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Computerized Brain Disease Classification Using Transfer Learning

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Abstract: The prevalence of the neuro generative disease is rapidly increasing in recent years. According to WHO nearly 70 million people suffer due to the brain disorders. The types of brain diseases are Alzheimer Disease, Dementia, Brain Tumor, Epilepsy, Mental Disorders, Parkinson's disease. Among this Alzheimer disease, Brain Tumor, Parkinson's Disease and seizure disorders are the most common diseases. The main causes of this diseases are the genetic and environmental factors including diet, smoking and traumatic brain injury, diabetes and other medical diseases contribute to the risk of developing this form of diseases. The main purpose of this work is to develop the computerized brain disease detection method. In this proposed work three brain disease are taken namely Alzheimer, Tumor, Parkinson. The inceptionv3 model and VGG19 are used to detect the brain disease. For efficient detection the transfer learning approach is used. In every deep learning model combined with two set of action one is feature extraction and another one is classification. In this proposed work a novel method is implemented. The deep learning models are used only for the feature extraction purpose. The convolutional features are extracted from the brain images and the Random Forest classifier classify the brain diseases in to Alzheimer, Tumor, Parkinson and Normal brain. Comparison of these the Inceptionv3 with Random Forest outperform well with the accuracy of 95%.

Keywords: *Brain diseases, Alzheimer, Tumor, Parkinson, Inceptionv3, VGG19, Random Forest, Transfer Learning.*

1. Introduction

The brain is the more complex part of the human body. It is three-pound organ which is a seat of intelligence, interpreter of senses, initiator of the body movement, and controller of behavior. There are 100,000 miles of blood vessels in the brain and 100 billion neurons (nerve cells). Each neuron has between 1000 and 10,000 synapses (connections with other neurons). Most of the brains are the cerebral cortex, and the cerebral cortex alone has approximately 33 billion neurons. Each neuron has connected to another neuron through a synapse. Approximately 100 million neurons are organized in a closed network to regulate brain activity. Afferent neurons detect the information and process it to the spinal cord, and the information is sent from the spinal cord to the brain. Efferent neurons absorb impulses from the brain and activate the appropriate responses. Nerve cells are made up of axons, dendrites, and cell bodies. The central nervous system is made up of two special types of cells, called nerve cells and glial cells [1]**.** The figure 1 shows the structure of neuron.

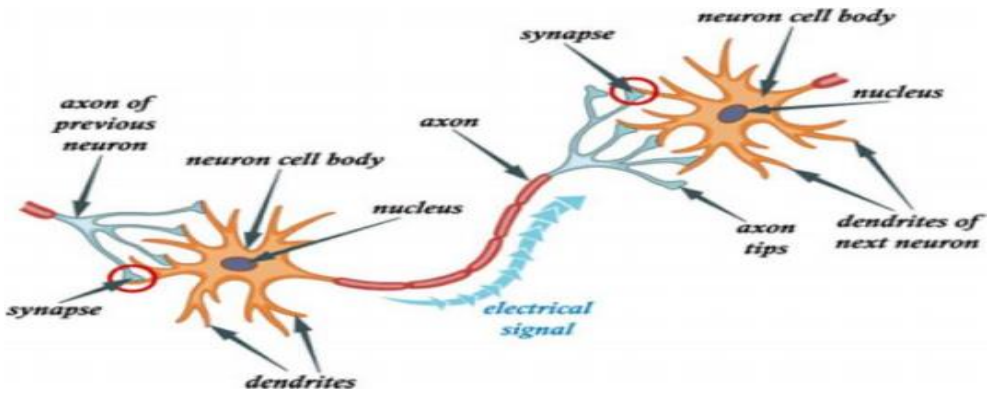

Fig. 1. The Structure of Neuron

The benefit of medical imaging modalities is that X-ray, Ultrasound, CT, and MRI scans are widely used in the medical field to diagnose various diseases in humans. The MRI image technique is used to create high-quality images of the human body's internal organs. When

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compared to other medical imaging modalities, MRI provides detailed images of brain anatomy in three dimensions with high resolution and unparalleled soft tissue.

