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Machine Learning Algorithms for the diagnosis of Alzheimer's and Parkinson's Disease

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ABSTRACT

Dementia is a general term used to indicate any disorder related to human memory. The various memory related problems severely affects the human brain and so the individual feels difficulty in doing their normal physical as well as mental activities. There are different types of dementia exists, but the commonly seen and fatal types of dementia are Alzheimer's disease (AD) and Parkinson's disease (PD). In this paper different efficient Machine Learning Techniques are selected analyzed their behaviors in the diagnosis of AD and PD using Positron Emission Tomography (PET). The PET image dataset used in this work consists of 1050 images with AD, PD and Healthy Brain images. The total number of images is split into two different categories for training and testing in the ratio of 7:3. The different machine learning classifiers used are Bagged Ensemble, ID3, Naive Bayes and Multiclass Support Vector Machine. The classification of the AD and PD is carried out by comparing the test image with the trained samples in the database. On comparison of trained samples with the input image for the PET images, bagged ensemble learning classifier worked better than the other classification algorithms and yields an accuracy of 90.3%.

Keywords: Alzheimer's Disease (AD), Bagged Ensemble, Decision tree, Dementia, Machine Learning Techniques, Naive Bayes, Parkinson's Disease (PD), Positron emission Tomography (PET), Support Vector Machine (SVM).

1 INTRODUCTION

Dementia is the related term for human condition that disturbs the normal functioning of the brain. This includes diseases which severely affect memory, language, behavior, thinking skills and problem solving capacity of an individual [1]. Dementia cannot be referred as a disease which develops as the part of ageing, but it mainly seems in old people who are above 60 years. As per the study of WHO, in 2019 about 50 million people were suffering from different kinds of dementia and around 10 million new patients are getting diagnosed every year [2]. The condition of dementia is so pathetic that there is no cure for these diseases, but an early detection od disease can do some monitoring techniques to help the patient in doing their regular activities.

1.1 Types of dementia

There exist various types of dementia which differs in the symptoms and occurrence in parts of the human brain [3]. The fatal types of dementia exists are AD and PD.

1.2 Alzheimer's Disease

AD is the most commonly reported syndrome in all the dementia types. It is mainly seen in people having age more than 60. This fatal brain disorder mainly affects the significant parts of the brain like hippocampus, ventricles and cerebral cortex. This chronic neurodegenerative disease has early symptoms as difficulty in remembering recent events and problems with language. This condition developed to later symptoms as disorientation, mood swings, impaired judgment and difficulty in speaking, swallowing and walking. The below figure 1 shows the difference between the brain structure in healthy and AD [4].

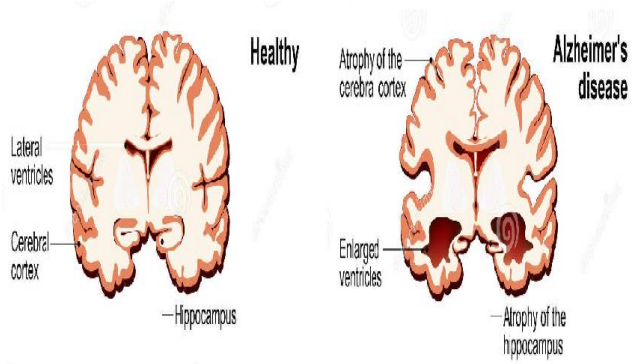


Figure 1: Healthy Vs Alzheimer's Brain

1.3 Parkinson's Disease

PD is the disorder in nervous system which develops progressively and restricts movement. In PD a few neurons in the brain gradually break down. This result in the production of chemical messenger in the brain called dopamine. The increase in dopamine level leads to the abnormal brain activity and affects the middle part of the brain called substantia nigra. The early symptoms of PD are constipation, depression, loss of smell, low blood pressure and sleep issues. Lately the symptoms develop to shaking, rigidity, slowness of movement and difficulty in walking. The below figure 2 show the brain structure of healthy and PD.

