

Detecting Anatomical Landmarks for Fast Alzheimer's disease by Random Forest Classification

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Abstract

Alzheimer's disease is the most often dementia that is observed mostly in the elderly, wherein the brain memory related elements destroys results in cognitive imbalance and memory loss. In case of India, the Alzheimer's disease is the most popular condition present around the elderly ages. The MRI or PET scan are the effective methodologies present to scan human brain and identify the Alzheimer's spots present in the brain. But in case of Alzheimer's disease, the early detection is quite a tedious process as the healthy people's (HP) brain scan seems more or less similar to the Alzheimer's disease patient's scan (AP). So in-order to identify the Alzheimer's disease in the early stages Random Forest Algorithm is used. The Random Forest Algorithm is a type of Ensemble learning algorithm that is employed for both classification and regression. The advantage of the algorithm is that Result's accuracy obtained by the algorithm. The Random Forest algorithm identifies the minute variations associated with each and every data set provided for training and classifies them as separate classes based on their functionalities. Thus the prediction accuracy provided by the Random Forest Algorithm are pretty much efficient than the predecessors algorithms. The disadvantage with the regression is that the higher plan calculations provide less accurate results.

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Keywords; The MRI scan stands for Magnetic Resonance Imaging and the PET scan is abbreviated as Positron Emission Tomography.

I. INTRODUCTION

Alzheimer's disease is a type of dementia that is most common affecting mostly elderly and children etc., [9] Dementia is defined as group of conditions characterized by impairment of at least two memory impairments [11]. Nearly 10 million cases are being registered for people affected with dementia in India. It is a very common disorder caused on the neurodegenerative disorder. Alzheimer's disease is non-curable, improvising brain disorder that slowly destructs memory and thinking skills and eventually not able to carry out easy human tasks. The Alzheimer's disease appears mostly for the elderly people of the age 50-60 yrs. Alzheimer's disease is currently ranked as the sixth leading cause of death in America. Dementia ranges in severity from the

mildest stage, where the patients experience cognitive functioning problems initially to the most severe stage result in death eventually. The major causes for the dementia vary depending upon the brain changes that takes place. Other dementia includes 'Lewy body dementia', 'front temporal disorders' and 'vascular dementia'. Alzheimer's disease is coined after Dr. Alois Alzheimer in 1906, when he noticed some abnormalities in woman brain tissues who died of unusual mental illness. These plaques and tangles in brain are considered as the most significant characteristics of Dementia.

Alzheimer's disease is independent of the age factor. The major criteria is that all the patients suffering

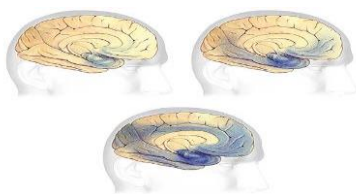
from Alzheimer's are apparently above 60-65 years. Researchers have estimated that by the year 2020 nearly 14.12% of the elderly people in India will be affected with Alzheimer's disease.

In case of Alzheimer's disease, the neuron loses its ability to communicate with the other neurons via electric pulses through the axioms. Researchers estimate that two major chemical compound Beta-amyloid and tau are major reasons for the destruction of the neurons in the brain causing the chemical imbalance in the brain. In early stages of Alzheimer's memory loss is mild, whereas in severe stages patients lose their ability to even carry out a conversation with the environment. Alzheimer's disease as explained before is not currently curable, but the researchers are performing multiple experiments and researches for cure. The Alzheimer's patients are treated for their symptoms but in order to avoid the more death rates, early detection of Alzheimer's disease must be identified. The Random forest algorithm provides more accurate classification of Healthy patients / Non-demented patients from Demented Patients/ Alzheimer's patients.

The most common symptom of Alzheimer's is difficulty remembering newly learned information because the changes typically affect learning part of the brain. [10]

Plaques, which are the containments of the protein elements called beta-amyloid spelled as BAY-tuh AM-uh-loyd which is responsible for the buildup spaces amongst the nerve cells.

On the other hand, Tangles are the twisted fibers of another protein element called tau which constructs up the inside cells of the brain's neuron and axioms.