Parkinson's disease (PD) is the second most common neurodegenerative disease after Alzheimer's in elderly people. Advanced MRI techniques at high and ultrahigh magnetic fields, taken together, aid in a better understanding of the nature and progression of Parkinson's disease [2].

Tumor is a type of cancer that is an intracranial mass caused by the controlled growth of cells. Neurons, glial cells, lymphatic tissue, blood vessels, pineal gland and pituitary gland, and skull cells are all found in the brain. Some tumors or cancers, such as lung cancer, melanoma, breast cancer, kidney cancer, bladder cancer, and certain sarcomas, can spread to the brain.

Alzheimer's disease (also known as pre-senile dementia) is a serious degenerative brain disorder that usually affects adults between the ages of forty and sixty. Although current treatments cannot prevent the disorder from worsening, they can temporarily slow the worsening of symptoms and improve the quality of life of victims and caregivers if identified early.There is a need to develop an automatic Alzheimer's disease diagnostic system that is highly accurate, quick, and user-friendly. At the moment, the majority of techniques used to detect Alzheimer's disease based on brain structural images are based on volume measurement [3]. The fig 2 shows the overall framework of brain disease classification.

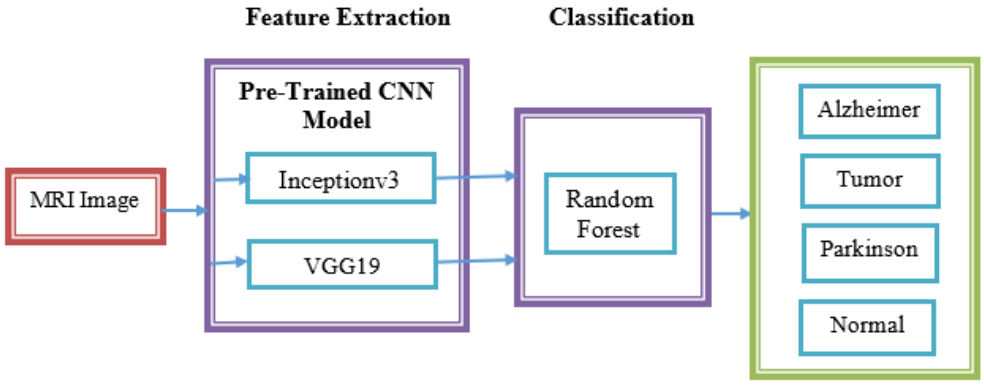


Fig. 2 Overall Framework of Brain Disease Classification

2. Literature Survey

When the central nervous system is completely degenerated, it leads to Parkinson's disease (PD). Cell degeneration completely affects the nigra in the brain. The important clinical presentation of Parkinson's disease is movement disorder. The affected person has low movement and feel difficulty in walking. Both PD and AD affect seven million people globally [4]. The prevalence of people affected by PD in industrial countries is around 0.3 % of the world population. PD generally occurs in the elderly people, 4 % people affected over 60 years [5].

Alzheimer's disease is a chronic neurodegenerative disease of the elderly people that begins slowly and gets worse over time [6]. The main symptom of this disorder is short-term memory loss. The person has difficulty remembering recent events. The expected worldwide prevalence of AD, as predicted by the World Health Organization, is 0.441% in 2015 and 0.556% in 2030. AD can be categorized into three different stages depending on its severity, a moderate stage in which the person has more severe cognitive deficits and becomes dependent on caregivers. In the last severe stage, the mental makeup and attitude of the person may completely change and they completely depend on the caregivers [7].

3. Modelling

PRE-TRAINED CONVOLUTIONAL NEURAL NETWORKS

In this work the pre-training techniques is used as feature extraction for the MRI images, called the Transfer Learning and fine-tuning. In this work transfer learning has been used in Inceptionv3 and VGG19. Inceptionv3 and VGG19 use their network weights to perform the task of feature extraction and classifying the MRI image data sets into Brain diseases Alzheimer, tumour, Parkinson and normal image.

