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Classification of EEG Signals Using Wavelet Transform and Hybrid Classifier for Parkinson's Disease Detection

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***Abstract*—** Feature extraction and classification of Electroencephalograph (EEG) signals for normal and abnormal person is a challenge for engineers and scientists. Various signals processing techniques have already been proposed for classification of non-linear and non-stationary signals like EEG. In this work, Support Vector Machine (SVM) and Multilayerperceptron (MLP) based classifier was employed to detect Parkinson's Disease from background electroencephalograph signals. Signals features are extracted using the Discrete Fourier transform (DFT). And the stastical features are calculated using the percentage power than output of this stage are different frequency bands and which are the input to the classifiers. The proposed classifier show the promising classification accuracy.

Keywords- **Electroencephalograph (EEG), Support Vector Machine(SVM), Multilayerperceptron (MLP), Discrete Fourier Transform (DfT), Parkinson's Disease (PD).**

I. INTRODUCTION

The growth in the population age brings the growth of number of diseases. And one of the major group of diseases that affect elderly people is that neurodegenerative diseases.

The Parkinson Disease (PD) is disorder of certain nerve cells in the part of the brain which produces dopamine. These nerve cells break down, dopamine levels drop and brain signals which are responsible for the moment become abnormal. PD usually begins in the middle or late life (after age 50). It progresses gradually for 10-15 years. This results in more and more disability. Patients suffering from PD present more clinical abnormalities of moment like resting tremor, rigidity, bradykinesia and postural instability.

Electroencephalograph (EEG) is the recording of electrical activity along the scalp, produced by the firing of neurons within the brain. In clinical context EEG refers to recording of the brain's spontaneous electrical activity over a short period of time, as recorded from multiple electrodes placed on the scalp. In this paper the main diagnostic application of EEG is in the case of Parkinson's disease.[1]

Brain patterns form wave shapes that are commonly sinusoidal; usually they are measured from peak to peak and normally range from 0.5to 100 µV in amplitude. Brain waves has been classified into four basic groups or bands depending on the frequency range (as shown in Fig1).[2]

- β beta (>13 Hz),
- α, alpha (8-13 Hz),
- θ, theta (4-8 Hz),
- δ, delta (0.5-4 Hz).

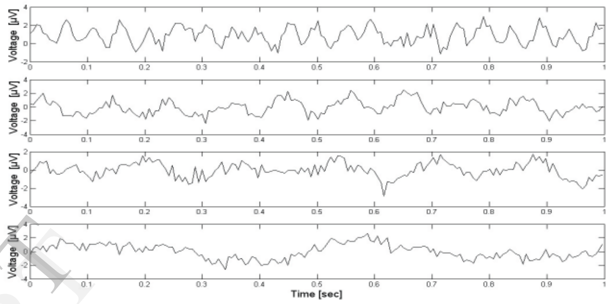

Fig.1.Brain wave samples with dominant frequencies belonging to β, α, θ and δ bands respectively (upper to lower).

Two basics steps must be performing to analysis of EEG signals: Feature Extraction, & Signal Classification. Feature extraction can be calculated based on statically characteristics or syntax description components of domain, frequency, time and time-frequency domain can be used to extract features from EEG signals. The fourier analysis is extremely useful for data analysis, as it breaks down the signal into constituent sinusoidal of different frequencies. For sampled vector data, Fourier analysis is performed using the discrete fourier transform (DFT). The fast Fourier transform (FFT) is an efficient algorithm for computing the DFT of sequence. It is not a separate transform.[2.2.3]

In past few years many research groups focused their work on classifying EEG records to desired mental task classes. Several algorithms has been investigated by purpose or increasing the classification rate and accuracy.

In this work an algorithm based on Discrete Fourier Transform (DFT) and Hybrid classifier (combination of SVM & MLP) is used to detect the PD signals from EEG signals. The dataset of 10 subjects which contain normal as well as Parkinson's disease persons are included.

