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EEG Based Diagnosis of Alzheimer`s Disease Detection Using SVM Classifier

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Abstract

Alzheimer's disease is a neurodegenerative disease that demolishes memory and other important cognitive and behavioral functions. It is one of the severe mental diseases in which brain cell connections and the cells themselves degenerate and die. Alzheimer's is caused by an integration of genetic, environmental and lifestyle factors that affect the brain over time. An early diagnosis provides patient with a better chance of benefiting from treatment and also helps his family to take preventive measures for patient. Therefore, the aim of this research work is to detect Alzheimer's in early stage by means of analyzing the electroencephalogram signals in time and frequency domain. In present research work, wavelet based features are analyzed and given as an input for classifier. Daubechies wavelet is used for signal analysis. Accordingly, statistical features such as mean, variance, standard deviation, skewness and kurtosis are computed and used for classification. Support Vector Machine, a semi-supervised classifier is used for classifying the data into two classes giving satisfactory results. The research is carried on experimental database. Therefore, the presented work presents a reliable methodology for Alzheimer's diagnosis.

Keywords— *Alzheimer's; Electroencephalogram; Wavelets; Machine Learning; Support Vector Machine.*

I. INTRODUCTION

Alzheimer's disease is one of the most common and tremendously growing neurological diseases in the world. Electroencephalogram signals (EEG) gives out powerful and relatively cheap tool of diagnosis of different neurotically disease. Since in brain, there are millions of neurons interconnected in very complex manner, the resultant EEG signal is very complex, non linear, non stationary and non Gaussian in nature. AD being neurodegenerative disease causes serious cognitive decline it is a common form of dementia. During the past 10 years it is observed that number of AD patients is increasing gradually and its prevalence in the world is assumed to be doubled in next 20 years.[1]

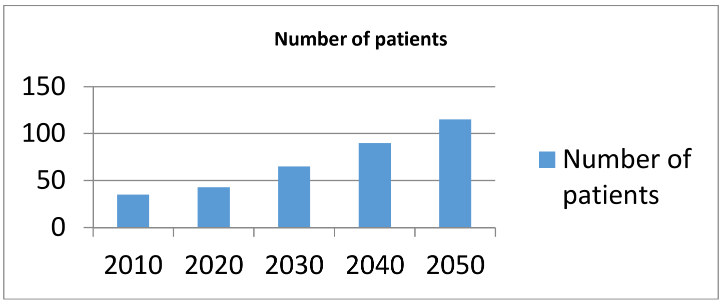

Fig.1: Estimated number of patients up to year 2050

As AD is predicted to be increased in the near future due to aging, several preventives are taken into consideration for the early diagnosis of disease. AD is mainly described by the neuronal

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widespread loss of cells, neurofibrillary tangles, senile plaques in Hippocampus. Brain changes due to AD may start 20 years before symptoms seen. At the early stage of the disease, patients can function normally but afterwards brain cannot tolerate neuronal damage which has occurred. AD patients may face difficulty in remembering newly learned information at this stage[1].World Health Organization and Alzheimer's disease International stated a report calling on government to accomplish national dementia plans which focuses on 1) Put up public awareness about disease and reducing disgrace 2) Enhancing better early diagnosis techniques 3) Helping AD patients by giving better care and support.

Early diagnosis and effective treatment of AD patients in MCI stage are critical issues in dementia research. The issue in AD diagnosis today is to identify the disease before cognitive loss have reached peak of dementia that is at its Severe AD stage. There is a need, today, for boosting the diagnosis of AD with its early and specific diagnosis. Current existing techniques for detecting AD depend on cognitive impairment testing which unluckily does not yield precise detection until the patient has progressed beyond moderate AD. While current medications do not stop or reverse Alzheimer's, they can help to reduce the symptoms such as loss of memory and confusion. An early diagnosis of Alzheimer's gives AD patient a better chance of benefiting from treatment.[1]

This project is aimed at detecting an AD at an early stage using Support Vector Machine (SVM) classifier. SVM has been possibly regarded as one of the most excellent classification methods in machine learning. The aim of our study is to develop a classification system for the early detection of AD subjects. The Support Vector Machine comes under supervised learning. Supervised learning is the data mining task of inferring a function from a set of training data. SVM being an efficient classifier gives 96.67% of accuracy which is better than KNN and ANN algorithms. In this algorithm, every object is given by a point in N- dimensional space the value of each feature is represented by particular coordinator. [1]-[3]