Transfer Learning

Transfer Learning is a technique used to process a small or large amount of labelled information from the source domain to the target domain in order to build as efficient predictive model. Every pre-trained model performs two kinds of action one is feature extraction and another one is classification. Inceptionv3 and VGG19 CNN model was pre-trained using ImageNet dataset. Then remove the last layer of fully connected or SoftMax layer. A new fully connected layer was added, using the rest of the network for feature extraction and model training. In this proposed

work the Inceptionv3 and VGG19 are used for feature extraction alone.

3.1 INCEPTIONV3 PRE-TRAINED MODEL

Inception network is an up-to-date deep learning model. It is mainly used to solving image identification and detecting problems. The Inception deep convolutional architecture was launched by GoogleNet in 2015 and it was named as Inceptionv1 [8]. Next, the inception was refined by batch normalization and then Inceptionv2 came into existence. Now, in Inceptionv3, more factorization is introduced.

Based on the earlier versions, the factorization of 3 × 3 convolutions takes place instead of standard 7 × 7 convolution. A set of 3 standard inception models are incorporated for the network Inception part at 35×35 besides 288 filters each. It is minimized to 17 × 17 grid with 768 filters with grid reduction. It is proceeded by 5 recurrence of factorized inception modules. The Inception modules consists a set of 8 × 8 level with linked output filter bank size of 2048 for each tile. However, the network quality is relatively stable towards modifications. The Inceptionv3 is 42 layers deep, which works more efficiently than VGGNet and it performs concatenation of many various sized convolutional filters into a new filter [9]. This model reduces the number of parameters which under goes the training and thereby minimizes the computation complexity. Fig. 2 illustrates the overall architecture of Inceptionv3 model. The architecture consists of factorization into smaller Convolutions, Factorization into Asymmetric Convolution, Grid Size Reduction, Auxiliary Classifier and Regularization via Label Smoothing.

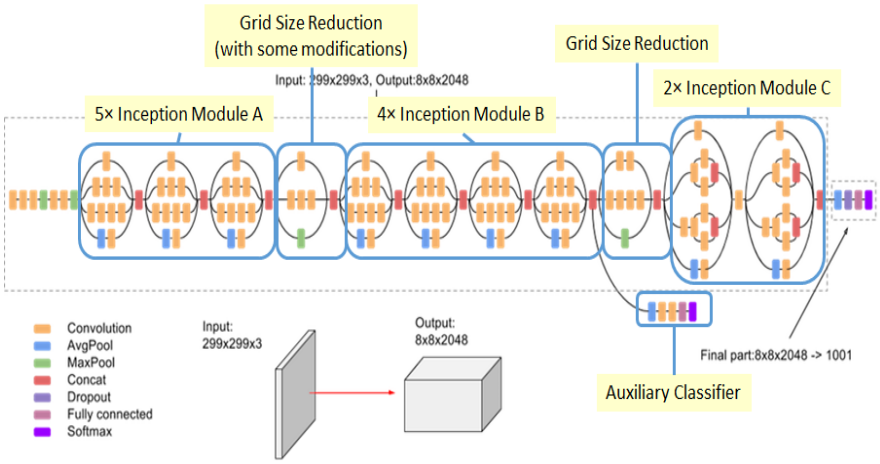


Fig. 3 Architecture of Inceptionv3

Factorization into smaller convolutions

In this stage, the dimensions/parameters are reduced without decreasing the efficiency of the factorizing convolutions.

Grid Size Reduction

At this point, when more convolutional layers are applied, the Grid size decrease is realized by pooling, followed by the convolution operation.

Auxiliary Classifiers

Auxiliary classifiers improve the convergence of very profound networks. The main intention is to push the essential gradients to the lower layers during the training by combating the disappearing gradient issue in very deep networks.

For one image, we extract a 2048-dimensional feature from the last fully-connected logits layer. The layers before the fully connected layer of the pre-trained networks perform the feature extraction for the images and the fully-connected layers are used for classification. In this work, the fully connected layers are replaced by Random Forest classifier to perform classification. This model is referred as a single transfer learning network.

