A Comparative Study of Machine Learning Algorithms on Alzheimer's Clinical Data Set and Prediction Using CNN with 2D MRI Data

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Abstract: Medical professionals can more accurately predict the course of the disease with the assistance of artificial intelligence and efficient image processing strategies. Alzheimer's Disease(AD) timely identification is considered as one of the most significant difficulties in medical imaging diagnostics involving AD categorization over AD recognition. The primary root of dementia, which mainly affects older people, is Alzheimer's disease. Especially with regard to therapy, this disorder treatment is expensive. Early Alzheimer's condition is diagnosed possibly by early Alzheimer's identification, which reduces the likelihood of death. This led to recognition of Alzheimer's disease which is a critical issue in the healthcare field. Researchers also have the possibility to create deep learning-based computer strategies that can guide clinical decision-making, technological developments as well as computational techniques. This leads to improved patient management and delivery outcomes as well as a lessening in the strain on physicians during diagnosis. In this work, a Convolutional Neural Network(CNN) is used to classify the stages of AD and identify it in 2D magnetic resonance imaging(MRI) dataset. The methodology commences with fundamental pre-processing steps including image resize and pixel standardization, after which the retrieved features are transformed into a reconstructed vector and supplied together with labels to the CNN. According to the four various AD stages taken into account, each different stages of Alzheimer are detected as non-demented, mild demented, moderate demented, and very mild demented. The accuracy of the model recorded as 80.55\%. The evaluation of the prediction model reveals an effective outcome in accuracy. Also the aim is to identify the top classification model for leveraging machine learning strategies to recognize Alzheimer's illness. The dataset is used from clinical records of patients from the Open Access Series of Imaging Studies (OASIS) from Kaggle website. The experimental results gives that ExtraTreesClassifier has the maximum accuracy score of 84.82\% and is more suitable for the Alzheimer Disease Prediction on clinical data.

Keywords: Machine learning, Alzheimer disease, Convolutional Neural Network.
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Introduction

Alzheimer's disease remains the most prominent type of dementia as well as the sixth most common reason for death in the United States. Alzheimer's disease, often called Alzheimer's. It is a "progressive neuro - degenerative brain condition caused by increased

neuronal deterioration in parts of the brain". Alzheimer's disease involves significant physical as well as psychological consequences for such Alzheimer's patients and family members. Memory loss is the target illness of this disorder when it first occurs. Alzheimer's symptoms become extremely serious as even the disease advances [1]. A person having this condition would undergo different emotional states (e.g., sadness, laziness etc.), variations in behaviours, and even a greater reduction in physical capabilities. Despite the global effort to find new methods to treat the disease, there has been no complete cure. Nevertheless, therapies for Alzheimer's symptoms are, available.

These remedies aren't strong enough to stop Alzheimer's disease from worsening, but they might help to reduce the symptoms significantly. As a result, the quicker someone is diagnosed with Alzheimer's, the quicker they can get aid [2]. Alzheimer's dementia has recently drawn a lot of interest in scientific research since this inevitably results in death. Computer-aided detection systems which use learning-based methods, in specific, have been effectively implemented in the detection of various illnesses. This data, if recognized early, can be helpful to clinicians as well as patients [3]. The use of deep learning in feature extraction has surged recently. It has been used to accurately match the 2D depth network to the 2D pictures produced by MRI as well as to diagnose AD.

