

# A Hybrid Approach of Feature Extraction and Classification Using EEG Signal

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**ABSTRACT:** In this work, we proposed a Hybrid approach for feature extraction and classification using EEG signal. This method uses the decomposition of signals into the frequency sub bands by wavelet method (DWT) and a set of statically features and frequency domain features were extracted from the EEG signals to represent the distribution of wavelet coefficients in Time domain and frequency domain. Data dimension methods like ICA, PCA and LDA are reviewed and ICA is used for feature extraction the reduction of dimension of data and then these extracted features as signal vector are given input to the classifiers and the performance and accuracy of classifiers like SVM, ANN and k-NN are compared with proposed method and a modified algorithm is developed which is best in terms of accuracy and performance..

**KEYWORDS:** BCI, Electroenceplogram, DWT, PCA.

## I. INTRODUCTION

EEG is the neuron imaging technique which was discovered for measuring the disturbances that occurs inside the brain because of the electrical activity of the brain. This is a unique technique which can be used to interface the human brain with outside environment via electrical signals generated from EEG device. These electrical activities develops inside the brain which is produced by the physical activities or strong imagination to control desired object. It involves the spatial mapping of electrodes and special functions which are mapped to the various regions of our brain to get a particular or desired signal for the specific application. There are various limitations in EEG data acquisition system the first one is the electrical activities that are recorded from the outer layer of brain called scalp which contains noise. This noise is due to the disturbances and electrical movement of electrodes, so we have to remove the noise factor and the other is that it depends upon the number of electrodes that are used. If we apply larger number of electrode then also signal degradation occurs which decreases the BCI performance so the selection of optimum number of channel that suited for both accuracy and performance is needed. There are several challenges in the BCI system such as information transfer rate, error rate, autonomy and cognitive load [4]. The information transfer rate depends on how many sensors are used to acquire brain activity signal and bandwidth of channel from which this signals are given to system. The error rate described by classification error occurred by allocating task to external device. The load on brain to control the complex task is also challenge stated in hybrid BCI interface system [6] which depends on how much critical the system is (critical system means how many dimension the user has to control). The hybrid BCI is nothing but the controlling of virtual helicopter in 3-D environment [6] which can be done by combination of motor imaginary events (hand, foot and tongue movement). In real world application there are several projects going on such as user interface control, biofeedback, creative expression and environmental control [15-20]. EEG is a unique technique which can be used to interface the human brain with outside environment via electrical signals generated from EEG device. These electrical activities develops inside the brain which is produced by the physical task or strong imagination to control desired object. It involves the spatial mapping of electrodes and special functions which are mapped to the various regions of our brain to get a particular or desired signal for the required application there are various limitations in EEG data acquisition system the first one is the electrical activities that are recorded from the outer layer of brain called scalp which contains noise as the result of disturbances and electrical movement of electrodes so we have to remove the noise factor and the other is that it depends upon the number of electrodes that are used. If we apply larger

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number of electrode then also signal degradation occurs which decreases the BCI performance so the selection of optimum number of channel that suited for both accuracy and performance is needed. Due to these parameters the cost of system, resolution is effected [1]. The advantages of using EEG technique are: Most of the other EEG technique are bulky and requires heavy equipment but in this method there is less hardware cost significantly as compare to other technique. These sensors can be used in every field other than medical research where MRI, SPECT, MRS and other techniques. These technique requires large equipment and handling cost and are very costly and bulky. These methods has very high temporal resolution, on the order of milliseconds as compare to other techniques. It is commonly recorded at sampling rates between 250 and 2000 Hz in in medical research, but advanced EEG data gathering systems are capable of recording at sampling rates more than this sampling rate if desired we can record and unlike other technique which are non-invasive but on the other hand they provides better resolution [2].

## II.LITERATURE SURVEY

Literature is enriched with lot of information about Comparative Analysis Optimization Technique in feature extraction and classification using EEG. To see which algorithm is the best solution in less time conjunction and best Optimization Technique. Literature review of various research paper are studied, so that a sense can be developed according to advancement and scope in this area.