3.2 VGG19 PRE-TRAINED MODEL

VGG19 is a deep Convolutional Neural Network (DCNN) that is used to classify images. The input size of VGG19 is 224 x 224 RGB image which is given as the input to the network. It means the matrix of the shape (224,224,3). For pre-processing the mean RGB value from each pixel is computed over the training set. The kernel size is 3 * 3 with the stride size of 1 pixel is covered throughout the image. The spatial padding is used to preserve the spatial resolution of the image. The max pooling is performed over a 2 * 2 pixel windows with stride 2 followed by Rectified Linear Unit (ReLu) is introduced for non-linearity to make the model class classify better and to

improve computational time Fig.3 shows the overall block diagram of VGG19.

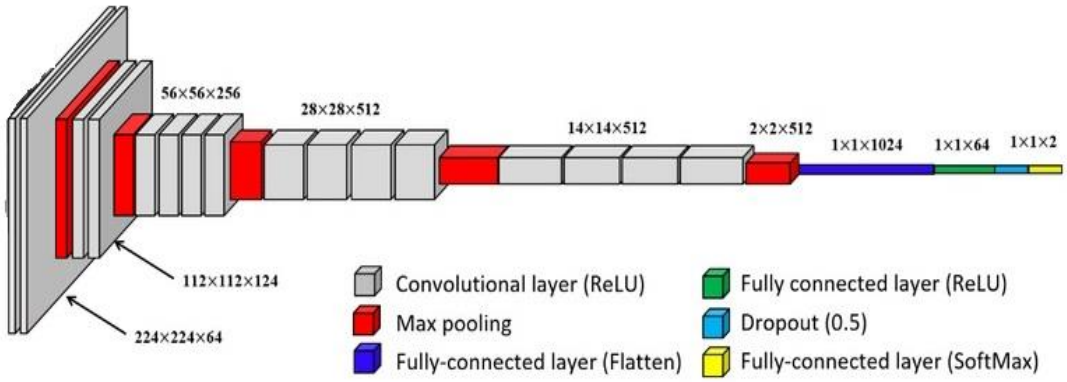


Fig. 4 Block diagram of VGG19

The three FC layers from which first two were of size 4096 and after that a layer with 1000 channels for 1000-wayILSVRCclassification and the final layer is a softmax function. Since this model is pre-trained for different ImageNet database classified for 1000 classes, in the proposed work the final network layer is removed. The convolutional features are extracted from the VGG19 pre-trained model. Then the extracted features are fit into the Random Forest classifier for the classification of brain diseases as Alzheimer, Tumor, Parkinson and normal brain image.

3.3 RANDOM FOREST CLASSIFIER

Random Forest (RF) is otherwise called as the random decision forests [10]. RF is a set of tree predictors that is known as forest. RF is particularly used for categorizing and regression issues [11]. For implementing the out the classification process, a trained RF model is carried out and the steps are given below:

1. Take the test features and employ the rules of every arbitrarily generated decision tree for predicting the output and store the expected result (target)
2. Determine the votes for every predicted target.
3. Assume the high voted predicted target as the last prediction from the RF model.

To perform the classification process, the trained RF model is needed to render the test features using the rules of every arbitrarily generated trees. The overall structure is given in Fig. 4.