The rest of the paper is organized as follows section 2 contain methodology, section 3 contains Results and discussion section 4 contains Future Work, and in section 5 contain conclusion.

II. METHODOLOGY

In the signal classification system, First the signals are enrolled in the system, this stage is called as the training stage and the unknown signals are identified in the testing stage.

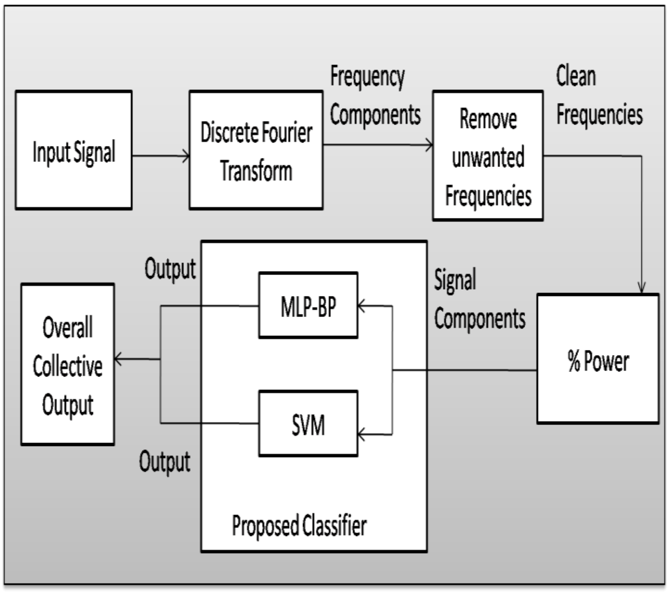

Fig.2 System Architecture.

The steps involved in electroencephalograph (EEG) signal classification and detection of the Parkinson's Disease patient detection are as follows:

1. Feature Extraction: The input to this subsystem is the EEG signal data. Then by applying the Discrete Fourier Transform, the frequency components of that signal are obtained. Then the unwanted frequencies (i.e. the frequencies which are greater than 30 Hz) are removed. Then these frequency components are input to the next step.

2. Feature Vector Calculation: In this stage feature vector is obtained by applying the percentage power formula on the frequency components which are the output of the previous step. The output of this stage are different frequency bands and these are the inputs to the classifier.

3. Feature Classification: In this step there are two different classifiers are used to classify the signals, these are Multilayer Perceptron – Backpropogation (MLP-BP), and Support vector Machine Classifier (SVM). The input to these classifiers are different frequency bands. And the output of each classifier is either person is normal or having Parkinson's Disease.

Discrete Fourier transform (DFT) and Feature Vector Calculation:-

Fourier analysis is extremely useful for data analysis, as it breaks down a signal into constituent sinusoids of different frequencies. For sampled vector data, Fourier analysis is performed using the discrete Fourier transform (DFT). The fast Fourier transform (FFT) is an efficient algorithm for computing the DFT of a sequence; it is not a separate transform. It is particularly used in area such as signal processing, where its uses range from filtering and frequency analysis to power spectrum estimation []. Computation using DFT of each level gives an indication to the frequencies that the bands contained in.

The DFT is used for periodic, discrete-time or digital signals x[n]. The DFT for a signal with period N is

$$X[k] = \sum_{n=0}^{N-1} x[n]\, e^{-j\frac{2\pi k}{N}n}.$$

These equations say that the coefficients X[k] represent the periodic discrete-time signal x[n]. Notice, that only N samples of the time signal x[n] are used to compute X[k] (for k = −∞. . .∞), and also only N of the coefficients X[k] are used in the inverse transform.

• A periodic discrete-time signal has a periodic spectrum (just like any other discrete time signal), i.e., X[k + N] = X[k].