Md. Sheikh et al. [11] proposed a unique method in which algorithm was developed for feature extraction and classification of EEG signal to build BCI systems in real time, mainly feature extraction and classification of signal was done using EEG signal which includes various training algorithm for parameter extraction and its classification. The experiment was done using Bio pack data acquisition system unit which is also called MP36R [4], this was done by many users has been examined with different modules of pre-training data. The final efficiency of each implemented algorithm was compared with the existing methods and suggested the best suited method for the motor imagery application. J.Sita and G.J. Nair [19] proposed the study of open source electroencephalogram (EEG) data from 30 subjects which performs basic motor task which was responsible for the brain motor areas for the particular task. The extracted features from various technique such as Principal component analysis and independent component analysis (ICA) of the EEG data were used to obtain feature vectors from the Gaussian method from the weighted concept from each feature vector. These feature vectors were the inputs to the classifiers. Two dimensional mapping technique is used for activity based selection of features which are located in the primary and sensory motor regions of the brain The output feature vectors thus obtained are given as input to two classifiers, viz. linear discriminant analysis (LDA) and quadratic discriminant analysis (QDA).These two classifiers are then compared and found that the LDA gives normal accuracy and QDA gives better accuracy than other methods and depending upon this research, an efficient feature extraction method can also be used in addition with proposed method.

Sarah M. Hosni et. [17] proposed a method in which EEG signals recorded from a subject performing imaginative task and the results were discriminated with almost 70% accuracy. They have used an AR representation of half-second EEG windows and for the classification of feature selected a RBF SVM classifier was used and the results suggests that the Parametric AR model based method was the best suited method for the parameter extraction and significantly for the classification more accurate than the others frequency domain methods, which were commonly used in extracting features in EEG research. A common technique for the eye blinks or movement of eye based system was done using ICA method was proposed instead of traditional method because these method avoids rejection of meaning data. A G. Yehia et al. [15] proposed Principal Component Analysis method on spectral features of EEG signals for high accuracy SSVEP recognition. EEG signals are filtered by using this approach. Signals were pre-processed using spectral and time domain filters so that signal to noise ratio can be improved to a great extent and further accuracy and efficiency can be increased. Features were then extracted from the spectral representation after obtaining the spectral principle components. SSVEP target frequency that corresponds to the frequency of a flickering object is determined using a linear classification process.

Lei Sun et.al [12] proposed a method which removed the noise and interference present in the EEG data. Which continuously distort signals and degrades classification accuracy.so the wavelet denoising technique was used for the reduction of noise in EEG and for the signal estimation hamming window was used and they obtained classification accuracy for denoised signal about 65% and if we use wavelet technique with CSP (common spatial pattern) or ICA (independent component analysis) feature extraction methods accuracy can be further improved.

### III. METHODS AND TECHNIQUES

#### A. Subjects and Data Recording

All the EEG signals were recorded with same 128 channel amplifier system and for the data acquisition various EEG devices are available for example BCI P300 machine from Guger Technologies. In this BCI P300 machine data acquisition and data analysis can be done there are various tool boxes that are Stim box, SSVEP, g.USB Amplifier and g.GAMMAAsys. For recording the EEG signal g.GAMMAcap is used which is the second version of gtec's high end electrode cap for non-invasive EEG channels from predefined positions using g.tec's genuine active and passive electrodes..[6]

#### B. Analysis using discrete wavelet transform

Wavelet analysis technique defines an algorithm which involves the multistage window method. In this method the length of window has variable size this feature of wavelet is used in this technique. This method involves the use of large time interval where we need low frequency information and where we have to find high frequency information we need to set the length of window to be shorter so accordingly we can use this type of technique. Fourier transform cannot be applied to the transitory signals as plenty of signals in EEG contains non stationary components so this technique cannot be applied for EEG so wavelet transform must be used in wavelet transform variety of probing function are used and depending upon the comparison with the threshold function window length can be control and we can easily extract features from the signals. This concept leads to the equation for the continuous wavelet transform (CWT). One major advantage of wavelet technique is its flexibility to perform general analysis — that is, to analyze or can be apply to localize the window size and localization area of a larger signal is done. In the wavelet packet technique, signal is compressed and noise is removed by using the Fourier transform technique exactly same ideas can be developed to extract the feature of EEG signal the basic idea and technique will be the same as traditional method but the only difference is that we can easily analysis the complex problem in easy and flexible manner and here we have to deal with EEG signal as in wavelet analysis approximations method are used to spilt the details of signals as shown below and these details will be the required feature. The extracted wavelet coefficients provide a compact representation that shows