The damage caused by Alzheimer's initially appears

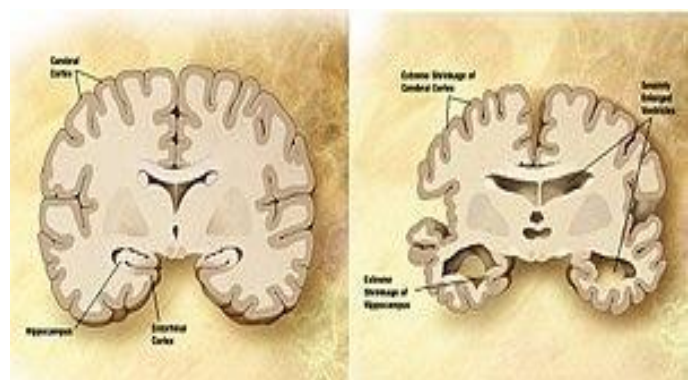
in the brain's hippocampus, which is caused due to destruction of neurons resulting in reduction of brain size. As many neurons die, the brain's size starts to shrink resulting in death ultimately.



Random Forest algorithm obtains the training data sets that consist of multiple parameters like AGE, MMSE (Mini Mental State Examination) and CDR (Clinical Dementia Rating).

The MMSE is conducted with set of questionnaire that subjects multiple mental states related characteristics to evaluation providing numerical results. CDR is a numerical rating associated with each and every patient providing a 5-point scale that emphasizes the six major domains of cognitive and functional characteristics appropriate to Alzheimer's disease.

The below figure depicts the differentials between a Healthy Patient's (HP) brain and an Alzheimer Patient's (AP) brain.



In which the HP brain Cerebral Cortex, Hippocampus and Entorhinal Cortex are healthy and normal without any defects or variations whereas in case of AP brain there are:

- Extreme Shrinkage of Cerebral Cortex,
- Extreme Shrinkage of Hippocampus[26], which is responsible for consolidation of short-term memory and long-term memory and also is spatial memory that enables navigation.
- Severely enlarged ventricles, the ventricular system is a set of four interconnected cavities where a cerebrospinal fluid (CSF) is produced.

II. PROPOSED SYSTEM

Random forest algorithm is an ensemble learning method for classification as well as regression techniques which collects the dataset for training and constructs multitude decision trees while training data set and provides the class result (or) mean prediction obtained from the overall dataset etc.,[1] Random decision tree identifies over-fitting on their training data set.

The first random forest algorithm was created by Tin KamHo , who employed the sub space methodology in a randomized fashion for the heuristic discrimination.

A. Algorithm

Primary Definitions: Decision tree learning: Decision trees algorithm is the most popular methods for various task that involve classification and other data processing related tasks. Random forest's algorithm is similar to decision tree algorithm but in contrast this algorithm groups multiple decision trees and train on the different parts of the same training data set with a goal of reducing characteristics of accumulating different/divergent dataset.

Bagging: This is an algorithm that the Random Forest Classifier imposes on the training dataset for the purpose of model construction and applies the common technique known as bootstrap-aggregating or bagging to training model. For instance, provided a training data set named $X = x_1, x_2, \dots, x_n$ with responses $Y = y_1, y_2, y_3, \dots, y_n$ bagging repeatedly

fits the trees for those samples.[3]

$$\hat{f} = \frac{1}{B} \sum_{b=1}^B f_b(x')$$

The bootstrap-aggregation algorithm improves the existing to a better model performance because it reduces the variance characteristics associated with the dataset without increasing the redundancy or errors associated with the result.

The prediction/classification for each individual tree is very sensitive to the noises associated with the data set in the training set. Simply training trees on single data set would produce strongly correlated trees which reduces the accuracy of the Random Forest Classifier.

B. From Bagging to random forest:

The above procedure defines the bagging process associated with the algorithm. Random forest algorithm uses a modified tree learning algorithm which selects each classes/objects split in learning process. For a classification process with p features nearly $\sqrt{p}$ (rounded down) features are used for the split of dataset for proper training and prediction.

C. Data-set Description

The proposed Model applies Random Forest Algorithm to classify the Non-demented Patients from Demented patients.

The data-set is obtained from Kaggle [2], which provides

Two data-sets named `oasis_longitudnal.csv` and `oasis_cross_sectional.csv` applicable for different range of people.

The data-set includes the following parameter for processing, they are:

- ID- identification
- M/F – Male/Female
- Hand – Dominant hand

- Age – Age of the patient expressed in years as a major factor.
- SES – Social Economic Status of the individual.
- MMSE – Mini-Mental State Examination Results
- EDUC – Educational Qualification of the individual.
- CDR – Clinical Dementia Rating score obtained by the respective individual.
- eTIV – Estimated Total Intracranial Volume of the individual brain obtained from scan result.
- nWBV – Normalize Whole Brain Volume of the individual obtained from the scan results.
- ASF – Atlas Scaling Factor heuristic value scored by the individual.
- MRI Delay

The Educational Qualification and other characteristics are taken for considerations for the purpose of cognitive functionalities possessed by the individual. The MMSE is 10 minutes Examination conducted for the patient in order to describe the mental ability associated with the patient. The MMSE provides a 30 point score-card as a result.

