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Binary Classification of Alzheimer’s disease using MRI images and Support Vector Machine

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***Abstract*—Dementia is a chronic syndrome affecting the daily functioning of a person due to complications through deterioration in thinking, behavior and memory. Alzheimer’s disease (AD) is the most common cause of dementia, aggregating up to 1 million new cases in India alone each year. Magnetic Resonance Imaging (MRI) of the brain has been found to be a very useful modality for the detection of cerebral and neural related abnormalities. Feature extraction along with Machine Learning (ML) algorithms can be used for detection of AD. The main objective of this work is to process 2D MRI axial slices of the brain and hence, build a prediction model to classify AD subjects from normal control individuals. The axial slices of the brain have been taken from Kaggle database. Feature extraction is done using Gray Level Co-occurrence Matrix (GLCM) and Haralick features in spatial domain. The features are given to Support Vector Machine (SVM) for classification. A comparative study using other supervised ML algorithms, namely k-Nearest Neighbors (k-NN), Random Forest and Linear regression classifiers were done. The accuracy achieved using 13 Haralick features for two level classification is 84%.**

Keywords—Dementia, Alzheimer’s Disease, Kaggle Database, GLCM, Haralick, Classifier.

I. Introduction

Alzheimer's disease is a progressive neuro degenerative disorder that results in neurons wasting away and dying. The root cause is estimated to be the dysfunction of brain proteins neurofibrillary tangles and amyloid plaques. This results in a series of chemical reactions that cause brain synapses to lose connection causing permanent neural damage. It is a chronic disease with no cure and present medications can only slow down the rate of degradation but not terminate the disease. The total estimated worldwide cost of dementia was US$ 818 billion in 2015, which represents 1.09% of global GDP as presented by the World Health Organization [1].

A combination of genetic, head trauma and socio-economic conditions are contributing factors to its onset. Mild cognitive impairment is a precursor to dementia, where memory losses at a younger age is observed. Parameters considered during detection are the person’s age, gender, socio-economic status, genetic and health history, trauma and cognitive state testing questionnaire called Mini-Mental State Examination (MMSE) The literature review by Dubois B et.al. gives information on timely diagnosis on AD [2].

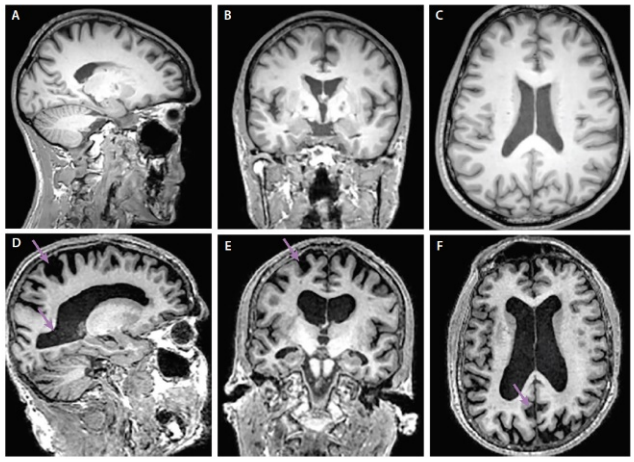

Fig.1: MRI scans showing clear difference between normal control (A, B, C) and severely demented brain (D, E, F)

In the current context computer aided diagnostics using advanced prediction algorithms are being considered as emphasized by D.S. Marcus and partners [3]. The proposed prediction model makes use of the axial slice of the brain to observe textural feature differences in the affected area. In MRI processing, skull stripping is important as discussed by M. Evanchalin Sweety and G. Wiselin Jiji [4]. B. S. Mahanand et al., in their papers discuss the importance of Voxel Based Morphometry (VBM) as features [5] and Biomarkers responsible for AD [6]. Whereas S Saraswathiet.al. highlights the importance of statistical voxel values of brain patches used to determine the textural changes in the gray matter [7]. First order textural features in spatial domain can be attained using GLCMas discussed by S. Aruchamy et. al, which gives the image properties by considering the spatial relationship between two neighboring pixels, where the first pixel is the reference pixel, and second pixel is the neighboring pixel [8]. Haralick features developed by Robert Haralick is one of the popular algorithms that extracts features from the GLCM which aims to create a facet model in the feature detection area [9].