the energy distribution of the EEG signal in time and frequency. The following statistical features can be used to represent the time–frequency distribution of the EEG signals such as mean of the absolute values of the coefficients, average power of the wavelet coefficients in each sub-band and the following statistical features were used to represent the time frequency distribution of EEG signals which are mean of the absolute of coefficients in each sub bands and Average power of wavelet Coefficients in each sub band. These features represents the frequency distribution of signal. Standard deviation of the coefficients in each sub bands and ratio of absolute mean values of adjacent sub bands represents the amount of changes in frequency distribution so these features were calculated for the specific application and used for the classification of EEG signals.

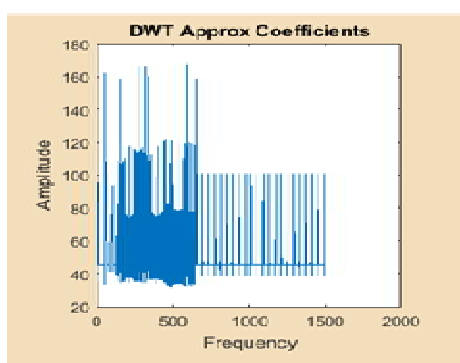


Fig. 1 DWT approximate coefficients

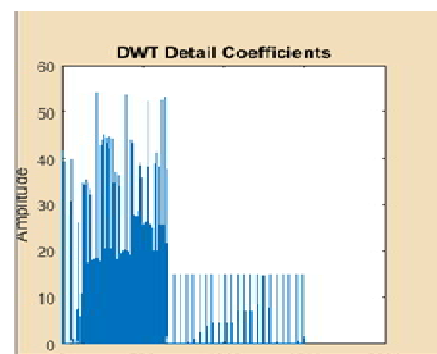


Fig. 2 DWT detail coefficients

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### C. Feature Extraction

ICA is a feature extraction method that transform multivariate random signal into a signal having components that are mutually independent. Independent components can be extracted from the mixed signals by using this method. In this manner, independence denotes the information carried by one component cannot be inferred from the others. Statistically this means that joint probability of independent quantities is obtained as the product of the probability of each of them. The ICA technique appears ideally suited for performing source separation in domains where, the sources are independent, the propagation delays of the 'mixing medium' are negligible, the sources are analog and have p.d.f.'s not too unlike the gradient of a logistic sigmoid, and the number of independent signal sources is the same as the number of sensors, meaning if we employ N sensors, using the ICA algorithm we can separate N sources. In the case of EEG signals, N scalp electrodes pick up correlated signals and we would like to know what effectively 'independent brain sources' generated these mixtures The role of feature extraction of EEG can also be done by using ICA technique which decompose the multivariate signal and convert into independent non Gaussian signals or we can say it is a powerful technique to separate linearly mixed independent signals ICA is particularly useful in EEG signals because it can easily separate out artifacts embedded in the data. It is also called data dimension method where different kinds of dimension algorithm are used to obtain the desired result. The classification is done by training the KNN classifier in term of the common features that are extracted from the signal and this concept can be used to recognize the EEG signal for real time for example it can be used with motor imagery application as shown below in Fig 3 and another important technique for feature extraction is Principal component analysis (PCA) which is a well-established method for feature extraction and dimensionality reduction. In PCA, the method is to represent the d-dimensional data in a reduced-dimensional space. This will reduce the space, data dimension, time and complexities of signal which makes extraction of signal easier as compare to other techniques. This technique is mostly useful for parameter extraction of signals from multiple sources [10].ICA and PCA are the efficient methods of feature extraction in which the classification accuracy can be improved along with the wavelet denoising technique which can be used to develop an efficient method for the feature extraction and classification for motor imagery task and other applications in bio medical engineering..[16]