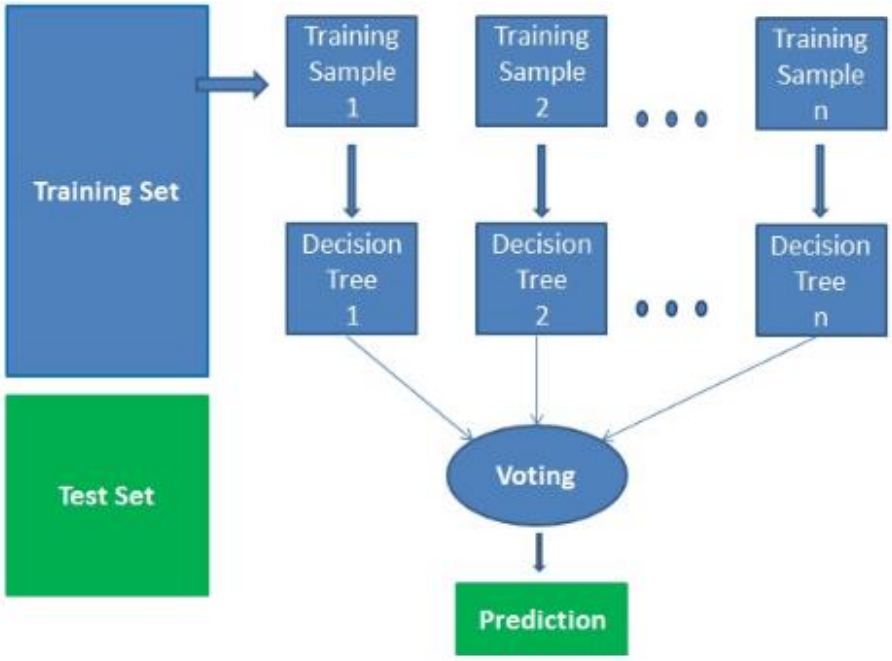


Fig. 4 Random Forest classification process

During training, all the trees are trained with the same parameters. Here, the bootstrap procedure is followed for each training set, then we randomly select the usual number of vectors and the vector is replaced randomly. At each node during the training, a novel subset is produced. All the variables are not utilized to divide the node; a subset is selected randomly to generate a new subset in a node. But the size is affirmed for every node and tree. During training, the present tree is drawn by replacement, while certain vectors are left out. This is called as out-of-bag.

4. Performance Analysis

4.1 Dataset Description

The datasets have been collected from Kaggle datasets. A total of 6754 MRI images were collected in which 2539 Alzheimer, 1460 Normal, 356 Parkinson and 2399 Tumour affected images used for training. 1046 MRI images are used for testing which was classified by Random Forest Classifier.

4.2 Environmental setup

Deep learning environment has been set by installing python 3.6 versions along with anaconda library.OpenCV contrib (version 3.3.0) library is successfully linked with python 3.6 interpreter.Using conda install command install the tensorflow backend and keras. Pip install the required libraries such as numpy, PIL, Scikitlearn, scipy, sklearn, h5py are imported.

4.3 Performance Measures

A set of evaluation parameters namely Accuracy, Precision, Recall and F-score are used in this work. These measures are determined based on the confusion matrix derived from the outcome of the classification process. The confusion matrix is 2*2 matrix containing a set of four elements, namely True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) where TP identified as prediction is correct, TN as prediction is wrong, FP as correct value is predicted wrong, and FN as wrong value is predicted right. They are defined as follows:

Accuracy

The accuracy of a measurement system is a level of measurement that yields are true (no systemic errors) and consistent (no random errors) results.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (1)$$

Precision

In classification work, the precision for the class is the number of TP (i.e. the number of items correctly labeled as belonging to the positive class) divided by the total number of elements labeled as belonging to the positive class (i.e. the sum of true positives and false positives, which are items incorrectly labeled as belonging to the class)

$$Precision = \frac{TP}{TP + FP} \qquad (2)$$

Recall

Recall is defined as the number of TP divided by the total number of elements that actually belong to the positive class (i.e., the sum of true positives and false negatives, which are items which are not labeled as belonging to the positive class but should have been)

$$Recall = \frac{TP}{TP + FN} \qquad (3)$$

F-Measure

F-Measure is a measure of test's accuracy and it takes into account of both the precision and recall of the test to compute the score (Harmonic mean).

$$F - Measure = 2\frac{Precision * Recall}{Precision + Recall} \qquad (4)$$

Performance of Inceptionv3

The input layer takes an image in the size of 299 x 299 x 3 and the output layer is the Soft Max prediction on 1000 classes. From the input layer to the last is the max poolin g layer by 8 x 8 x 2048 which is referred as the feature e xtraction of the model, while the rest of the network is r egarded as the classification of the model. In this work, in ceptionv3 is used to extract the features hence we arri ve at 2048 feature vector for an individual image. The tot al parameters of the Inceptionv3 network without the top layer is 21,802,784. In that 21,768,352 are trainable and 34,432 are non-trainable parameters.