The MMSE threshold for dementia is:

- 20-24 is mild dementia
- 12-20 is moderate dementia
- <12 is severe dementia.

The eTIV is the total intracranial volume which defines the volume space within the skull is the summation of Brain, Ventricular and Extra-Ventricular CSF. The average TIV for men is $1469 \pm 102 \text{ cm}^3$ and for women is $1289 \pm 111 \text{ cm}^3$. The hippocampus region in the brain starts to expand resulting in the brain size shrinkage and reduction in the TIV.

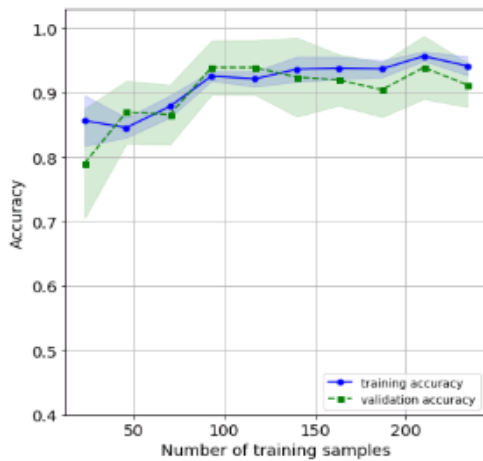
D. Propose Model

Random Forest Classifier is available under the scikit-learn library of python. The Classifier accepts multiple parameters as input defining the characteristics of the classifier, they are:

- n_estimators: This parameter defines the number of trees present in the algorithm for classification, the more the number of trees the better is the classification. The default value of this parameter is 10.
- criterion: This parameter defines the quality of the split of the training data set based on their characteristics. The default value of this parameter is “GINI” [7], which specifies the gini impurity used to classify the multiple classes present in the data set with higher accuracy. “ENTROPY” can be used for information gain.
- max_depth: The maximum depth of the tree in the forest classifier, which if not specified expands until the leaf nodes are reached or until all leaf nodes contains less the min_samples_split. The value specified is 5
- min_samples_split: This parameter is the total number of dividing associated with the internal node. The value specified in the proposed system is 10.
- min_samples_leaf: This parameter is the minimal number of sample space associated with the classifier to become a leaf node. The provided value is 5.
- random_state: This parameter describes the seed used by the random generator associated with the classifier. The value specified is 0.

TABLE I

The Learning curve associated with the Random Forest Classifier obtained as a result



The learning curve depicts the ability of the model to improvise the outcome and accuracy of the model's result. The x-axis is the total number of training samples distributed among the axis, whereas the y-axis is the accuracy of the model associated with the data-set.

E. Proposed System Outcome

The Proposed System provides more accurate result than the predecessor system with an accuracy of 92% approximately. The outcome of the developed model is cross validated with multiple instances and obtained a valid and reliable result. Multiple visualization plots were constructed to verify the outcome. The various visualization techniques are,

- Validation Curve (Table II),
- Learning Curve (Table I),
- Receiver's Operating Characteristics (Table III) &
- Confusion Matrix (Table IV)

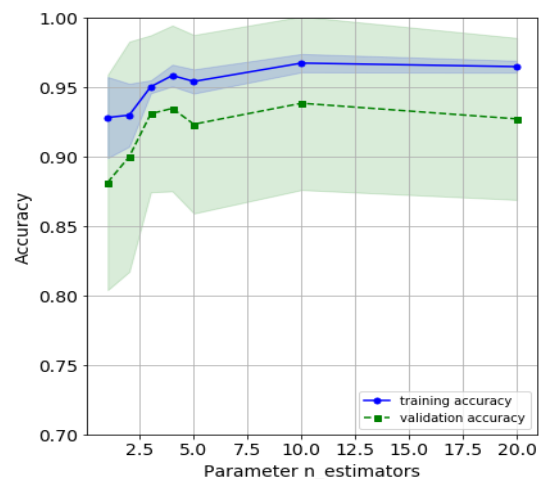
The model is trained with 70% of the data set obtained from OASIS datasets longitudinal, which contains the around 350 data sets of combination of Healthy Persons (HP) and Alzheimer's Patient (AP).

The obtained data set is subjected to pre-processing, where all the NaN values associated with the dataset are identified and missing values are replaced based on their MEAN values using the Imputer.