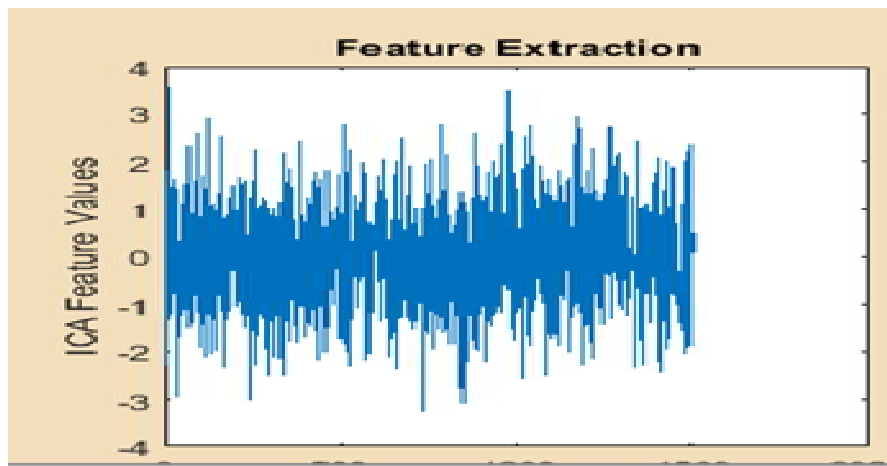


Fig. 3 Feature extraction by ICA

### D. Classification methods

Support vector machine consists of a vector in which all the learning is acquired in the training set which is very useful to develop a new data. Support vector machine algorithm is declared as efficient and most reliable method for the parameter extraction and classification. The basic principle of SVM classifiers is that it segregate the data by an accurate hyperplane in which all the data points of one class is almost separated from another class. In this classification hyperplane stands for the largest displacement among the two or more classes. The main advantages of

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SVM classifiers is that it reduces the error rate of misclassifying signals in the desired training set.[4]Support Vector Machine is one of the popular machine learning and optimal method for classification of EEG signals. Different kernel function plays a vital role in nonlinear separable methods .EEG signals are pre-processed by using different artifact removal algorithms such as ICA, PCA. Features like power spectrum, entropy, and mutual information and so on are extracted from pre-processed signals for generating feature vectors. SVM classifier accept feature vector and produce classified signals based on the chosen application. RBF kernel function is chosen as classifier for generating optimal decision boundaries.K-NN is a simple and intuitive method of classification used by researchers for classifying signals. This classifier makes a decision on comparing a newly labelled sample (testing data) with the baseline data (training data). Training data set includes classes. For given set of values, k-NN. The k-nearest neighbour classification is performed by using a training data set which contains both the input and the target variables. Then test data which only contains input variables is compared with reference set. K-NN classifier works with k patterns, the distance of unknown 'k' determines its class, by considering nearest neighbour points. Majority voting scheme where class gets one vote for each instance in neighbourhood samples. The given target data is classified. In training and testing, k-NN needs to specify value of k. In this work, the value of 'k' varied k=1 to k=10. And at the end the classification performance is checked for different values of 'k' to evaluate its accuracy. An Artificial Neural Network, often just called a Neural Network (NN), is a computational model based on biological neural networks. In this supervised learning (the learning signal is the difference between the desired and actual response of the neuron) strategy is used and we have compare the all the three classification algorithm with the proposed methodology and results are compared.[5]

## E. Design methodology



Fig. 4 Design Methodology

The design methodology defines the whole process or procedure laid down for the completion of the task. The design methodology is the step wise step layout of the techniques used for obtaining the desired result. It is the way to describe the complete progressive model in which different step deals with the different methods to achieve the ultimate goal or objective of the work. It is the implementation of various techniques that is supported by representing the method in the flowchart form or diagrammatic way to illustrate the design and structure of the method. The first and foremost part to achieve the objective starts with the process of the data acquisition or EEG signal acquisition by the datasets. EEG

