PLV time course for every electrode pair and, PLV time course is computed over multiple trials. PLV statistic can be argued to be a proxy for connectivity. [11] If the EEG signal in two channels while an experimental condition rises and falls together more than a baseline value, then there is more synchronization or loosely speaking, enhanced connectivity between these two electrodes, and if it is less than the baseline value, there is desynchronization or loosely speaking, decreased connectivity between the two electrodes. However this metric does not care about the co-variation in the power of the EEG signal between two electrodes.

H. POWER SPECTRAL DENSITY [PSD]

PSD technique of feature extraction shows the strength of the variations as a function of frequency, means it shows at which frequencies variations are strong and at which frequencies variations are weak. The unit of PSD is energy per frequency width and you can obtain energy within a specific frequency range by integrating PSD within that frequency range. [12] Measurement of PSD is done directly by the method called FFT or computing autocorrelation function and then transforming it.

I. Principal Component Analysis [PCA]

PCA technique is used for analyzing and for dimension reduction of data artifacts without losing essential information. [13] By using PCA technique the information present at all the time series multi channel is extracted as principal components. By eliminating the artifacts and by making the principal components this technique reduces the dimensions of signals.

J. TIME FREQUENCY REPRESENTATION [TFR]

TFR technique of feature extraction decompose the EEGs signals into a series of frequency bands, and the instantaneous power is represented by the, envelop of oscillatory activity, which makes the spatial patterns for a given electrode montage at a time-frequency grid. [14]

K. WAVELET PACKET DECOMPOSITION [WPD]

WPD technique extract features in both time and frequency domain with the coefficients mean of wavelet transform. Initial features are taken as the power at special subsets and the separabilities were measured by using Fisher's criterion. In Fisher's criterion, the coefficients with higher separability were considered effective and formed as final vector. It divides the original signal into two subspaces based on frequency. [15] Wavelet packet tree shows the

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decomposition of low frequency wavelets. It provides better performance results and it is superior to autoregressive model. It shows better performance in the extraction process of non stationary signals like.

L. WAVELET TRANSFORMATION [WT]

WT technique of feature extraction is used to perform the feature extraction with the B-Spline parameters. WT act as low pass filter as well as high pass filter and with these filtering characteristics it stood as B-spline clients. By applying multi resolution analysis filter coefficients can be obtained. [16]

IV. CONCLUSION

This studies shows that various feature extraction techniques which are employed gives performance as per situation requirements. ICA technique is computationally efficient and shows high performance for large sized data, also decomposes signals into temporal independent and spatial fixed components. This technique can't be applicable for under determined cases and requires more computations for decomposition. [17] PCA is a powerful technique for analyzing and for reducing the dimensionality of data without important loss of information assumes data is linear and continuous. This technique for complicated manifold PCA fails to process data. WT technique is capable to analyze signal with discontinuities through variable window size, and it can analyze signals both in time and frequency domains. It can extract energy, distance or clusters, and lacking of specific methodology to apply WT to the pervasive noise. AR technique requires only shorter duration of data records and reduces spectral loss problems and gives better frequency resolution. Difficulties exist in establishing the model properties for EEG signals and not applicable to non stationary signal. WPD technique can analyze the non stationary signals and increased computation time. FFT is a powerful technique of frequency analysis and applicable only to stationary signals and linear random processes. It suffers from large noise sensitivity and poor time localization makes it not suitable to all kinds of applications.

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