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The various features extracted are then fed into different classifiers. A lot of works concentrates on using Neural networks for classification demonstrate by S Saraswathi et. al, [7] and C. S. Sandeep et. al, [10] which uses advanced feed-forward prediction techniques. The entire dataset is split into training and testing subcategories to help train the classifier and subsequently validate the results. Binary classification aims to distinguish data into AD and Normal Control (NC). Choice between neural network and support vector machine is discussed in detail by Uma Rani K and Mallikarjuna S. Holi [11]. SVM and adaptations are ventured by Srinivas Aruchamy et al. [12], by Yi Ding et al [13] and by P. A. Freeborough and N. C Fox [14] with accuracies of 84%, 92.86% and 84.40% respectively. Principal Component Analysis (PCA) helps in unsupervised statistical transformation to determine interrelationship between variables that gives the best line of fit. Using this, the SVM can be visualized to see data plots of the feature arrays. Performance analyses parameters like accuracy, sensitivity and specificity help realize the efficiency of the prediction model. Cross validation is a popular technique that divides the entire available dataset into 'k' dividends to generate a 'k' fold comparison methodology where each sub-division is treated as a testing set against the remaining training set iteratively, to get the best sub-division with highest performance parameters. For comparative analysis purposes, other supervised ML algorithms have also been used.

II. PROPOSED METHOD AND IMPLEMENTATION

The objective of this study is to develop a model to help in prediction of Dementia, specifically AD using MRI images, and efficiently identify using signal processing techniques along with a good classifier. The block diagram in figure 2 gives the overview of the steps carried out.

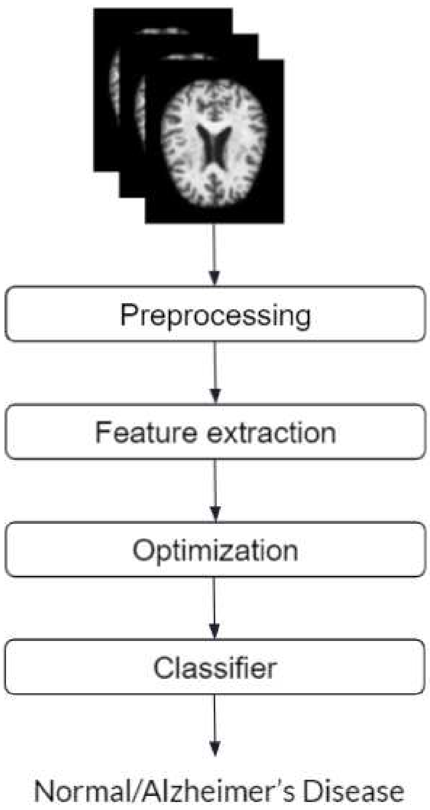

Fig 2: Block diagram of proposed system

A. Database

The data used in this study is taken from the Kaggle database [15]. Kaggle is a revolutionary platform allowing users to find and publish data sets to build models in a web-based data-science environment. 2D axial slices of the brain MRI is considered for this study as difference between demented and normal brain is distinguishable in this view, facilitating image processing. The use of dataset is shown in table 1.

TABLE I. DATASET DIVISION

Dataset	Non-Demented	Very Mild Demented	Mild Demented	Moderate Demented	Total
Training	2560	1792	717	52	5121
Testing	639	448	127	12	1279

B. Preprocessing

The intention of preprocessing is to enhance image quality by suppressing noise. The dataset available had skull-stripped axial slices of the 3D MRI, contrast enhancement was further performed through Adaptive Histogram Equalization as shown in figure 3. Finally, Gray-level conversion of images was done.