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signal acquisition is done by various bio medical devices(g.usbamp).We have taken different Motor Imagery datasets from PhysioNet, BCI competition IV which is EEG motor Imagery movement dataset. The next part is to apply pre-processing techniques to load the given information available in the signal. There are various classical methods EEG processing which removes noise from the given data but wavelet denoising is most efficient method among all techniques. These techniques are used to pre-process the EEG signal so that adequate features can be extracted from the given signal. The selection of various features are used to obtain the information about the signal through means of the different methods like the Independent component analysis, Principal component analysis, wavelet packet technique, Fast Fourier transform and these methods are used to select features like Power spectral density, Maximum pitch, Signal energy, Correlation. These features in the form of signal vectors are given input to the classifiers so the accuracy, error rate and signal to noise ratio which depends upon the selection of important features. The Classification is the most significant and essential technique for brain computer interface. The basic intend of the classification technique is to segregate the data with respect to given information. The extracted features are save in database and in the form of signal vectors are fed as input to the classifiers. The other input to the classifier is test signal or training set so classifiers compares the signal vector with the training or test signal and gives the results in the form of error rate, accuracy and overall signal to noise ratio. If error rate is more then there is need of more training set and machine learning that involves further efficient feature selection and followed by classification process. A number of techniques have been compared with its diagram in the results section.

## IV.RESULTS AND DISCUSSIONS

The SVM classification shows very low value of PSNR (Power to Signal Noise Ratio). It means that the quality of signal to noise ratio is not good enough. Then, the artificial neural network techniques shows improved ratio. Higher the value of PSNR, greater will be the quality of a signal. K-NN method shows moderate value of PSNR. Thus, hybrid approach of wavelet and ICA feature extraction along with k-NN shows moderate PSNR.

Techniques	PSNR	MSE	Accuracy
SVM classification	24.85	0.038	96.2
k-NN classification	32.56	0.0043	99.57
ANN classification	66.19	0.015	98.51

Table 1.1 Comparison of various Classification techniques with proposed method

The SVM classification shows very low value of PSNR (Power to Signal Noise Ratio). It means that the quality of signal to noise ratio is not good enough. Then, the artificial neural network techniques shows improved ratio. Higher the value of PSNR, greater will be the quality of a signal. K-NN method shows moderate value of PSNR.The graph showing the variations of PSNR in different techniques is illustrated in Fig. 5 and Fig 6. As shown below.

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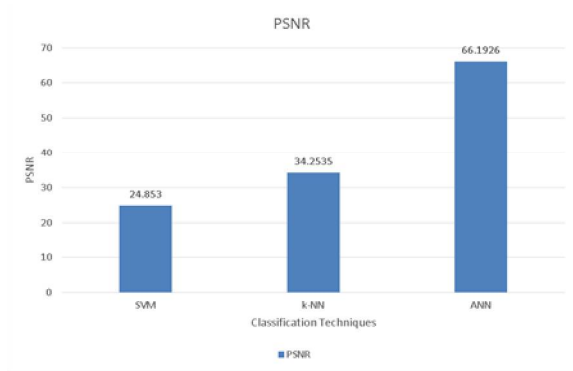