Related Works

A brief summary of earlier works carried out in the field of machine learning algorithms and prediction using CNN with 2D MRI related works are presented. Alzheimer's disease diagnosis needs a detailed medical evaluation relying on the patient's medical history, a battery of neuro-psychological tests, as well as other pathological judgements. These tests can be expensive as well as time-consuming [4]. Regrettably, all clinical trials to counteract Alzheimer's disease have ended in failure so far though. Clinical trials, it is speculated, could perhaps target sick people at initial stages, before major brain atrophies eventuate. Several findings demonstrate that AD-related brain degeneration usually starts years before clinical symptoms appear. This implies that standard structural brain imaging scans may be used to detect Alzheimer's disease sooner. Regrettably, clinical as well as research-grade recognition accuracies keep going to be limited. Learning based methods have indeed been progressively used in the health care system in past years. Deep learning methods, but on the other side, are used successfully in the timely identification of Alzheimer's disease [5]. For instance, one researcher examined the use of learning based techniques using clinical information to forecast the progression of Alzheimer's disease within years ahead. They suggested a multi-layered architecture of neural networks with an input layer, a hidden layer, and an output layer. The data store was being used by the authors for their experimentations. The authors have conducted their experiments using the data repository. Identifying folks with early hypertension brain clinical features may permit therapeutic approaches to delay progression in disease over a period, which can be beneficial for customizing disease management as well as planning future spheres [6]. Multiple failed clinical studies for Alzheimer's disease dementia prove that therapies are unlikely to be helpful in the subsequent stages of the disease duration, so when a patient has had substantial neuronal degeneration [7]. As a consequence, many clinical studies are now enrolling sick people with pre-clinical Alzheimer's disease or even very initial Alzheimer's disease memory loss. Most researchers indicated that their proposed method can recognise people at increased risk of growth to Alzheimer's disease cognitive impairment approximately months even before treatment of Alzheimer 's disease [8]. Electronics Heath Records-derived data for sick people who are being screened for the risk of Alzheimer's disease memory loss include all the systematic data in the form of laboratories, medications, as well as procedures, but also medical reports, and that are textual summaries of physician-patient occurrences as well as records of follow-up visits [9]. As per the summary statistics, knowledge from patient records is infrequently included for progress of predictive analysis pipes. However, these documents frequently contain extra healthcare data not found in formalized sources of data, offering a rich source of information for decision support [10]. The majority of the notes are available narratives with really no formalized structure that could be processed by traditional Machine learning

techniques such as Support Vector Machine, regression, decision trees and many more. Natural Language Processing (NLP) is a research area of analytical models that offers a viable solution for handling clinical regards effectively [11]. Deep learning-based NLP models, such as recurrent neural networks as well as long short attention networks, are shown in recent years to outclass traditional phrase techniques for obtaining relevant data from patient records. Memory loss, that makes it difficult for a person to remember things, is the most prominent sign of Alzheimer's. This also causes intermittent memory lapses. Alzheimer's disease dramatically affects reasoning and logic, which makes it hard for the affected person to come to conclusions or deliver accurate judgments. Because as illness worsens, the patients routinely overlook daily tasks as well as the most basic ones [12]. A person with this condition experienced a series of psychological but also personality changes, such as depression, confusion, as well as frequent mood swings. Aggression, social disengagement, behavioural disturbances. Significant regions of the brain are lost in the process of the issues with brain proteins, which hinder the brain cells from functioning properly as well as ultimately leading to cell death. Amyloid plaques as well as tangles in the brain, which are indications of considerable brain deterioration driven on by Alzheimer's disease, are present in the human brain in AD patients [13] [14].

Design

The primary cause of dementia, which mainly affects elderly people, is Alzheimer's disease. Especially with regard to therapy, this disorder is expensive. Early Alzheimer's condition is diagnosed possible by early Alzheimer's identification, which reduces the likelihood of death. This made an early recognition of Alzheimer's disease a critical issue in the healthcare field [15] [16]. The main aim of the study is to predict the correct stage of Alzheimer by using the 2D MRI brain image data of the patient. Fig 1 is the System architecture of Alzheimer disease prediction prediction using CNN. The 2D MRI brain image is fed into the system through the User Interface. There are mainly two phases Training phase and Testing phase. The data pre-processing, Feature selection, classification and prediction happens in the both the phases. The model is trained first and then the model is saved. The saved model is fed into the Convolutional Neural Network algorithm. An image's various properties as well as characteristics are analysed in depth via CNN. The CNN algorithm is used to predict the stages of Alzheimer disease in the patient's 2D MRI brain image sample. Accordingly, to the four different AD stages are taken into account. The different stages of Alzheimer's detected are: Non-Demented, Mild Demented, Moderate Demented, and Very Mild Demented. The algorithm predicts in which state the patient's condition is among the four different stages of Alzheimer.

The test based OASIS dataset is fed into each of the predefined algorithms. The f1-score, Recall and Precision are calculated. A confusion matrix is obtained based on the Score. An accuracy score is given based on the previously calculated values. The algorithm with the best accuracy score is considered as the most suitable algorithm for the Alzheimer disease prediction.