• The X[k] terms are evenly spaced samples of the continuous spectrum

X1(ej) of the signal x1[n] = x[n] for 0 ≤ n < N; x1[n] = 0 for n < 0, n ≥ N

Properties of Discrete Fourier Transform:-

1. Linearity & Periodicity:-

Linearity : let $\{X_0 , X_1 \ldots\ldots X_{N-1}\}$and $\{Y_0 , Y_1 \ldots\ldots Y_{N-1}\}$ be the two sets of discrete samples with corresponding DFT is given X(m) and Y(m) then the DFT of samples set $\{ X_{0+} Y_{0,} X_{1+} Y_{1,\ldots\ldots} X_{N-1} + Y_{N-1}\}$ is given by X(m)+Y(m).

Periodicity: We have evaluated DFT at m=0,1,…. N-1. There after (M>N) is shows periodicity.

2. DFT symmetry:-

If samples are real, then extracting in frequency domain X(0),…… X(N-1)seems counter intuitive. Because from N bits of information in one domain (time), we are deriving 2N bits of information in frequency domain.

The suggests that there is some relationship between X(0)……., X(N-1) as per DFT symmetry property, X(N-m= X*(m)m = 0,1,….. N=1 where symbol * indicates complex conjugative.

3. DFT phase shifting:-

Dft phase shifting property states that, for a periodic sequence with periodicity N i.e. X(m)=X(m+iN), I as an integer, an offset in sequence manifests itself as phase shift in the frequency domain. In other words , if we decide to sample X(n) starting at n equal to some integer k, s opposed to n=0, the DFT of those time shifted samples.

$$X\ shifted\ (m) = e^{j2\pi\frac{km}{N}}\ Xm$$

Feature Classification:-

BCI Classifier's Problem :-

Some problem related to BCI classifier were reported by [7] which can be summarized as follows

1. Course of Dimensionality and small training set:- Dimensionality means that features come from various channels in different time intervals. So 0that when size of training dataset is small as compare to size of feature vector then classifier gives poor results.
2. Bias-Variance tread off:-
   It is due to the noise of BCI system i.e. biasness in mapping from & variation of training set that cause error. As a solution biasness & variation must be removed.

By using classifier but the problem is that if we use stable classifier it has high biasness & low variance and if we use unstable classifier it has low biasness & high variance.

Support Vector Machine

An SVM also uses a discriminate hyper plane to identify classes. However, concerning SVM, the selected hyper plane is the one that maximizes the margins, i.e. the distance from the nearest training points. Maximizing the margins is known to increase the generalization capabilities. An SVM uses a regularization parameter C that enables accommodation to outliers and allows errors on the training set.

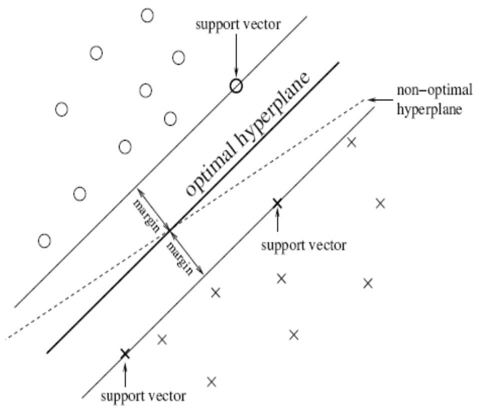

Fig 3. SVM and the optimal hyperplane for generalization.

Such an SVM enables classification using linear decision boundaries, and is known as linear SVM. This classifier has been applied, always with success, to a relatively large number of synchronous BCI problems. However, it is possible to create nonlinear decision boundaries, with only a low increase of the classifier's complexity, by using the "kernel trick". It consists in implicitly mapping the data to another space, generally of much higher dimensionality, using a kernel function K(x; y). The kernel generally used in BCI research is the Gaussian or Radial Basis Function (RBF) kernel:

$$K(x,y) = \exp\left(\frac{-\parallel x - y \parallel^2}{2\sigma^2}\right)$$

The corresponding SVM is known as Gaussian SVM or RBF SVM.