The training process analyse the normal and brain disease Alzheimer, Tumour, Parkinson images training data to find the decision tree to classify into their respective classes. Random forest is structured for a complete learning procedure for categorizing with a set of decision trees that grow randomly by selecting the sample data. A nonlinear decision tree is applied to discriminate the various stages. Random Forest is trained to ascertain normal and various brain disease features. The bootstrap procedure is followed for each training set; the samples are selected randomly. For training 6754 feature vectors, each of 2048-dimension are extracted from the images. At each point, a new subset is generated; present tree is drawn

by replacement of vectors. This is called as out of bag. The training process analyses the normal/abnormal data to categorize the Parkinson's disease affected images into its respective four classes namely Alzheimer (Category 1), Normal (Category 2), Parkinson (Category 3) and Tumour (Category 4). For testing 1050 feature vectors each of 2048 dimensions are given as input to the Random Forest model. While testing, predictions are arrived by finding the average of the study of each decision tree.

Table 1 Confusion Matrix for Random Forest with Inceptionv3

	Alzheimer	Normal	Parkinson	Tumour
Alzheimer	462	0	0	0
Normal	0	100	0	1
Parkinson	0	0	91	0
Tumour	0	102	0	294

Table 2 Classification Report for Random Forest with Inceptionv3

	Precision (in %)	Recall (in %)	F1- Score (in %)	Accuracy (in %)
Alzheimer	100.00	100.00	100.00	100.00
Normal	100.00	49.50	99.00	90.19
Parkinson	100.00	100.00	100.00	100.00
Tumour	74.24	99.66	85.09	90.19

Performance of VGG19

The input layer takes an image in the size of 224 x 224 an d the output layer is the SoftMax prediction on 1000 class es. From the input layer to the last is the max pooling lay er by 7 x 7 x 512 which is referred as the feature extractio n of the model, while the rest of the network is regarded a s the classification of the model. In this work, inceptionv 3 is used to extract the features hence we arrive at 2048 f eature vector for an individual image. The total parameter s of the Inceptionv3 network without the top layer is 20, 024,384 all are trainable parameters.

The training process analyse the normal and brain disease Alzheimer, Tumour, Parkinson images training data to find the decision tree to classify into their respective classes. Random forest is structured for a complete learning procedure for categorizing with a set of decision trees that grow randomly by selecting the sample data. For training 6754 feature vectors, each of 2048-dimension are extracted from the images. At each point, a new subset is generated; present tree is drawn by replacement of vectors. This is called as out of bag. The training process analyses the normal/abnormal data to categorize the Parkinson's disease affected images into its respective four classes namely Alzheimer (Category 1), Normal (Category 2), Parkinson (Category 3) and Tumour (Category 4). For testing 1050 feature vectors each of 2048 dimensions are given as input to the Random Forest model. While testing, predictions are arrived by finding the average of the study of each decision tree.

Table 3: Confusion Matrix for Random Forest with VGG19

	Alzheimer	Normal	Parkinson	Tumour
Alzheimer	462	0	0	0

Normal	0	100	0	1
Parkinson	0	0	91	0
Tumour	0	106	0	290

Table 4: Classification Report for Random Forest with VGG19

	Precision (in %)	Recall (in %)	F1- Score (in %)	Accuracy (in %)
Alzheimer	100.00	100.00	100.00	100.00
Normal	100.00	48.54	65.35	89.80
Parkinson	100.00	100.00	100.00	100.00
Tumour	73.23	99.65	84.42	89.71

Comparison of Existing Models

The brain disease classification dataset is implemented with the existing models Random Forest, Inceptionv3 and VGG19. The table 5 shows the accuracy of the existing models Random Forest, Inceptionv3 and VGG19.