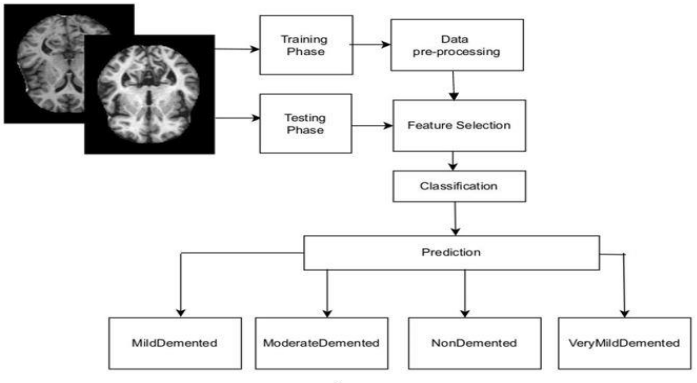


Fig. 1. System architecture of Alzheimer disease prediction

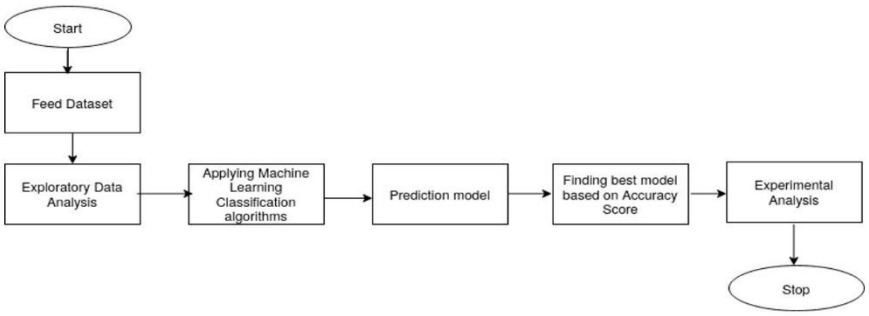


Fig. 2. Flow chart of comparative study of machine algorithms on Alzheimer disease clinical dataset

Methodology

The framework applies transfer learning using pre-trained CNN models to diagnose Alzheimer's disease (AD) in 2D MRI brain scan dataset. In order to classify brain MRI images as well as to determine various phases of AD, the pre-trained CNN models have been used. The fig 2 shows the flow chart of study of machine algorithms of Alzheimer disease clinical dataset.

The proposed system consists of two phases.

- Training Phase
- Testing Phase

Training the model

The 2D MRI dataset has been downloaded from the Kaggle website. The dataset is of the size 35 MB. The dataset needs to be loaded and has to be trained accordingly. The dataset is large and it's not possible to train the model with minimum RAM and also it requires a Graphical Processing Unit(GPU) to train the model. Hence there is a platform named Paper-space which provides better hardware capabilities such as Graphical Processing Unit(GPU), RAM etc. By using the Paper-space site the model has been trained. The model is saved so that there is no necessity for training the model again and again.

Epochs

There were 100 epochs for the model to be fit. The epochs indicate many times that machine learning algorithm has cycled over the entire training dataset. More the number of epochs, the better will be the training, the more will be the accuracy rate.

Callback()

Defining a custom callback function to stop training the model when accuracy goes above 99\%.

This indicates that the model has reached its peak accuracy.

Feature Extraction and Classification

Using different machine learning approaches, automatic classification and feature extraction on brain MRI images is performed out to diagnose Alzheimer's. An image's various properties can be analyzed in depth via CNNs.

Three distinct modules of CNN are:

- The Convolutional layer
- Pooling Layer
- Fully Connected Layer

These components layers are stacked to generate a CNN architecture. A convolutional layer often serves as the first layer in a CNN network. This layer uses a convolution operation between both the input as well as a filter with a size of M x M and passes the result onto the following layer.

Convolution layer

Convolution layer creates a dot product among two matrices, one is the kernel, and another one is the constrained area of the input vector. The result of these a two-dimensional representation of the image is called as an activation map.

Pooling layer

By generating an average statistic from the surrounding outputs, the pooling layer supplements for the channel's output at particular areas. This assists in decreasing the representation's spatial size, which lowers the computation time and weights involved. Each slice of the image is subjected to the feed-forward network separately.

Fully Connected Layer

In this layer all the neurons are completely connected before and after pre-processing. Hence it can be computed using a matrix multiplication followed by a bias effect.

Evaluation Metrics

Evaluation metrics need to be considered while calculating performance of the prediction model. The values of F1-score, recall, precision, accuracy score and confusion matrix are the important aspects need to be considered.