A pre-conditional operation is to be performed on the input data, where the aging criteria along with the CDR value are subjected during the pre-processing. Group associated with the data-set are segregated as demented and Non-Demented groups. Not all the input columns of the data-set are subjected to training, more correlated and data with more information gain are identified and subjected for training the Classifier model.

TABLE II

The Validation curve associated with the Random Forest Classifier obtained as a result



The above graph depicts the validity of the model trained with the 70% of the training dataset. In this graph, the x-axis is applied with number of estimators associated with the Random Forest Classifier during the training and testing, y-axis is provided with the accuracy of the model, which is obtained based on the calculation using,

Correct Predictions Number

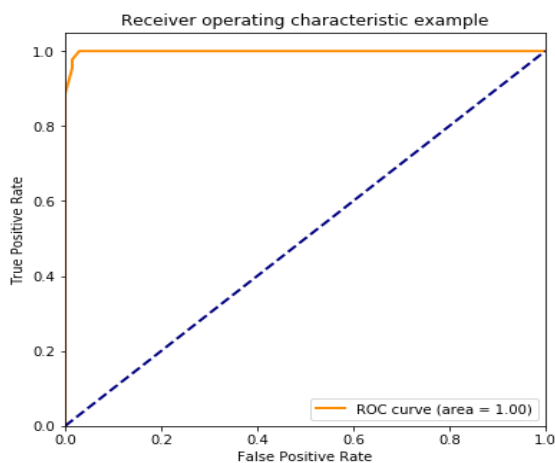
Accuracy = -----

Total Number of Occurrences

The accuracy associated with the training data-set is 96% approximately and testing data-set is 92% approximately rounded up to two decimal places.

TABLE III

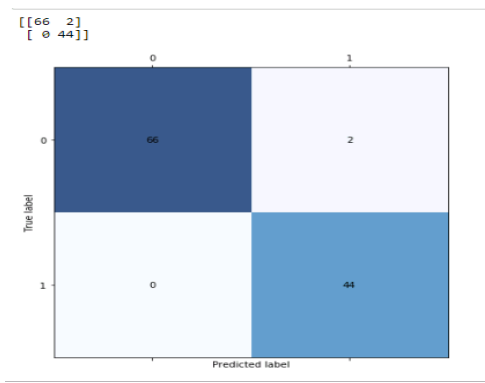
The Receiver Operating Characteristics curve associated with the Random Forest Classifier [16].



The above graph provides a binary classifier system for the given model based on the threshold value as its discrimination threshold is varied.

TABLE IV

The Confusion Matrix obtained for the trained model.



The confusion matrix is defined as mathematical matrix association of variables, where the rows represent the instances in the predicted class and the column present in the matrix represents instances in actual class. The confusion matrix is also known as matching matrix or error matrix.

It allows the visualization of performance of an algorithm.

F. Experiments and Exploratory Analysis

The proposed system is devised with a model, which deploys Random Forest Algorithm for the purpose

of classification of the data-set from regular Healthy patients and affected Alzheimer patients. The dataset is obtained from OASIS (Open Access Series of Imaging Studies), which consists of longitudinal data-set that comprises of all ages of patients and their associated attributes as specified above.

The Random Forest Classifier is initialized with specific characteristics that produce more accurate result and greater accuracy on prediction score of the classifier.

The entire dataset is split into two groups named,

✓ Training Dataset which is about 70% of the entire volume and the model is trained with particular constraints based on the age criteria and the CDR rating values associated with each and every user.

✓ Test Dataset which is the remaining 30% of the entire volume is subjected for prediction experiment for the trained model in order to evaluate the model's prediction score and ROC score for theoretical analysis of the system, which turned out with more accuracy around 92% accuracy is associated with the model for the test dataset and about 96% approximately for the training dataset.

The output obtained on processing the model is displayed beneath.

❖ Random Forest score (Train): 0.9687

❖ Random Forest score (Test): 0.9221

❖ K-fold cross validation:

❖ Iteration 0: 0.963

❖ Iteration 1: 1.000

❖ Iteration 2: 0.923

❖ Iteration 3: 0.923

❖ Iteration 4: 0.962

❖ Iteration 5: 0.962

❖	Iteration 6:	0.962
❖	Iteration 7:	0.923
❖	Iteration 8:	0.846
❖	Iteration 9:	0.880
❖	CV accuracy:	0.934 +/- 0.043