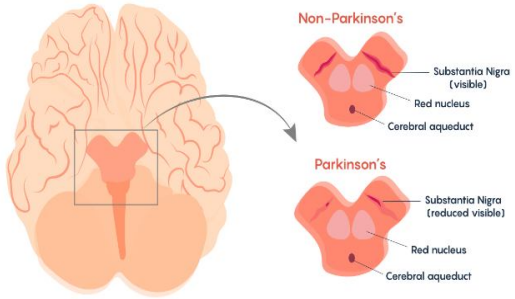


Figure 2: Healthy Vs Parkinson's disease

2 LITERATURE REVIEW

The main objective of this work is to analyze the different machine learning techniques to work with the diagnosis of AD and PD with the reference of healthy brain. There are a number of researches gave unbelievable contributions in the field of dementia detection [25]. Most of them concentrate on the diagnosis of a single type of dementia using computer aided diagnosis. The different types of data they used are historical data, physical exam, cognitive test laboratory studies and imaging. Rather than imaging the entire different medical test can categorize only normal or abnormal conditions. So the best type of medical test for categorizing different types of dementia using a single or combination algorithms is medical imaging. The aim of the proposed study is to diagnose different types of dementia using an algorithm and it is a challenge to differentiate between the different dementia since the symptoms of the diseases seems to be similar. So the best type of disease identification is the study in the change of human brain in different dementia condition.

2.1 Related Alzheimer's and Parkinson's diagnosis works:

AmiraBen Rabeh et al. worked on the diagnosis of Alzheimer disease in early step using SVM [5]. They used MRI based grayscale image with size 500*500. They used segmentation to extract hippocampus, corpus callosum and cortex regions for extracting features. Then they applied SVM to classify the images to normal or AD. They attained an average accuracy of 71.33% with all the proposed solutions.

Davud Asemani et al. developed a work on Alzheimer disease and its ageing effects on haemodynamic response function with fMRI [6]. They used MRI scans acquired using a 1.5 T Vision System with 128 scanned images. They used Region of Interest method to extract vision and motor cortices from the images. From their study they found that noise in the data will be much in elderly adults.

Jin Liu et al. designed individual hierarchical networks with 3-D texture features for Alzheimer's disease classification [7]. In this novel work they used 710 T1-weighted MRI brain images as the dataset. They used FAST method for feature extraction and FLIRT method for feature alignment. They used MKBoost method for the classification of images and yield an accuracy of 86.56%.

Jun Zhang et al. had worked on landmark - based features from MRI images for Alzheimer's disease diagnosis [8]. They collected MRI and PET images from ADNI dataset. They used linear alignment for all the images in the dataset, landmark discovery for training and landmark detection for testing. They achieved an accuracy of 88.30%.

Salim Lahmiri et al. had developed an approach for the classification of Alzheimer's disease using MRI images [9]. In their work the MRI images from ADNI database are converted to one-dimensional signal by row concatenation. They used MSA (multi-scale analysis) to obtain HE (Hurst's exponent) at various scales to characterize the brain MRI, and a SVM classifier is used for classification. They achieved an accuracy of 97.1%

Shubham Bind et al. done a survey on Parkinson disease prediction using machine learning based approaches [10]. They recorded the performance of Artificial Neural Network, Naïve Bayes, K Nearest Neighbor, Random Forest and Support Vector Machine.

Tarigoppula V.S Sriram et al. had done work using machine learning algorithms for Parkinson disease prediction [11]. From UCI repository they collected voice dataset for Parkinson disease. They used different machine learning algorithms for the detection of Parkinson disease and recorded that Random forest algorithm performs well with an accuracy of 90.26%.

Prashanth et al. introduced a work on machine learning algorithms for Parkinson's disease diagnosis with multimodal features [12]. They used non-motor features of RBD (Sleep Behavior Disorder) and olfactory loss and other significant biomarkers. They classified the data set images from PPMI database using Naive Bayes, Boosted Trees, Support Vector Machine and Random Forest classifiers. They observed that SVM classifier gave the best performance with 96.40% accuracy.