Fig.5 PSNR values for various Classification methods

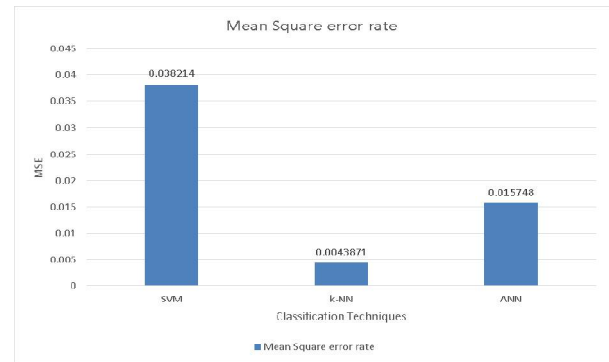


Fig.6 MSE values for various Classification method

The value of MSE (Mean Square Error) should be low enough for better quality and improved analysis of EEG signal. The value of MSE in SVM classification and ANN classification are relatively very high. But to reduce this error, k-NN classification method is applied, and then it results in lower values of range of 0.0043. The value MSE of different techniques are compared. The graph showing the variations of MSE in different techniques is illustrated in fig 6. The value of Accuracy should be high enough for better quality and improved analysis of EEG signal. The value of Accuracy in SVM classification is very low, whereas ANN and k-NN classification shows relatively high accuracy. Accuracy is totally dependent upon MSE values Low MSE means high accuracy. ANN and k-NN classification have low MSE values so the classification accuracy is high as compared to SVM technique. The value Accuracy of different techniques are compared. The graph showing the variations of Accuracy in different techniques is illustrated in Fig. 7.

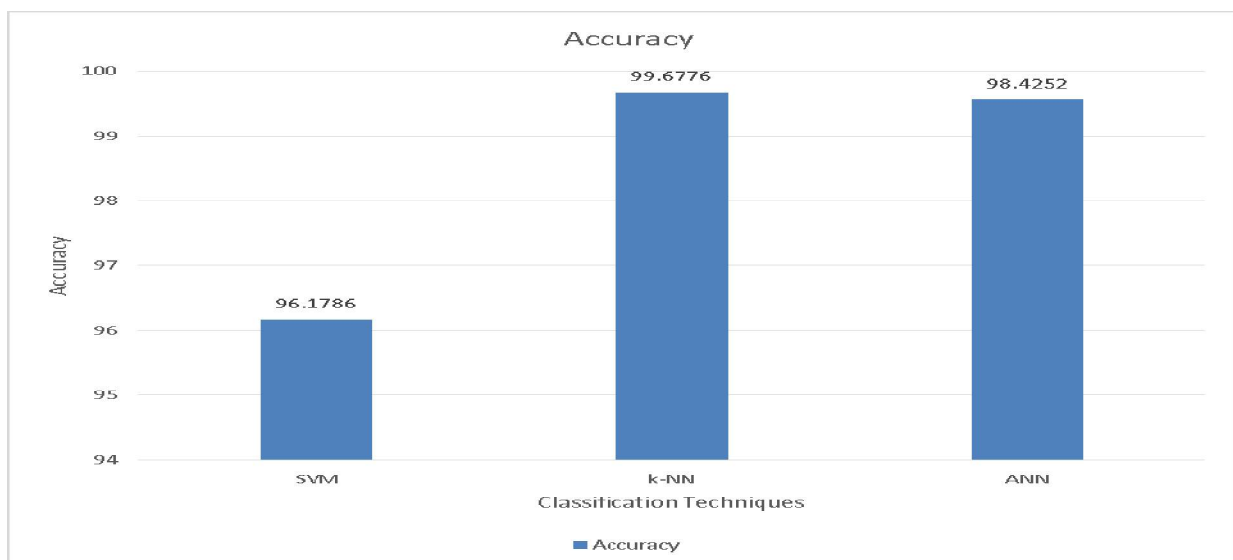


Fig.7. Accuracy values for various Classification method.

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## V. CONCLUSION

In this study, the motive was to select the best Classification technique to be applied on Motor Imagery dataset. The Classification techniques are been applied to the EEG data to classify the signal and evaluate performance. A number of Classification techniques like SVM, k-NN and artificial neural network etc. are applied on the EEG datasets to achieve the higher PSNR value and lower the value of MSE. Out of all the techniques, k-NN shows the much better results as compared to the other techniques. But the objective is to reduce the mean square error and improved PSNR value. So, to achieve the target of optimized result, in addition to the already applied classification techniques, a number of feature extraction techniques have also been applied on the EEG datasets. The previously obtained Classification technique i.e. k-NN is used along with ICA (Independent Component analysis) and DWT (discrete wavelet transform). The ICA (Independent Component analysis) combined with DWT (discrete wavelet transform) shows improved results with k-NN classification. The value of PSNR is same for both the techniques, but the value of MSE is reduced in case of k-NN classification as compared to SVM and artificial neural network. The value in k-NN classification with ICA and DWT is compared with SVM and artificial neural network and k-NN classification.

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