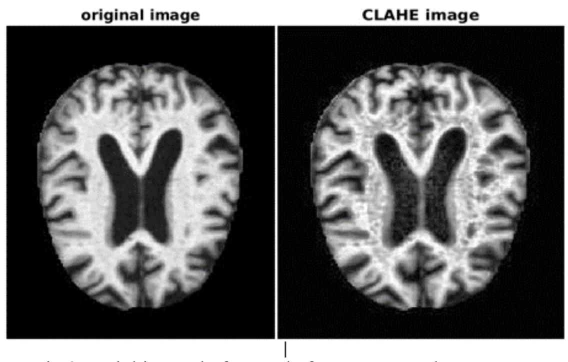

Fig 3: Axial image before and after contrast enhancement

C. Feature extraction

The preprocessed image is then subjected to feature extraction techniques that best describe the textural relationship in spatial domain of the image pixels. GLCM is a very popular and efficient technique in this domain. It calculates the second order statistical image properties, i.e., the spatial relationship between two neighboring pixels depending on two factors – relative distance between pixel pairs measured in pixel number and their relative orientation. The matrix thus computed is then used to generate 2 sets of features as listed below:

- **GLCM – 4:** Four features from the GLCM namely contrast, energy, correlation and homogeneity. These give information about the local uniformity and dependency of the gray level pixels in the image.
- **GLCM – Haralick:** Fourteen features from the GLCM namely energy, contrast, correlation, variance, homogeneity, sum average, sum variance, sum entropy, entropy, difference variance, difference entropy, information measure of correlation 1, measure of correlation 2 and finally maximal correlation co-efficient. The measure, sum variance was found computationally unstable as described by Löfstedt, T et. al. [16] and was not considered in the

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feature array generated, hence, resulting in 13 features to work with.

D. Classification

These feature arrays generated are then given to different supervised ML algorithms, namely Support vector machine (SVM), k-Nearest Neighbor (k-NN), Random Forest and linear regression.

- **SVM** plots the already labelled data set as points in a plane and develops the hyperplane that best separates tags, which maximizes the margin between these tags.
- **k-NN** classifies data points based on the majority votes observed in the vicinity of it, within the trained dataset pool.
- **Linear Regression** helps fit a curve by considering the square of the residuals of the data points.
- **Random Forest** combines the precedence of binary trees with cross validation and backtracking by simultaneously growing multiple decision trees.

III. Classification Results

This work concentrates on supervised machine learning algorithm dealing with labelled training and testing data, specifically SVM. Classification was done in 3 comparative analysis directives, discussed in the subsections ahead in detail.

A. Comparative study based on input features to classifier

A two level SVM model was built and the GLCM-4 and GLCM- Haralick features extracted from 5121 training and 1279 testing images were given to the classifier separately to predict whether the subject is demented and non-demented. The result is tabulated in table II.

TABLE II. TWO LEVEL SVM CLASSIFIERS.

Feature extraction methodology	Number of features extracted	Accuracy
GLCM-4	4	58%
GLCM-Haralick	13	63%

It can be observed that as the number of features is increased the accuracy increases substantially, as observed in table II. Haralick feature extraction gives a better descriptor of the image information and accuracy.

B. Comparative study based on dataset size

To improve accuracy of the classifier, binary classification is performed splitting the large dataset into smaller chunks. GLCM- Harlick features extracted from the images of difference data set sizes, are then given to the SVM classifier. The results obtained are shown in figure 4.

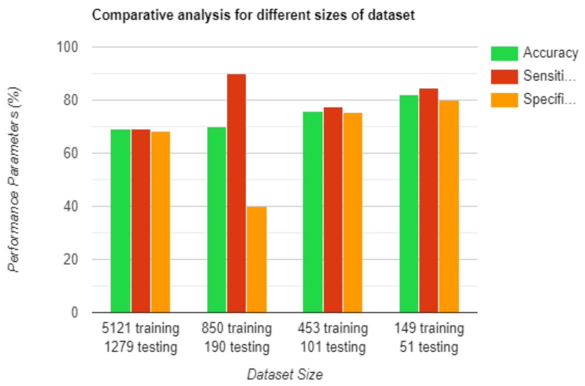

Fig 4: Bar graph for different datasets

It can be seen that the accuracy of classification increases for the SVM classifier as the size of the dataset decreases. The SVM thus constructed with the best accuracy for 200-imaged dataset is shown in fig 5.