Enas Abdulhay et al. proposed a work for the diagnosis of Parkinson disease on gait and tremor investigation with the help of machine learning techniques [13]. They used Physionet dataset with Vertical Ground Reaction Force (VGRF) feature. They analysis other features like stance, swing and stride time for the entries. They got an accuracy of 92.7% for the proposed work.

Mohammad R. Salmanpour et al. predicted Parkinson's disease with some optimized machine learning methods [14]. They used PPMI database for the investigation and employed 10 predictor algorithms, provided with all 93 features. In their work they tried different methodologies and minimized the error rate compared with other existing works.

The literature survey infers that the detection of both AD and PD from a same type of brain image data set was not done earlier. The highlight of the work is that a single algorithm is used in the detection of both AD and PD in terms of classification.

3 PROPOSED WORK

The work flow of the proposed system is given below in figure 3 and layer wise description in AD and PD diagnosis is given in figure 4.

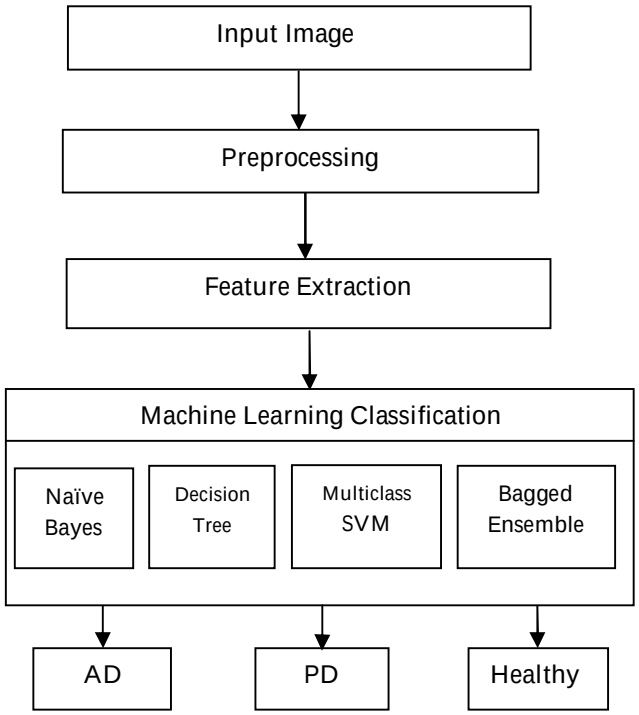


Figure 3: Architecture diagram for the diagnosis of AD and PD using Machine Learning Algorithms

Feature Extraction layer	Statistical Features	GLCM
	Edge Detection	SOBEL
	Corner Detection	FAST
	Histogram Features	HoG
Automation Layer	Training, Testing and Classification	Bagged Ensemble
		ID3
		Naive Bayes
		Multi Class SVM
Output Layer		Alzheimer's Disease
		Parkinson's Disease
		Healthy Brain

Figure 4: Different layers in the Diagnosis of AD and PD

3.1 Image Dataset

In the proposed work the image dataset selected for diagnosis is FDG (Fluorodeoxyglucose) – PET. FDG PET brain functional images give the detailed study of glucose metabolism, working of neuron and its synaptic activity. Nowadays for the tracking of metabolic activities in different neurological and aging diseases, FDG PET has been broadly used. In the human brain FDG – PET image stores the activities in the regions like basal ganglia, frontal eye fields, posterior cingulate cortex and visual cortex [15 - 18]. The first phase of the work started with the collection of FDG – PET brain functional images from the Laboratory of Neuroimaging (LONI) in DICOM file formats. DICOM is abbreviated as Digital Imaging and Communications in Medicine is the standard for the usage of information regarding medical imaging and its related data. Images are stored in MATLAB and displayed as gray scale images.