II. RELATED WORK

Prof. Dr. V. K. Bairagi studied and proposed the technique for the diagnosis of Alzheimer's Disease using EEG signal. In this, Preprocessing facilitates the posterior analysis of the data. Two different cleaning methods namely Independent Component Analysis (ICA) Wavelet-based De-noising have been presented. Different features have been explored in the present study such as Spectral-based features, Wavelet based features and Complexity-based features. This paper concludes that concluded that power in low frequency bands of EEG signals such as Delta (0-4.5 Hz) and Theta (4.5-8 Hz) increases, while power in high frequency bands such as Alpha (8-12 Hz) and Beta (13-30 Hz) decreases in the case of patients with Alzheimer's disease due to the neuronal loss of cells and neuro fibrillary tangles associated with the brain cells.[1]

Yudong Zhang, Shuihua Wang, and Zhengchao Dong studied classification of Alzheimer Disease Based on Structural Magnetic Resonance Imaging by Kernel Support Vector Machine Decision Tree. A hybrid classification system for distinguishing NC, MCI, and AD based on structural MRI images is used. PCA is used to reduce the dimensionality of the feature vectors of the MRI data and the resultant principal components retained important information. The KSVM-DT method gathered the principal components from MRI data. Limitation of this method is that the classifier establishes machine-oriented rules not human-oriented rules. Another limitation is accuracy of system.[3]

P. Padilla, M. López, J. M. Górriz, J. Ramírez, D. Salas-González, I. Álvarez studied a NMF-SVM based technique for computed aided diagnosis of Alzheimer's disease. The proposed technique is based on the combination of nonnegative matrix factorization (NMF) for feature selection and reduction and SVM with bounds of confidence for classification. NMF-SVM, SPECT, PET these three different approaches for the classifier are provided.[4]

Esteve Gallego-Jutglà, Mohamed Elgendi, Member, Francois Vialatte, Jordi Solé-Casals, Andrzej Cichocki, Member, Charles Latchoumane, Member, Jaesung Jeong, Member, Justin Dauwels, Member studied diagnosis of Alzheimer's Disease from EEG by Means of Synchrony Measures in Optimized Frequency Bands. This study demonstrates the discriminative power of EEG synchrony for diagnosing Alzheimer's disease. Narrow frequency bands between 4 and 30Hz are systematically tested, besides the standard wide frequency band (4–30Hz), for evaluating multiple synchrony measures. Assessment has been done through statistical tests (Mann–Whitney U test) and LDA (leave-one-out cross validation). This paper concludes that it is promising to combine synchrony measures with each other or with other EEG features, such as relative power.[7]

III. METHODOLOGY

The EEG signals for training as well as testing phase are taken from the dataset file of EEG signals. The EEG dataset used includes recordings for both healthy and AD subjects. Given below is the block diagram to demonstrate how the flow of processes will taken place to achieve desired output.