Confusion matrix

In table 1 gives as a confusion matrix. It is frequently used to demonstrate effectively on how a classification model performs on a collection of test data for which the true values are known

.

TABLE I. CONFUSION MATRIX

	Predicted Class		
Actual Class	Class=Yes	True Positive	False Negative
	Class=No	False Positive	True Negative

There are four main terminologies to be known.

- True Positives (TP) - These are the correctly predicted positive values
- True Negatives (TN) - These are the correctly predicted negative values
- False Positives (FP) – When actual class is no and predicted class is yes.
- False Negatives (FN) – When actual class is yes but predicted class in no.

Accuracy

It is a ratio of correctly predicted observations to the total observations.

$$Accuracy=(TP+TN)/(TP+FP+FN+TN) \quad (1)$$

Precision

It is the ratio of correctly predicted positive observations to the total predicted positive observations.

$$Precision=TP/(TP+FP) \quad (2)$$

Recall

It is the ratio of correctly predicted positive observations to all observations in actual class - yes.

$$Recall=TP/(TP+FN) \quad (3)$$

F1 score

It is the average of Recall and Precision.

$$F1\text{-}score=2*(precision*Recall)/(Recall + Precision) \quad (4)$$

Result and Discussion

We considered dataset from Kaggle web portal that is the total number of 2250 of dataset. In each of the classes used for experiment 2250 data of 2D MRI brain images of patients who suffered disease or Not. The downloaded dataset contains MRI images which is further divided in four classes.

Fig. 3. 2D MRI brain image of Non Demented class.

Fig. 4. 2D MRI brain image of very mild demented class.

Fig. 5. 2D MRI brain image of mild demented class.

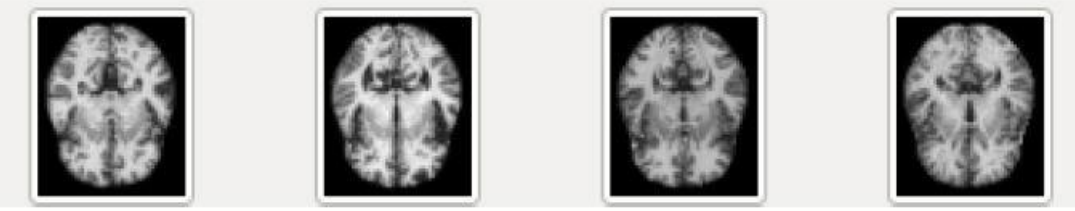


Fig. 6. 2D MRI brain image of moderate demented class.

The first class is non-demented to a person. Who is not having Alzheimer's disease as shown in fig 3. The second class is very mild-moderate demented to person. Who having Alzheimer's disease in the early stage as shown in fig 4. The third class is mild-demented to person shown in fig 5. The final class is very moderate demented to person. Who having high degree of Alzheimer's disease shown in fig 6. Flask is a framework written in Python. It is based on the Werkzeug WSGI toolkit and Jinja template engine. Both are Pocco projects. It supports extensions that can add application features as if they were implemented in Flask itself. Paper-space which provides better hardware capabilities such as Graphical Processing Unit(GPU), RAM etc. By using the Paper-space site the model has been trained. The model is saved so there is no necessity for training the model repeatedly. The fig 7 gives the information about the people affected by Alzheimer at different ages. From the dataset it validated that 440 males and 538 females who are demented and 522 males and 750 females who are non-demented shown in the fig 7. The Density graph showing count of people are demented or Non-demented at different ages are shown in fig 8.

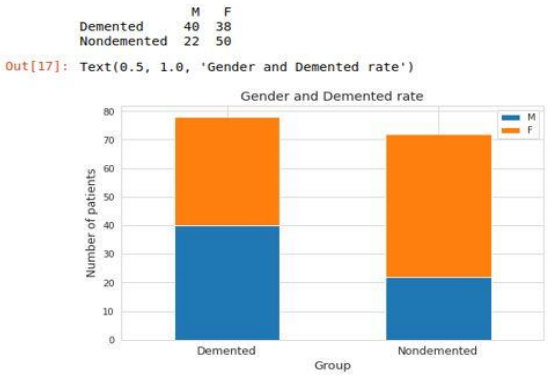


Fig. 7. Number of Demented and Non-demented count of Male and Female.