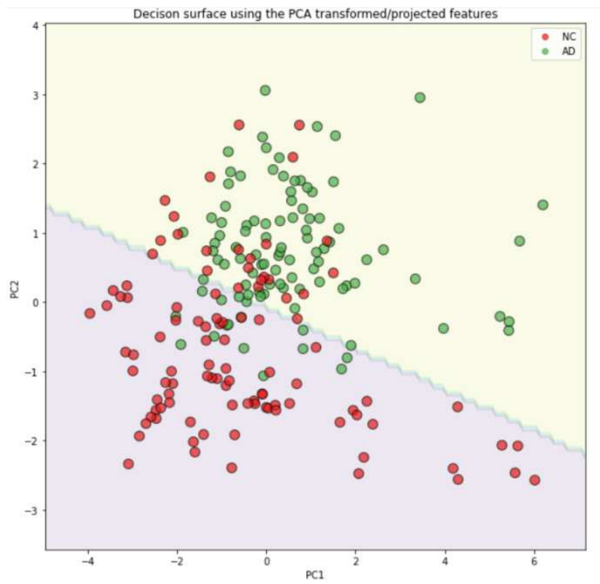

Fig 5: SVM Constructed

The performance substantiation for binary classification was done using k fold cross validation. Here, the dataset was tested by dividing it into k-fold comparative dividends. The best performance observed is as tabulated in the table III.

TABLE III. CROSS VALIDATION IMPROVING PERFORMANCE

Type	Dataset size		Before cross validation Accuracy	After cross validation	
	Train	Test		k-fold	Accuracy
Binary classification	149	51	82%	7	84%
Binary classification	5121	1279	63%	10	73%

The accuracy increased from 82% to 84% when subjected to 7-fold cross validation for the 200-images from the dataset. For larger dataset, it was noticed that there is a significant rise in accuracy from 63% to 73% when subjected to 10-fold cross validation.

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C. *Comparative study of different classifiers*

To have a comparative study of the performance of the SVM model built, the GLCM- Haralick features extracted from 200 images were given to different classifiers namely k-NN, random forest and linear regression. Figure6 shows a comparison of all the four classifiers without cross validation, where it can be observed that SVM gives the highest classification accuracy of 82%.

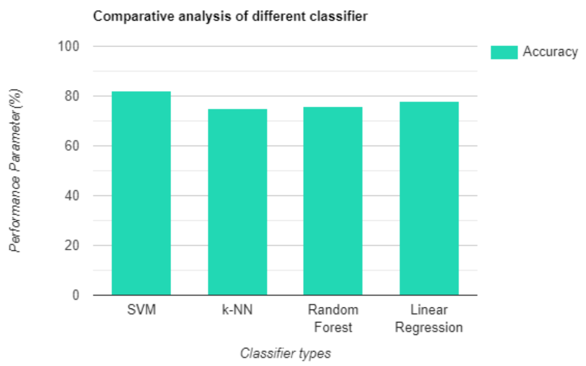

Fig 6: Performance of different classifiers

IV. CONCLUSION AND FUTURE WORK

The SVM model was developed to predict Alzheimer's patient from the given input MRI axial image. GLCM-Haralick features works consistently for the given images. SVM works best with smaller sizes of dataset, giving an accuracy of 84% for a dataset size of 200 images, while the accuracy is 73% for a dataset size of 6400 images. Along with this, it can also be seen that the SVM classifier outperforms other classifiers with an accuracy of 82%, while linear regression with 78%, random forest with 76% and k-NN with 75%.

Future endeavors can also incorporate other parameters into the input feature set like age, gender, Mini Mental State Examination (MMSE) score, etc. Unsupervised ML algorithms can also be tested for the same. The model developed allows scope for prognosis tracking.

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