Layer		**Description**
Input layer	Image Database	FDG - PET Images
	Preprocessing	Image Resize
		Contrast Stretching
		Histogram Equalization
		Weiner Filtering

3.2 Preprocessing

In medical image processing, preprocessing of an image is very significant thus the image can be processed further with reduced noise. This will boost the performance of forthcoming process such as segmentation, feature extraction, etc. The different preprocessing steps carried out in the proposed work are image resize, histogram equalization, contrast enhancement and wiener filtering [19, 20].

The input image is resized to a fixed size, so that all the trained images can be set in the same size. The contrast stretching will be performed to the resized input image to improve the quality of image. Histogram equalization is done to the contrast stretched image to improve the contrast in images. Then wiener filtering is performed to this image to remove the mean square error at the time of noise smoothing. The image getting after doing the wiener filtering is the resultant input image to perform feature extraction.

3.3 Feature Extraction

The features of the preprocessed image are extracted using GLCM, SOBEL, FAST and HoG and stored in the database [21].

3.3.1 GLCM

It examines the texture of the segmented and returns the spatial relationship of pixels. There are a lot of GLCM (Gray-Level Co-occurrence Matrix**)** features available and among that Correlation, Contrast, Entropy, Energy, Maximum probability, Homogeneity, Prominence, Shade, Dissimilarity, Standard Deviation and Mean calculation is used in this work.

3.3.2 SOBEL

It is the edge feature detector used in the work. Within an image, it calculates gradient of intensity at each pixels. The resultant matrix shows the smooth change in behavior of each pixel in the image which represents the edge. It also shows how that edge is likely to be oriented. A vertical and horizontal gradient matrix as the same size of the input image is recorded for feature analysis.

3.3.3 FAST

FAST (Features from Accelerated Segment Test) method is used as the corner detection method in this work. It extracts feature corner points to map objects. The main highlight of using FAST is its computational efficiency. The set of output corner points is stored in the database for feature training and testing along with other desired features.

3.3.4 HoG

HoG (The Histogram of oriented Gradients) is the histogram based feature extractor used in this work. The occurrences of localized gradient orientation portions are counted in an image. For an improved accuracy, dense grid of uniformly spaced cells and overlapping local contrast normalization is performed. A set of derived vector points and an output matrix is recorded for feature analysis.

3.4 Machine Learning Algorithms

All the different features extracted from the different feature extraction methods are trained and testing using the following different classification methods [22, 23, 26, 27].

3.4.1 Bagged Ensemble Classifier

A bagging ensemble classifier is a supervised learning algorithm does predictions using training samples with voting or by averaging of multi base classifiers. Each base classifier is trained in parallel with a training set which is generated randomly with replacement of the newly trained sample. The main advantage of bagged ensemble classifier is the reduction of overfitting problem.

3.4.2 Decision Tree (ID3) Classifier

Decision tree is a supervised learning algorithm used for both classification and regression. In a decision tree the nodes represent attributes, branches represent decisions and leaves represent labels for each instance. The decision tree creates a tree for entire data and process a single outcome at every leaf. Entropy is the measure of randomness or unpredictability. The entropy is calculated to determine the root node. Information gain is the measure of decrease in entropy after dataset is split.

3.4.3 Naive Bayes Classifier

Naive Bayes is a simple probabilistic based classifier algorithm which works based on Bayes theorem. In this method the different classifiers are constructed by assign class labels to problem instances. This is not done single algorithm for training, but carried out by a set of algorithms based on a common principle called Naive Bayes theorem.

3.4.4 Multi Classifier SVM

Support vector machine (SVM) is the supervised classification algorithm used for both classification and regression. SVM is mainly for binary classification, but the biclassification SVM can be extended to multi class classification with help of kernels. In the diagnosis of AD and PD with healthy brain one-against-all method is used in multi class SVM. Multiclass SVM works by constructing k SVM models and here k is the number of classes.

4 EXPERIMENTAL SETUP AND RESULTS

The proposed system worked on FDG - PET image database with 1050 images. All PET images are downloaded from the Laboratory of Neuroimaging (LONI) in DICOM file formats (https://ida.loni.usc.edu) with Alzheimer's images, Parkinson's images and Healthy brain. In the database of 1050 images, 750 images were set for training and 300 images for testing is used. The output of the process comes in any one of the given 3 labels:

Label 1: AD Label 2: PD Label 3: HB

The PET image database details with image count, patient's details and disease category is given in the below table 1 and the description of the input images are given in table 2.