In [5]:
```
print("Tota Rows and Columns (Rows,Columns) : ",df.shape)
```
```
Tota Rows and Columns (Rows,Columns) :  (373, 15)
```

In [9]:
```
df.head(5)
```

Out[9]:

	Subject ID	MRI ID	Group	Visit	MR Delay	M/F	Hand	Age	EDUC	SES	MMSE	CDR	eTIV	nWBV	ASF
0	OAS2_0001	OAS2_0001_MR1	Nondemented	1	0	M	R	87	14	2.0	27.0	0.0	1987	0.696	0.883
1	OAS2_0001	OAS2_0001_MR2	Nondemented	2	457	M	R	88	14	2.0	30.0	0.0	2004	0.681	0.876
2	OAS2_0002	OAS2_0002_MR1	Demented	1	0	M	R	75	12	NaN	23.0	0.5	1678	0.736	1.046
3	OAS2_0002	OAS2_0002_MR2	Demented	2	560	M	R	76	12	NaN	28.0	0.5	1738	0.713	1.010
4	OAS2_0002	OAS2_0002_MR3	Demented	3	1895	M	R	80	12	NaN	22.0	0.5	1698	0.701	1.034

Fig. 8. The Density graph showing count of people are demented or Nondemented at different ages.

Exploratory Data Analysis

Data pre-processing is an important task in this work. It refers to all the necessary transformations done on the data to be used. df.info() gives all the information about the dataset. It shows us the names of each row in the dataset and its properties.

The bar graph shown in fig 9 numbers of many people are affected by Alzheimer at different ages. It can be observed that the people are more affected by Alzheimer's at the age between 65 to 85. As per dataset Alzheimer seemed to be more at the age 73.

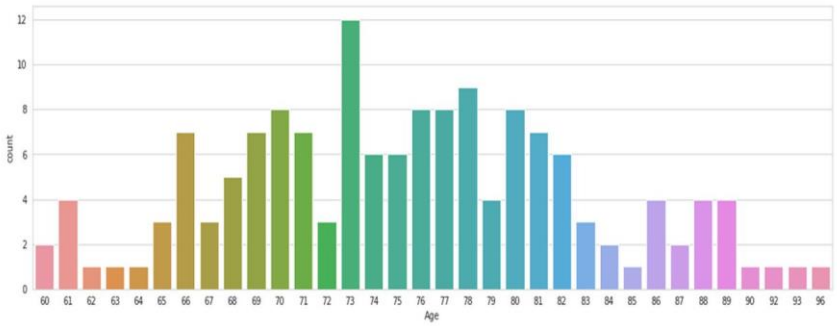


Fig. 9. Number of people being affected by Alzheimer's in different ages.

Experimental purpose we created object for Random Forest Classifier class with random state, and then initialize parameters estimators, max-features, max-depth , criterion and then we created an object for the GridSearchCV model class with an estimator as the Random Forest Classifier object we created and pass the parameters and initialized. Then considered to fit the model for training, and call the performance, accuracy function to give performance and accuracy details on the model.

Algorithms used

GridSearchCV: An approach for finding the optimum parameter values in a grid of parameters is entitled as GridSearchCV. It's a cross-validation approach. The forecasts are generated after identifying the optimized parameter values. A machine learning library for Python is termed as GridSearchCV. For an estimator, we have such a thorough check over the specified parameter values. In essence, an estimator object requires a score function; otherwise, any sort of scoring could pass. Fit and forecast are indeed the two primary approaches that can be utilized with GridSearchCv. The resultant of GridSearchCv its confusion matrix and its accuracy score are shown in the fig 10.

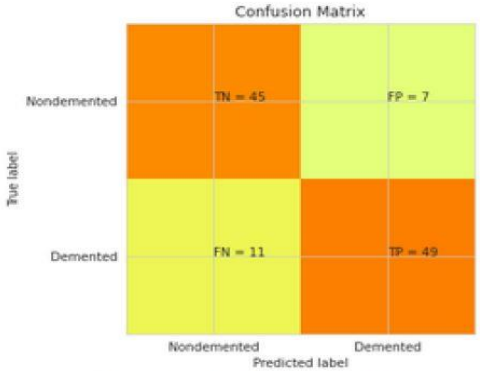
```
********** GridSearchCV **********

Confusion Matrix:
[[45  7]
 [11 49]]

Classification Report:
              precision    recall  f1-score   support

           0       0.80      0.87      0.83        52
           1       0.88      0.82      0.84        60

    accuracy                           0.84       112
   macro avg       0.84      0.84      0.84       112
weighted avg       0.84      0.84      0.84       112
```




```
Acuuracy Of the Model:  0.8392857142857143
```

Fig. 10. Confusion matrix, classification report and accuracy score of Grid Search algorithm.