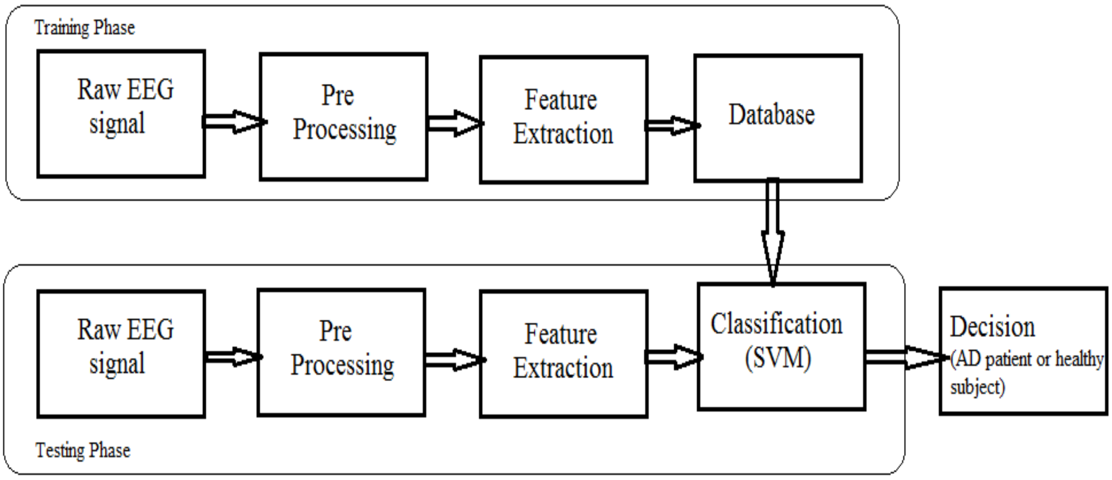

Fig.2: Block diagram of the system

Amplification: As EEG signal is very small intensity signal we need to amplify the signal using amplifier. This operation will help to increase the intensity of the signal and the signal can be easily studied. Filtering: To remove unwanted signals like noise or any useless frequency signal, initial filtering of EEG signal is done. In this project, LPF is used i.e. Low Pass Filter to remove unwanted signals.ADC: Analog to digital conversion is then performed on the signal and digital EEG signal is given to the next block for further process. Feature Extraction: Required features are extracted from the EEG signal. It transforms the data in the high-dimensional space to a space of fewer dimensions. Features used are mean, standard deviation, variance etc.
Classification: Database with required features are taken from both training and testing phase and given to classifier.SVM i.e. Support Vector Machine classification algorithm is used for classification. This will give us final output as a result which will tell whether a person is healthy or has Alzheimer's Disease.

The EEG dataset used includes recordings for both healthy and AD subjects. Preprocessing includes amplification, initial filtering of EEG signal to remove unwanted signal like noise. Also analog to digital conversion is made. In the next stage, wavelet based features are extracted from the preprocessed and digitized EEG signal. Features like mean, standard deviation, skewness, variance, kurtosis etc are extracted to detect AD in this project. The features extracted in the previous stage are given as input to the SVM classifier. In this classification a comparison of trained dataset and test dataset is done. Finally EEG signals are classified as signals with AD components and Non-AD components.

A. PREPROCESSING

EEG signals are basically non-stationary,noisy and sensitive to eye-blinking of patients, muscle activity which worsen the performance of AD diagnosis. To eliminate such artefacts and certain problems associated with recordings, preprocessing is required. Preprocessing step increases the visual reliability of a signal. It involves a set of techniques that enhances certain parameters of the signal in order to efficiently process it for further analysis. This step includes Amplification, Inital filtering of EEG signal to remove noisy and unwanted signal. Also Analog to digital conversion is made i.e. EEG signal is digitzed.

The Butterworth bandpass filter is used for filtering the EEG signal from 0.5 to 30 Hz. Initially, Raw EEG signal is preprocessed to eliminate an artefact by using wavelet-based denoising[ ].It is a one-dimensional wavelet based denoising technique for preprocessing the signal. In present work, decomposition of EEG signal into five frequency bands was done by the use of "Daubechies" wavelet[ ].

Frequency band decomposition is mentioned here like Delta = 0.5-4 Hz, Theta = 4-8 Hz, Alpha = 8-12 Hz, Beta = 12-30 Hz, Gamma = 30-100 Hz. Mathematically, the model for noisy signal is given by,

$$s(n) = f(n) + e(n) \qquad (1)$$

where e(n) presents gaussian white noise. The objective of this denoising method is to supress the noise part of signal and to recover original signal f(n).This is how preprocessing is done and the EEG signal is further given for feature extraction.[1]-[3].

B. FEATURE EXTRACTION

Feature extraction involves reducing the number of resources required to describe a large set of data. feature extraction starts from an initial set of measured data and builds derived values (features) intended to be informative and non-redundant, facilitating the subsequent learning and generalization steps, and in some cases leading to better human interpretations.

Fourier transforms is used extensively for analyzing various signals, such as biomedical signals like electrocardiogram (ECG), EEG, speech signals, and many more. Many of the times, Fourier transform is not always the correct or appropriate method for analysis of non stationary signals since its spectral content changes with time. A Fourier signal analyzes spectral components residing in the signal. On the other hand, it does not provide information related to the time localizations of the spectral components. A time-frequency representation provides time-localizations of the spectral components of the signal which provides necessary significant information. To represent power distribution of EEG signals over both time and frequency, wavelet transform proves to be a promising approach and it is suitable for spectral analysis for detection of brain disorders, such as Alzheimer’s, Epilepsy, tumors, and many more as compared to FFT.