Table 1: Count of images in the FDG – PET image database

Type of disease	AD	PD	HB
No: of images	350	350	350
No: of male patients	138	240	174
No: of female patients	212	110	176
Range of age	61-98	50-85	50-90

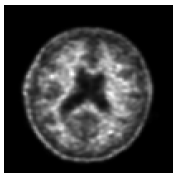
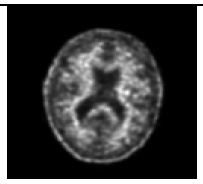
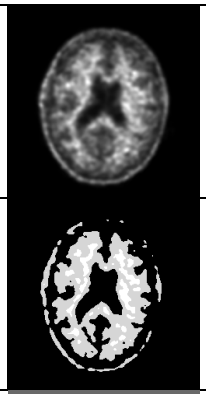
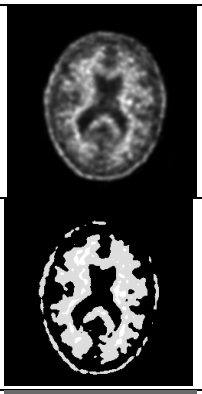
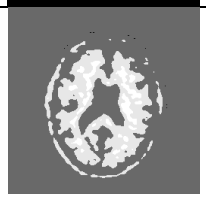
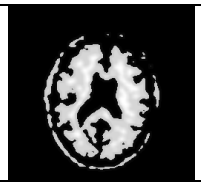
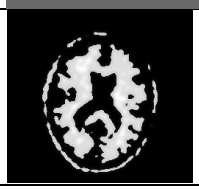
Table 2: Description of input image

Data	Description
Input	FDG - PET image
Image resize	256X256 pixels
Image Format	DICOM
Image type	Grey scale image
Image view	Axial view

4.1 Preprocessing Steps

The different preprocessing steps done by one to the input image for the classification of AD, PD or Healthy. Table 3 below shows the output generated for the preprocessing steps in the diagnosis of AD and PD using FDG-PET images.

Table 3: Preprocessing steps in the diagnosis of AD and PD using FDG-PET images.

Preprocessing Steps	Input 1	Input 2
Input Image		
Resized Image		
Contrast Stretching		
Histogram equalization		
Weiner Filtering		

4.2 Confusion Matrix

Confusion Matrix is a table structure defines the performance of a classifier on the test set data. It clearly shows the number true values known by the classified in the tested set of data. It can be simply defined as the visualization of the performance of an algorithm. For a multivariate classification model, the different entries related with the confusion matrix are as in the following table 4.

Table 4: Confusion Matrix for a multivariate classification model

	Predicted Class 1 (Positive)	**Predicted Class 2 (Negative)**	**Predicted Class 3 (Negative)**
Actual Class 1 (Positive)	**True Positive**	**False Negative**	**False Negative**
Actual Class 2 (Negative)	**False Positive**	**True Negative**	**True Negative**
Actual Class 3 (Negative)	**False Positive**	**True Negative**	**True Negative**

a) ***True Positive (TP):*** The actual class is positive and it classified as positive itself.
b) ***False Positive (FP):*** The actual class negative but it classified as positive.
c) ***False Negative (FN):*** The actual class is positive and it classified as negative.
d) ***True Negative (TN):*** The actual class negative and it classified as negative itself.

The resultant confusion matrix of the different learning algorithms is given below. Figure 5, 6, 7 and 8 shows the Confusion Matrix of Bagged Ensemble, Decision tree (ID3), Naive Bayes and Multi class SVM respectevily.