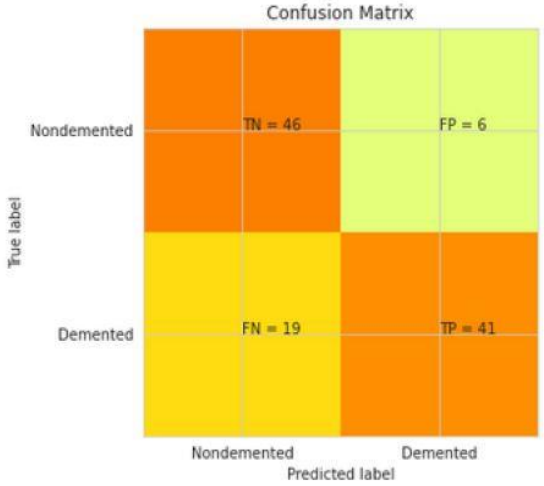
```
********** SVC **********

Confusion Matrix:
[[46  6]
 [19 41]]

Classification Report:
              precision    recall  f1-score   support

           0       0.71      0.88      0.79        52
           1       0.87      0.68      0.77        60

    accuracy                           0.78       112
   macro avg       0.79      0.78      0.78       112
weighted avg       0.80      0.78      0.78       112
```




```
Acuuracy Of the Model:  0.7767857142857143
```

Fig. 11. Confusion matrix, classification report and accuracy score of SVM algorithm.

The SVC/SVM kernel is just a function that transforms non separable issues into separable problems besides receiving low-dimensional input vectors and changing it into higher-dimensional spaces. It usually works in non-linear issues. Simply put, the kernel identifies how to divide the information depending on the labels or outcomes defined after conducting some incredibly sophisticated data transformations. The resultant of SVM its confusion matrix and its accuracy score are shown in the fig 11. Decision tree algorithm are supervised learning techniques. It can be applied to regression and classification issues. The decision tree can be used to symbolize any boolean function on discrete attributes. The resultant of Decision tree algorithm its confusion matrix and its accuracy score are shown in the fig 12. Extreme Gradient Boosting is known as XGBoost. Due to its scalability, it has recently gained traction and now dominated applied machine learning for its structured data. Gradient boosted decision tree algorithms (GBM) include an enhancement called XGBoost that was specially created to boost speed and efficiency. The resultant of Extreme gradient boosting its confusion matrix and its accuracy score are shown in the fig 13.

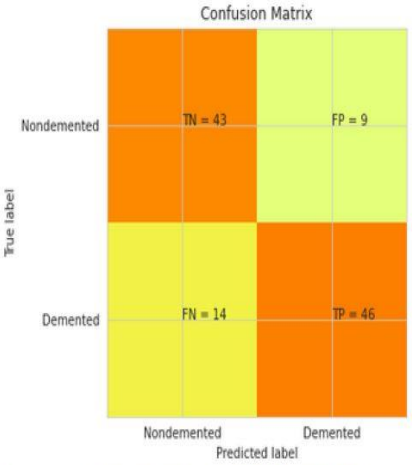
```
********** DecisionTreeClassifier **********

Confusion Matrix:
[[43  9]
 [14 46]]

Classification Report:
              precision    recall  f1-score   support

           0       0.75      0.83      0.79        52
           1       0.84      0.77      0.80        60

    accuracy                           0.79       112
   macro avg       0.80      0.80      0.79       112
weighted avg       0.80      0.79      0.79       112
```




```
Acuuracy Of the Model:  0.7946428571428571
```

Fig. 12. Confusion matrix, classification report and accuracy score of Decision tree algorithm.