Thus the output prediction score associated with the trained model is approximately 92.21% for the testing data thereby improving the accuracy of the model classification and easy identification of the Demented Patient from the healthy patients.

```
0 [label="EDUC <= 0.62\ngini = 0.43\nsamples = 165\nvalue = [179, 82]\nclass = Visit", fillcolor="#e581398a"];
```

```
1 [label="nWBV<= 0.72\ngini = 0.48\nsamples = 127\nvalue = [120, 77]\nclass = Visit", fillcolor="#e581395b"];
```

```
0 -> 1 [labeldistance=2.5, labelangle=45, headlabel="True"];
```

```
2 [label="CDR <= 0.25\ngini = 0.46\nsamples = 51\nvalue = [27, 50]\nclass = MR Delay", fillcolor="#399de575"];
```

```
1 -> 2;
```

```
3 [label="gini = 0.0\nsamples = 14\nvalue = [19, 0]\nclass = Visit", fillcolor="#e58139ff"];
```

```
2 -> 3;
```

Fig. 1. The Decision Tree Model Di-Graph Representation of the Random Forest Classifier is displayed above, based on the CDR and other parametric constraint.

The above decision tree describes the decision visualization unit that classifies each and every data set provided as input based on the particular condition.

G. Key Indices

There are multiple key indices associated with the proposed system, they are specified and described in this section,

- HP – Healthy Patient is an individual, who is diagnosed completely healthy.

- AP – Alzheimer Patient is an individual, who is diagnosed with dementia and respective stages based on the given pretext/ dataset as input to the system, that predicts the result and criteria of patients.

- CV accuracy – Cross Validation is defined as technique for assessing how the results of statistic analysis will generalize on independent data set.[2]

- $n_estimators$ – it is the numerical parameter, which initializes the number of trees associated with the Random Forest Algorithm for more accuracy.

- Cerebral Cortex is largest region present in cerebrum part of the brain, which plays a vital role in memory, attentiveness, perception, cognitive behavior, awareness, thought processing, language inference and consciousness characteristics associated with the brain.

There are various forms of Alzheimer's disease [30], they are

- Atypical Alzheimer – which is a rarest form of Alzheimer disease, where the hippocampus is not affected first, implied that memory loss isn't the first symptom inferred.

- Vascular Dementia – This type is caused due to the in-efficient blood supply obtained in the brain regions causing in multiple symptoms associated with rare phenomenon.

- Front-temporal Dementia – In this form either the front lobe (or) the temporal lobe shrink in size causing dementia symptoms.

H. Every Equations

Random Forest Algorithm:

$$\hat{f} = \frac{1}{B} \sum_{b=1}^B f_b(x')$$

$X = x_1, x_2, x_3, \dots, x_n$ training set

$Y = y_1, y_2, \dots, y_n$ responses obtained, where

$b = 1, 2, \dots, B$ B is the number of times bagging is performed. f_b is the function that fits the training dataset to the classification module.

Relationship with nearest neighbors:[4]

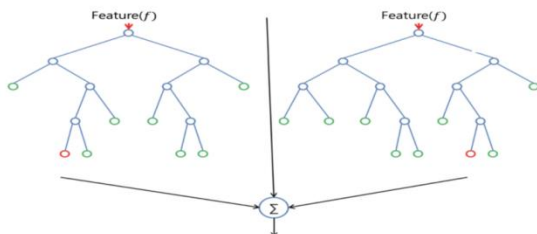
The relationship between Random Forest Algorithm and K-means Nearest Neighbor Algorithm is,

$$\hat{y} = \sum_{i=1}^n W(x_i, x') y_i, \text{ where}$$

$W(x_i, x')$ is the non-negative weights associated with the i^{th} iteration of the training dataset ie., X .

y_i is the i^{th} iteration of the output predicted value.

Fig. 2.The Working of the Random Forest Algorithm.



III. APPENDIX

The major variations between Decision Tree Algorithm and Random Forest Algorithm are as follows: [5]

- Random Forest Algorithm obtains a collection of decision trees from the given data set as input but in differences based on the characteristic of the data set with minute variations.
- In case of Decision tree, it predicts certain rule from the input data set for classification and decision making, whereas for Random Forest Algorithm obtains the dataset and selects observations in a randomized fashion/order and based on the features of the observations it used to build several decision trees and averages the overall results.
- Decision tree algorithm for a huge dataset provided may suffer from a crisis called “Over fitting” [26] (A over fitted model contains more parameters than can be justified by the given data set), in case of Random Forest it prevents over-fitting crisis imposed on the random forest classifier by creating subsets of the features of the dataset in a randomized order/fashion and establishes much more smaller decision tree using these subsets selected randomly.

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