Daubechies wavelet is used for signal analysis. The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function (called the father wavelet) which generates an orthogonal multi-resolution analysis. In this paper db2 wavelet transform with level 4 is implemented.

The wavelet coefficients are derived by reversing the order of the scaling function coefficients and then reversing the sign of every second one. Mathematically is represented as-

$$b_k = (-1)^k a_{N-1-k} \qquad (2)$$

Where k is the coefficient index, b is a coefficient of the wavelet sequence and a a coefficient of the scaling sequence. N is the wavelet index

The features can be extracted in time, as well as frequency domain. Statistical approach of the time domain features proves to be most simple and commonly used feature to represent the large sets of data. Statistical features, such as mean, mode, standard deviation, and variance can be used in general[1]. In present research work, mean power of the wavelet coefficients was computed using following formula:

$$\text{Mean} = \frac{1}{n} \sum_{i=0}^{n-1} x_i^2 , j = 1 \ldots N \qquad (3)$$

where xi’s are the computed coefficients of the signal at each sub band, n denotes number of coefficients at each band and N denotes number of band. These features values were computed at each level of DWT decomposition separately for each recording block from each task of each subject.

Standard deviation is a number used to tell how measurements for a group are spread out from the average (mean), or expected value. A low standard deviation means that most of the numbers are very close to the average. A high standard deviation means that the numbers are spread out[1].

$$\sigma^2 = \frac{1}{n-1}\sum_{i=0}^{n-1}(x_i - \mu)^2 \quad (4)$$

Skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive, zero, negative, or undefined[2-4].

$$\text{Skewness} = \frac{\sum(y_i - y)^3}{(n-1)^3} \quad (5)$$

Kurtosis is a measure of the "tailedness" of the probability distribution of a real-valued random variable

$$\text{Kurtosis} = \frac{1}{n}\sum_{i-1}^{n}\left(\frac{x_i - \bar{x}}{SD(x)}\right)^4 \quad (6)$$

Power Bandwidth in signal processing, it describes the difference between upper and lower frequencies of signal. The median frequency is defined as the frequency of a power spectrum at which 50 % of the power are at lower frequencies and 50 % of the power are at higher frequencies[5]-[7].

C. The Support Vector Machine Algorithm

Support vector machine is mostly preferred as it produces outstanding accuracy with less computation power. Support Vector Machine (SVM) algorithm can be used for regression as well as classification tasks. But, it is generally used in classification purpose.

The main objective of the support vector machine algorithm is to find a hyperplane in an N-dimensional space (N — the number of features) that distinctly classifies the data points. Support-vector machines (SVMs, also support-vector networks) are supervised learning models with associated learning algorithms that analyze data used for classification and regression analysis. Given a set of training examples, each marked as belonging to one or the other of two categories, an SVM training algorithm builds a model that assigns new examples to one category. Fig.3 shows conceptual diagram of SVM.

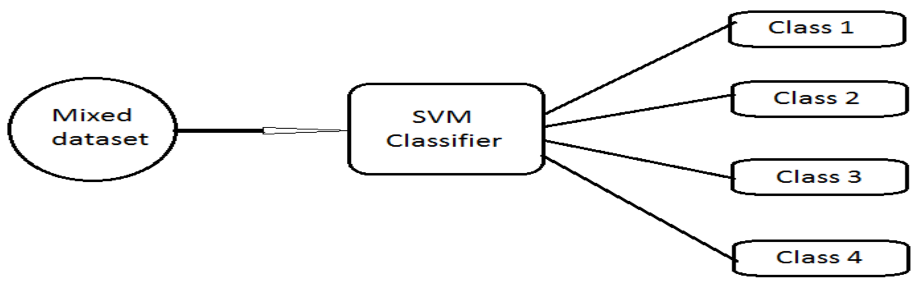

Fig.3 Support vector classifier

To divide the two classes of data points, there can be many hyperplanes possible that could be chosen. But the main objective is to find a plane having the maximum margin, i.e. the maximum gap between data points of both classes. Maximizing the margin distance provides reinforcement hence future data points can be classified with more confidence.