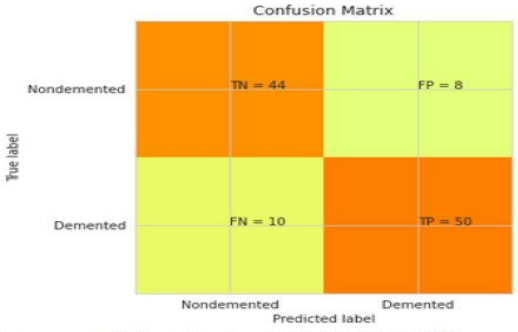
```
********** XGBClassifier **********

Confusion Matrix:
[[44  8]
 [10 50]]

Classification Report:
              precision    recall  f1-score   support

           0       0.81      0.85      0.83        52
           1       0.86      0.83      0.85        60

    accuracy                           0.84       112
   macro avg       0.84      0.84      0.84       112
weighted avg       0.84      0.84      0.84       112
```




```
Acuuracy Of the Model:  0.8392857142857143
```

Fig. 13. Confusion matrix, classification report and accuracy score of XGB Classifier algorithm.

ExtraTreesClassifier

It is a form of ensemble learning technique that generates its classification result through averaging the outputs of multiple de-correlated decision trees aggregated in a "forest". The only manner it differs technically from the Random Forest Classifier is that the decision trees in the forest are built. The basic training sample has been utilized to construct each decision tree within Extra Trees Forest. Next, each tree is provided a random sample of k features from the feature-set at every test node, from which it must choose the best feature to segment the data according to a specific mathematical criterion. If the Gini Index is applied to the development of the forest, the normalization totally decreases in the mathematical criteria applied in the attribute of split choice (Gini Index) which is computed. The Gini is the importance of the feature and is the name given to this value. Each feature is evaluated based on its Gini Significance in decreasing order to perform feature selection, and the customer then chooses the top k features that appeal to them. The resultant of extratrees classifier its confusion matrix and its accuracy score are shown in the fig 14.

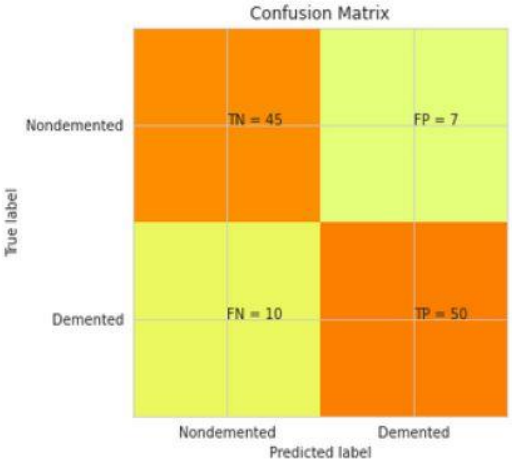
```
ExtraTreesClassifier :
********** ExtraTreesClassifier **********


Confusion Matrix:
[[45  7]
 [10 50]]


Classification Report:
              precision    recall  f1-score   support

           0       0.82      0.87      0.84        52
           1       0.88      0.83      0.85        60

    accuracy                           0.85       112
   macro avg       0.85      0.85      0.85       112
weighted avg       0.85      0.85      0.85       112
```




```
Acuuracy Of the Model:  0.8482142857142857
```

Fig. 14. Confusion matrix, classification report and accuracy score of ExtraTrees Classifier algorithm

The K-NN predicts the new information point in the group that is most comparable to the existing categories on the assumption that the case actually as well as the preceding cases are identical. After storing all of the obtained data, an unique data point is categorized by using K-NN technique based on to its resemblance. This indicates that new data could be reliably as well as quickly processed using the K-NN approach. The resultant of K-NN its confusion matrix and its accuracy score are shown in the fig 15.

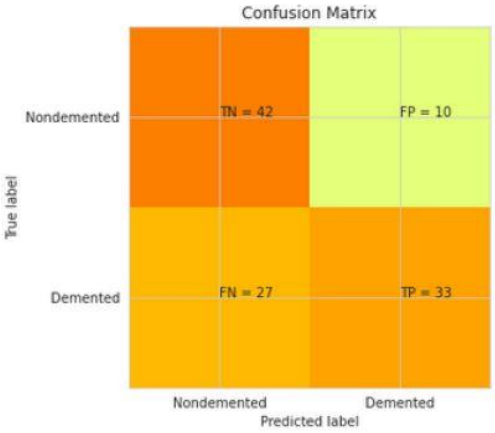
```
********** KNeighborsClassifier **********

Confusion Matrix:
[[42 10]
 [27 33]]

Classification Report:
              precision    recall  f1-score   support

           0       0.61      0.81      0.69        52
           1       0.77      0.55      0.64        60

    accuracy                           0.67       112
   macro avg       0.69      0.68      0.67       112
weighted avg       0.69      0.67      0.67       112
```




```
Acuuracy Of the Model:  0.6696428571428571
```

Fig. 15. Confusion matrix, classification report and accuracy score of K-NN algorithm

The table 2. lists the accuracy score obtained by all the six algorithms.