Multilayer perceptron (MLP)

A Mulitlayer Perceptron is a feed forward artificial neural network model that maps sets of input data onto a set of appropriate output. An MLP consists of multiple layers of nodes in a directed graph, with each layer fully connected to the next one. Except for the input nodes, each node is a neuron (or processing element) with a nonlinear activation function. MLP utilizes a supervised learning technique called backpropogation for training the network. MLP is a modification of the standard linear perceptron, which can distinguish data that is not linearly seperable.

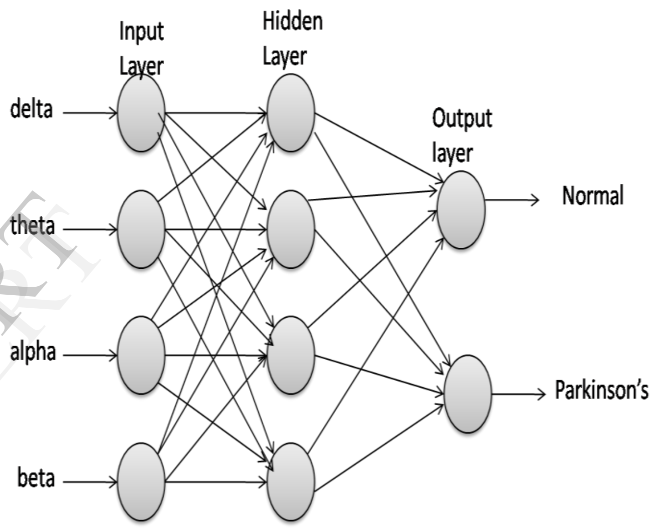

Fig.4 Feed-Forward Network

The basic neural network consists of 3 layers.

1. Input layer: The input layer consists of source nodes. This layer captures the features pattern for classification. The number of nodes in this layer depends upon the dimension of feature vector used at the input. In proposed system there are four input neurons which are delta band, theta band, alpha band and beta band obtained from feature extraction stage.

2. Hidden layer: This layer lies between the input and output layer. The number of hidden layers can be one or more. Each hidden layers have a specific number of nodes (neurons) called as hidden nodes or hidden neurons. The hidden nodes can be varying to get the desired performance. These hidden neurons play a significant role in performing higher order computations. The output of this layer is supplied to the next layer. In this system four hidden neurons are present.

3. Output layer: The output layer is the end layer of neural network. It results the output after features is passed through neural network. The set of outputs in output layer decides the overall response of the neural network for a supplied input features. The given system give output is person is normal or abnormal.

Strengths and weaknesses of Classifiers:[7][8]

1. SVM :-

Strengths:-

- Provides maximized margin (degree of seperat) in training data.
- Due to use of the kernel SVM is flexible in threshold attributes.
- Best in classification and always provides single unique solution rather than multiple solution.
- Generally best overall accuracy as compare to KNN and ANN.
- It did not required training again and again.
- Best for those BCI features which contains noise & outlier.
- Low error rate.
- BCI EEG data contain high dimensionality therefore SVM gives good results in case of high dimensionality and smaller training set

Weakness:-

- In testing phase SVM is slow.
- Contain high complexity = $O(n^2)$.
- Wastage of memory.
- If dataset is large then no solution to train it.

2. MLP :-

Strengths:-

- MLP d not use assumption or guess for decision making, it is capable to provide decision directly from trained data.
- Capable to learn complex decision boundaries.
- Good in classification performance but not good for discriminating the non class data.
- Best in signal classification.
- Capable of reduce signal noise.

Weakness :-

- High complexity i.e. $O(n^2)$.
- Only provides solution against linearly separated data.
- Sensitive to overtraining especially with such noisy and non-stationary EEG data.
- Recognition.