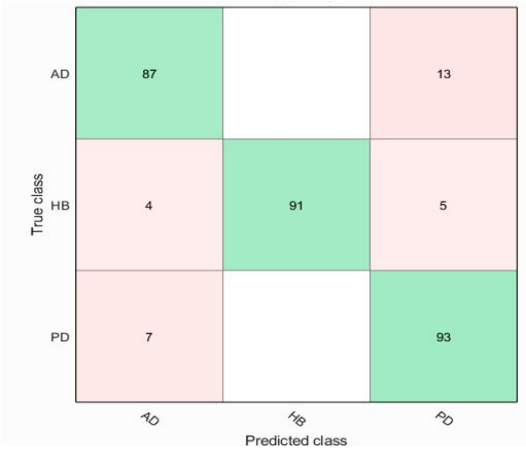


Figure 5: Confusion Matrix of Bagged Ensemble Classifier

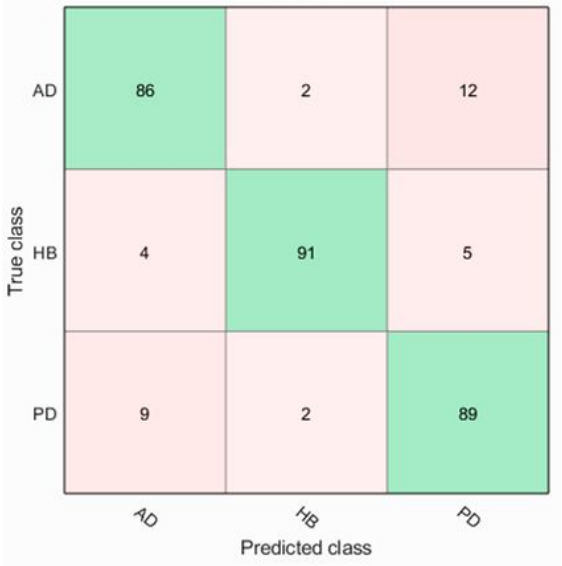


Figure 6: Confusion Matrix of ID3 Classifier

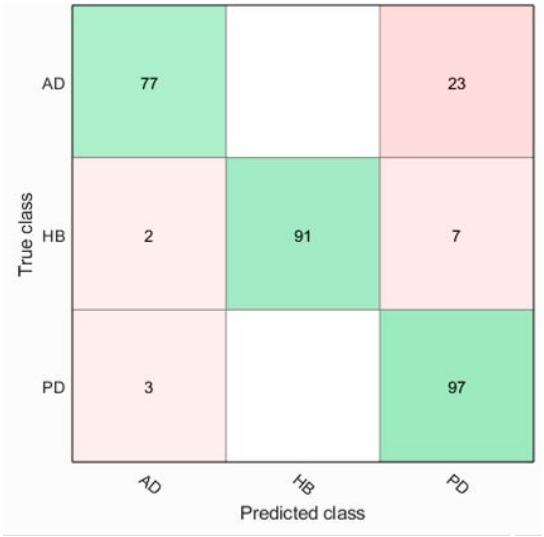


Figure 7: Confusion Matrix of Naïve Baes Classifier

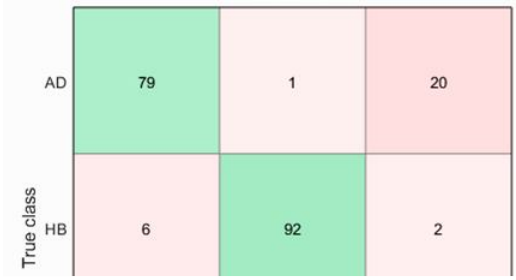


Table 5: Performance measures of different classifiers

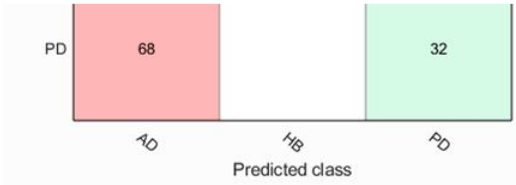


Figure 8: Confusion Matrix of Multi Class SVM Classifier

4.3 Performance Analysis

Performance analysis of the different machine learning approaches are discussed in the below table 5.