Table 5: Comparison of the Existing Models

Models	Accuracy (in %)
Random Forest	92.01
VGG19	79.87
Inceptionv3	93.20

Comparison of the Proposed Models

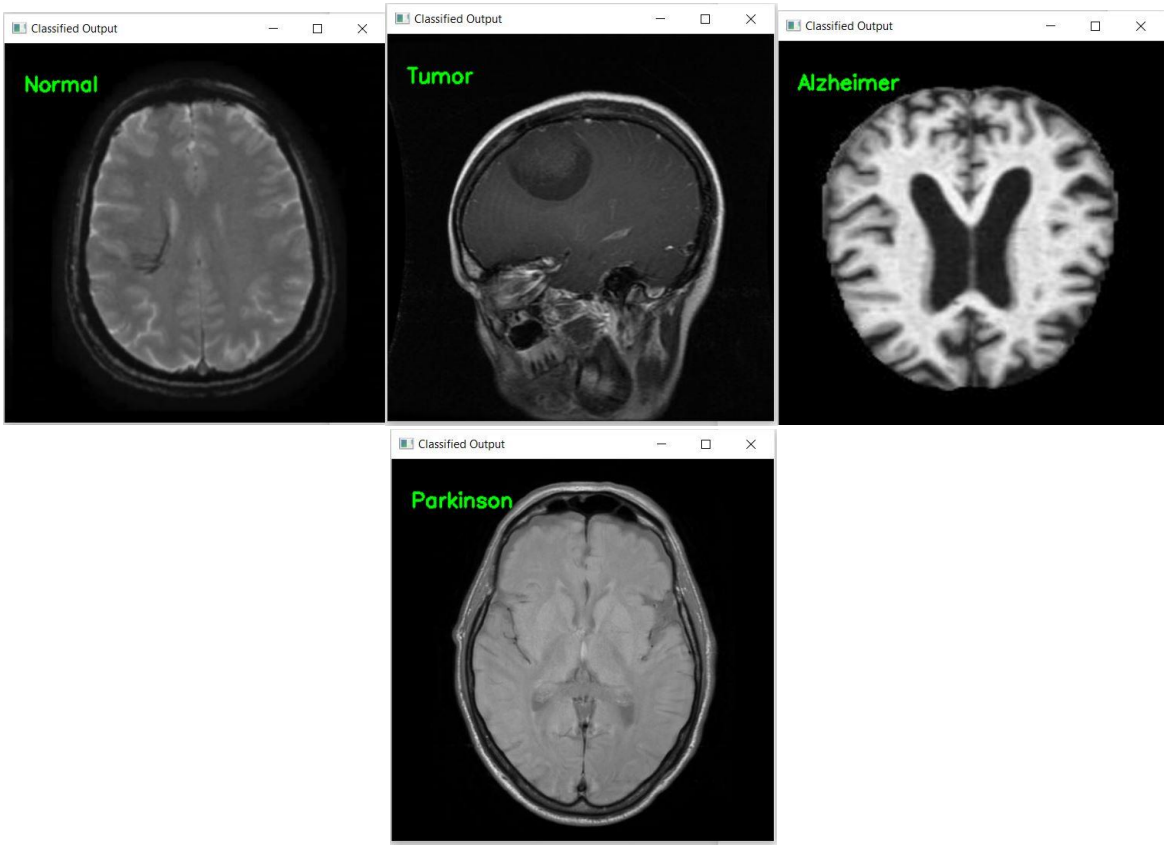
The table 5 shows comparison of accuracy of the modes Random Forest with both Inceptionv3 and VGG19. Comparison of the accuracy the Inceptionv3 with Random Forest produced higher accuracy 95%.

Table 6: Comparison of the Proposed Models

Models	Accuracy (in %)
Random Forest with Inceptionv3	95.09
Random Forest with VGG19	94.87

Sample output

The fig 5 shows the sample output of brain disease classification using Inceptionv3 and VGG19 using Random Forest classifiers. Four classes of diseases taken for classification namely Alzheimer, Normal, Parkinson and Tumor.



5. Conclusion

In this proposed work a novel approach is used to classify the brain disease. Four classes MRI images are classified as Alzheimer, Normal, Parkinson and Tumor. The Inceptionv3 and VGG19 pre-trained models are used as feature extractor. The convolutional features are extracted from the deep learning models. The extracted features are classified by using the classifier Random Forest. There are 6754 MRI samples are trained by using Inceptionv3 and VGG19 networks. There are 1046 samples are taken for testing. The Random Forest classifier classify the MRI images into the classes Alzheimer, Normal, Parkinson and Tumor. In this work the deep learning model and machine learning classifier are combined for the brain disease classification. Comparison of these two models the Inceptionv3 with Random Forest performed well with the accuracy of 95%.

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