3 RESULTS AND DISCUSSION

In this study we used EEG signals of Normal and Parkinson's disease patients, in order to perform an abnormal patient detection and to see in which stage it belongs to. EEG recording were divided into sub band frequencies such as α, β, δ and θ by using DFT. Then a set of statically features was extracted from frequencies δ (1-4 Hz, stage 4), θ (4-8 Hz, stage 3), α (8-12 Hz, stage 2), β (12-30 Hz, stage 1). After normalization EEG signals were decomposed using DFT and statical feature extracted from sub-bands and these features are classified using the SVM and MLP-BP classifier.

The objective of this application was to develop classifier that is able to identify any input combination as belonging to either one of the two classes: Normal or Parkinson's.

Dataset:-

The dataset used for this system is the EEG signal recorded from 10 persons which contain normal and Parkinson's disease persons, by using the 8 channels. It means the EEG signals from the person's brain are recorded using the 8 electrodes which are placed over the cap. This dataset contain the 8 channel data for each person and each channel contains the 4096 samples with its amplitude values.

Experimental setups:-

In this system Discrete Fourier transform is used to processing the input signals. The outputs of the Discrete Fourier transform are the frequency components. The unwanted frequency components are removed i.e. the frequencies which are greater than 30HZ are removed, because above that frequency the person is said to be normal. Then these clean frequency components are given as an input to the percentage power to calculate the feature vector. The feature vector size is 1*8 for each channel. The value 8 means the four frequency bands and each having its low and high value. And these feature vectors are given as an input to the classification stage.

category	No of trained signals	No of tested signals	Correctly classified by MLP-BP	Correctly Classified by SVM	MLP-BP accuracy in %	SVM accuracy in %
Training phase which include seizure and non seizure signals	10	10	10	10	100	100
Training phase which include seizure and non seizure signals	10	10	9	10	90	100

Table 1 Classification accuracy of EEG signal by using SVM and MLP-BP by considering %power features

Performance analysis of classifiers:

Classifier	Computation Complexity	Accuracy	Speed	Memory Need	BCI Applicablity
SVM	Initially high i.e. $O(n^2)$ but becomes less due to kernel tricks	Best	-Classification = Fast - Testing=slow - Exhaustive hypertraining = slow -Overall luckily very fast in BCI application.	Large	Yes
MLP	$O(n^2)$	Low learning accuracy	Good in classification, slow in discrimination	??	Yes applicable to all BCI

Table 2. Performance Analysis of SVM And MLP-BP

Additionally, because the problem involves classification into two classes, sensitivity, specificity, positive predicative value and negative predicative value were used as a performance measures.[13]

Positive Predictive Value (PPV) = TP / (TP + FP)

Negative Predictive Value (NPV) = TN / (TN + FN)

Sensitivity= TP / (TP + FN)

Specificity= TN / (TN + FP)

Classification Method	PPV	NPV	Sensitivity	Specificity
MLP-BP	100%	88.889%	50%	100%
SVM	100%	100%	100%	100%

Table 3 The values of statistical parameters of MLP-BP and SVM model for EEG signal Classifiers

4. FUTURE WORK

In the proposed project we tested the result for detection of the Parkinson's disease by using hybrid classifier which is the combination of support vector machine classifier and multilayer perceptron classifier. Then we can compare the results obtained by this work with the other classifiers

In this work 8 channel signals are used for the human computer interface. The process would become easier and more accurate if 16 channels are used for analysis and implementation.

5 CONCLUSION

Brain computer Interface is the simplest method to interface with any real input and output device using Electroencephalograph (EEG) signals based on the frequency, the signal can be classified into different bands of frequency. Each band will predict different conditions with the help of these frequencies control of interfaced device can be made easy and automated.

Instead of using one classification algorithm, we are combining the two classifier such as Support vector machine (SVM) & Multilayer Perceptron (MLP) because the SVM has best training accuracy and the MLP has best testing accuracy than other.

As Compare to other Classifier SVM and MLP are gives best classification accuracy. SVM gives 100% accuracy in treaning as well as testing, while MLP-BP gives 100% accuracy in training phase while 90% in testing.

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