Classifiers	**Bagged Ensemble**	**ID3**	**Naïve Bayes**	**Multiclass SVM**
F1 - Score	0.88	0.86	0.85	0.63
AUC Value	0.95	0.92	0.94	0.74

The different performance are defined below from Eq. (1) to (5) [24].

1. $Sensitivity\ or\ Recall = \frac{TP}{TP+FN}$ (1)
2. $Specificity = \frac{TN}{FP+TN}$ (2)
3. $Precision = \frac{TP}{TP+FP}$ (3)
4. $Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$ (4)

4.4 F1-Score

It is the weighted average of Precision and recall. This considers both FP and FN into account unlike from accuracy. The formula to find out F1- score is in equation (5).

$$F1 - score = \frac{2*(Precision*Recall)}{(Precision+Recall)} \quad (5)$$

The below given bar chart, figure 9 shows the performance of difference Machine Learning Algorithms in terms of Accuracy and F1-Score.

4.5 ROC curve

ROC is the Receiver Operating Characteristics represents degree or measure of seperability. The ROC curve is plotted with TPR value in x axis against the FPR in y axis. The curve fits in the ROC graph gives the AUC (Area under curve) value tells capability of different models in distinguishing labels.

The F1 - score value AUC value of the machine learning algorithms are given in the below table 6.

Table 6: F1- score and AUC value of different classifiers

Performance measures	**Accuracy (%)**	**Sensitivity/ Recall**	**Specificity**	**Precision**
Bagged Ensemble	90.3	0.89	0.92	0.87
Decision tree (ID3)	88.7	0.87	0.90	0.86
Naive Bayes	88.3	0.94	0.94	0.77
Multi Class SVM	69.3	0.52	0.62	0.79

Performance analysis of the classifiers in terms of accuracy and F1 – score is plotted in figure 9.

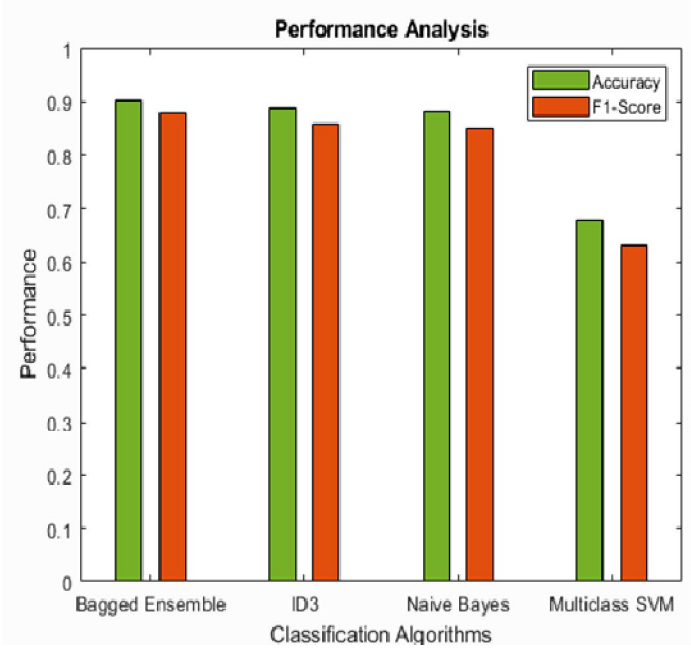


Figure 9: Performance analysis of the Machine Learning Algorithms

5. CONCLUSION AND FUTURE WORK

The diagnosis of AD and PD with reference to the healthy brain is carried out using different machine learning algorithms such as Bagged Ensemble, Decision Tree, Naïve Bayes and Multiclass SVM. Among these the Bagged Ensemble performs better than the other classifiers. The bagged ensemble classifier yields an accuracy of 90.3%. Sensitivity, specificity and precision values of the classifier are 0.89, 0.92 and 0.87 respectively.

Further as the future scope, the paper aims in using deep learning techniques for the diagnosis process and need to find out the best performance between machine learning and deep learning concepts.

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