Hyperplanes are decision boundaries which classify the data points. Data points on either side of the hyperplane can be assigned to different classes. Also, the dimension of the hyperplane depends on the number of different features. The hyperplane is just a line if number features is 2. But if the number of input features is 3, then the hyperplane will be a two-dimensional plane.

Non-linear transformations: Some binary classifiers may not have a simple hyperplane as a useful separating principle. For this kind of problems, a mathematical approach is formulated, which in turn returns nearly all the simplicity of support vector separating hyperplane.[1],[3] .There exists a class of functions $k < x,y>$ with the following problem, which consists of linear space S and a function mapping x to S, such that

$$k(x,y) = <\Phi(x), \Phi(y)> \quad (7)$$

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The dot product takes place in the same space *S*. This class of function includes the following:
1. Polynomials: For some positive integer *d*,
$k(x,y)=(1+<x,y>)^d$..(8)
2. Radial basis function: For some positive number σ, $k(x,y)=e\ exp(-< (x-y),(x-y) \geq (2\sigma^2)$.......................(9)
3. Multilayer Perceptron (Neural Network): For a positive number $p1$ and a negative number $p2$,
$k(x,y)=\tanh(p_1,<x,y>+ p_2)$..(10)

The mathematical approach depends on computational method of hyper plane by use of kernel function. Dot product technique is specifically used for obtaining calculations for classification purpose using hyper plane technique. Therefore a nonlinear kernel makes use of identical calculations, algorithmic solutions & classifiers are obtained which are nonlinear in nature. The obtained classifiers are hyper surfaces in some space *S* (say), but the space *S* may not be examined or identified. In the proposed research work, supervised learning model is used. Firstly, a Support Vector Machine is trained, and then uses the trained machine to classify new data. In order to obtain satisfactory or rather better classification accuracy, a variety of SVM kernel functions are used.[1],[4].

IV. RESULTS AND DISCUSSION

To detect minute changes in EEG signal, in this paper a tool is designed. In case of Alzheimer's disease diagnosis 10 signals from database of 100 patients are taken and extracted 16 channel EEG signal. Multichannel graph representation is shown in Fig.4.

If there is much irrelevant and redundant information present or noisy and unreliable data, then knowledge discovery during the training phase is more difficult. Data preparation and filtering steps can take considerable amount of processing time. Data pre-processing includes filtering, normalization, transformation, feature extraction and selection, etc. The product of data pre-processing is the final training set. Feature selection is determining a subset of the initial features. The selected features are expected to contain the relevant information from the input data, so that the desired task can be performed by using this reduced representation instead of the complete initial data.

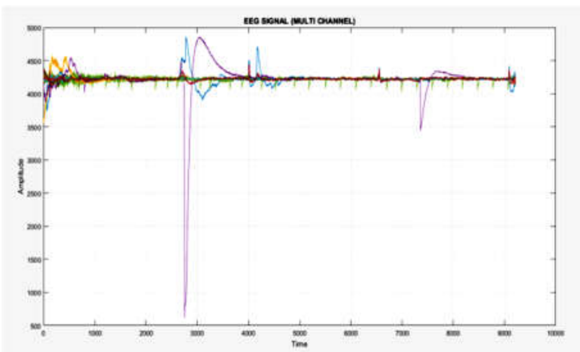

Fig.4: Pre-processed EEG

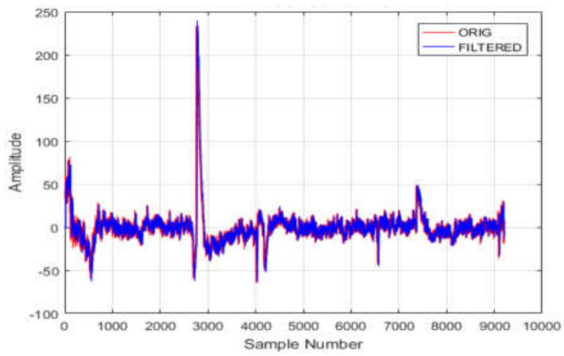

Fig.5: Filtered signal

Then the multi channel signal is converted to single channel. Fig.5 shows multi to single channel converted signal. A low pass filter is designed with sampling frequency 180HZ. The low pass filter removes high frequency noise components and passes signals below 50Hz frequency. Following figure represents the filtered signal.