Algorithm	Accuracy Score
GridSearchCV	0.8392857142857143
SVC	0.7767857142857143
DecisionTreeClassifier	0.7946428571428571
XGBClassifier	0.8392857142857143
ExtraTreesClassifier	0.8482142857142857
KNeighborsClassifier	0.6696428571428571

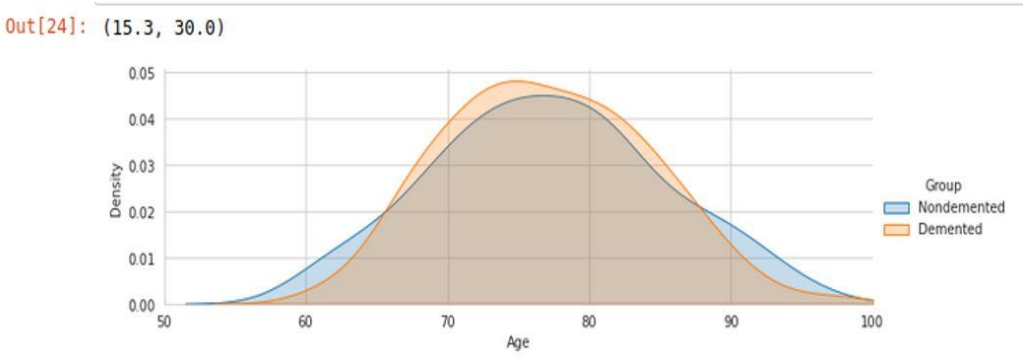


Fig. 16. Density graph showing count of people are demented or Non-demented at different ages.

Numbers of many people are affected by Alzheimer at different ages. It can be observed that the people are more affected by Alzheimer's at the age between 65 to 85. The mean age group Density graph showing count of people are demented or Non-demented at different ages in the fig 16. From the fig 14 it is observed that the values of accuracy score is high of ExtraTree classifier algorithm. It has the maximum accuracy score and is more suitable for the Alzheimer Disease Prediction on clinical data. KNeighborsClassifier has the minimum accuracy score and is less suitable for the Alzheimer Disease Prediction on clinical data.

The graph Fig 16 shows the various algorithm versus accuracy scores. The red dot gives the accuracy score located on the graph. It can be visualized that the ExtraTree classifier has an accuracy score of 0.84821 and is well suited for the prediction of Alzheimer disease. And K-Neighbours classifier has the least accuracy score of 0.6696 and is not well suited for prediction of Alzheimer disease.

Conclusion and Future work

Alzheimer's disease is a condition of the brain that deteriorates with time and disrupts memory, thinking, and the capability to carry even the simplest basic tasks. There seems to be significant research and development potential for using algorithms for deep learning to assist clinicians in making an Alzheimer's diagnosis. This study work examined the categorization of Alzheimer's stages of disease using brain MRI scans Learning strategies are used. In this circumstances to group Alzheimer's disease stages into various stages, including moderate dementia, mild dementia, non-dementia and very mild dementia. By offering more detailed and precise findings, computerized assisted solutions, its validated their utility and consistency in medical applications. The higher accuracy can be achieved with more training images and more processing capabilities, the proposed method achieved an accuracy rate of 84.82% The experiment on identifying the top classification model for detecting Alzheimer's disease using machine learning methods on the clinical records of patients from the Open Access Series of Imaging Studies (OASIS) resulted ExtraTreesClassifier has the maximum accuracy score of 84.82 percent and is more suitable for the Alzheimer Disease Prediction on clinical data. Better data gathering so that the model can be trained even better and by this we can get the best accurate rate of prediction. Different varieties of data gathering and real time data gathering directly from health care centres so that the project can yield better results. Researching on the use of more efficient algorithms for better performance of the model hence leading to better prediction of Alzheimer disease. Better enhancement of User Interface to make it more User Friendly.

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