Daubenchies wave db2 either level 4 is used for decomposition in Discrete Wavelet Transform (DWT). In feature extraction statistical features such as mean, standard deviation, skewness, kurtosis, power bandwidth, median frequency are extracted. Approximated coefficient and detail coefficients are shown using MATLAB.

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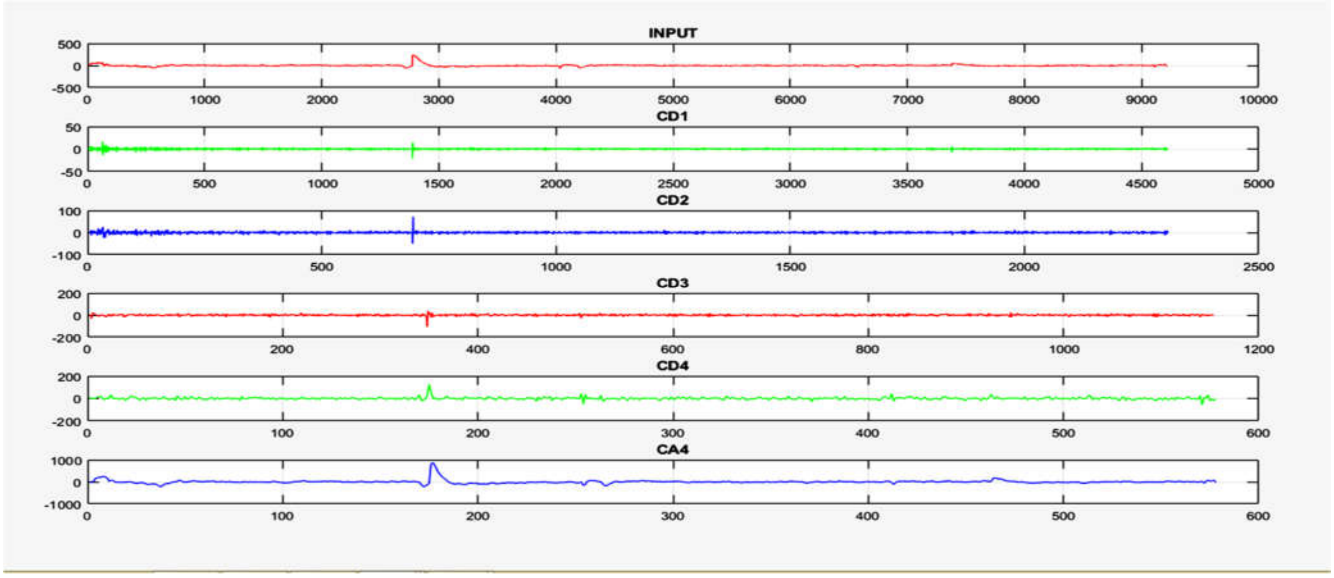

Fig.6: Output waveforms of discrete wavelet transform

A discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency and location information (location in time).

Daubechies wavelets is the most commonly used set of discrete wavelet transforms. This formulation is based on the use of recurrence relations to generate progressively finer discrete samplings of an implicit mother wavelet function; each resolution is twice that of the previous scale.

V. CONCLUSION

EEG signals can be used as reliable indicators of the mental states like Alzheimer. The subtle changes in the EEG signals cannot be discriminated by the naked eye; therefore, a computer assisted tool is necessary, in this we are trying to make it. The traditional time domain, frequency domain and wavelet domains are easy to implement. By using database here samples have been taken and pre-processed then using DWT and SVM algorithms, detection of Alzheimer's disease from EEG signal at early stage can be done. Mean, standard deviation, skewness, kurtosis, power bandwidth and median frequency these features are extracted using matlab. Thus, EEG can be used as the inexpensive, convenient tool for diagnosis of Alzheimer disease. In future, various different algorithms as well as classifiers such as neural networks can be used for increasing the accuracy of diagnosis of the disease in early stage. Research challenges includes the increase of accuracy up to 95% of EEG signal to detect the disease in the early stage, use of different classifiers for classification purpose & to remove the artifacts in EEG signal are some them. In future, the above system can also be made portable.

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