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Multiclass Classification of Alzheimer's Disease Using Hybrid Deep Convolutional Neural Network

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Abstract. Deep learning has gained a lot of attention in recent years for solving problems in several fields, including medical image processing. This paper proposes a very deep pipeline that creates a convolutional neural network-based pipeline using magnetic resonance imaging (MRI) scans to detect Alzheimer's disease and its stages. Diagnosing Alzheimer's disease in the elderly is difficult due to identical brain structures and pixel strength, and it necessitates systematic discrimination. Alzheimer's disease is a progressive loss of morality that results in issues such as a gradual deterioration in thought, actions, and social skills, making it difficult for an individual to work independently. Based on input images of Magnetic Resonance Imaging (MRI), we have developed an in-depth study model for predicting individual diagnosis of Alzheimer's Disease (AD), Cognitive Normal (CN) and Mild Cognitive Impairment (MCI). We have used four classes in this paper: Non-Demented, Mild Demented, Very Mild Demented, and Moderate Demented. To diagnose Alzheimer's disease, we used a combination of Inception and ResNet formulation. This proposed model achieves an accuracy of 79.12 percent, which is a significant improvement over the existing model.

Keywords: MRI, Dementia, Inception ResNet V2, Alzheimer, Deep Learning.

Introduction

Alzheimer's disease is a neurological disorder that causes memory loss and mental retardation due to the death of brain cells. Alzheimer's disease is the most prevalent type of dementia. As the plates contain a beta-amyloid form in the brain, this happens. People's ability to remember current events, to think, and to identify people they know is deteriorating as symptoms worsen. At some point, a person with Alzheimer's disease will need full-time assistance. Neuropathy is a form of disorder that affects the brain. Alzheimer's disease is a type of neuropathy. Symptoms are mild at first, but intensify over time. Alzheimer's disease is divided into three categories: non-demented (generalized mental), mild (first stage), severe dementia (late stage), and moderate dementia (near stage).

1.1 Deep Learning

Deep learning is a technology that simulates the network of neurons in the brain. It is the subfield of machine learning that makes use of deep neural networks. In deep neural networks, number of layers are linked to build deep learning model.

1.2 Working of Deep Learning

The Input Layer is the topmost layer. The Output Layer is the final layer. Hidden Layers are all the layers in between Input layer and Output layer. The term "deep" refers to a network that connects neurons in more than two layers, as shown in Fig. 1.

Neurons make up each of the Hidden layers. The neurons are all connected. The input signal received by the layer above the neuron will be processed and then propagated by the neuron. The weight, bias, and activation mechanism all affect the intensity of the signal sent to the neuron in the next layer. The network collects large volumes of input data and processes it across multiple layers, with each layer learning increasingly complex data features.From object detection to speech recognition, a deep neural network offers state-of-the-art precision in a range of tasks. They will learn on their own, without the programmers having to specifically code predefined information.

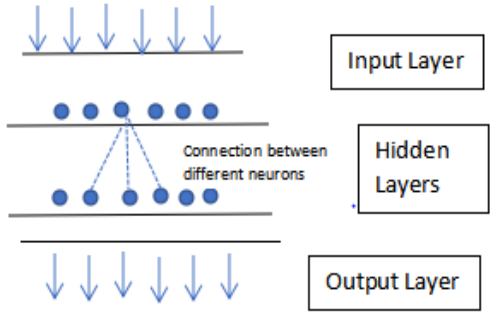

Fig. 1. Deep Learning Layers

There are two stages of the learning process. The first step is to transform the input data using a nonlinear transformation and then generate a statistical model as an output. The model will be improved in the second step using a mathematical approach known as derivative.

These two steps are repeated hundreds to thousands of times before the neural network reaches a degree of accuracy that is appropriate. Iteration refers to the repetition of this two-phase procedure. The success of a CNN is determined by extracting more complex high level features from data/images at each layer. The CNN is made up of several layers, each of which is capable of extracting high-level features. The perceptual activities are a greatest strength of CNN. When professionals need to extract information from an unstructured data set, such as photographs, CNN is most commonly used.

2 Literature Review

The main goal of that paper is to improve classification accuracy by preprocessing data before applying the CNN model. The authors in [1] introduced a deep learning-based Alzheimer's disease detection system. Images from the ADNI dataset are used to train the model, which contains fMRI and PET images of Alzheimer's patients as well as healthy people. The paper [2] presented a deep learning framework that intended to integrate multi-source data and tap into expert knowledge using deep learning algorithms. To evaluate the base classifiers at the stacking layer, a deep belief network based nonlinear feature-weighted method is proposed. This method violates conditional independence. Alzheimer's disease is being classified using the proposed deep learning algorithm. The experiments were carried out with the dataset acquired from the National Alzheimer's Coordinating Center and this scheme outperforms six well-known ensemble methods with classification accuracy by 4%.[2].

In [3], Medical imaging applications for Alzheimer's disease have been greatly enhanced by machine learning and deep learning methods, which provide diagnostic output that is similar to that of humans. In this paper, the author proposed a model using a two-dimensional deep convolutional neural network (2D-DCNN) and three-dimensional MRI dataset to develop a smart and accurate approach for diagnosing Alzheimer's disease. According to experimental findings on the ADNI (MRI images) dataset, the proposed 2D-DCNN model is performed well. This model is analyzed based on the parameters precision, efficiency, and robustness. The model classified the input MRI images into three classes: Alzheimer's disease, mild cognitive disorder, and normal control, with a classification accuracy of 99.89 percent for imbalanced groups.

The model proposed in [4] used transfer learning approach to train high-dimensional Deep Neural Network (DNN) models in order to achieve accurate results in detecting Alzheimer's disease from fMRI data. They used three different DNN models VGG19, Inception v3, and ResNet50 to classify AD, MCI, and CN patients. After just 15 epochs of preparation, VGG19 achieved 90% accuracy, Inception v3 achieved 85% accuracy, and ResNet50 produced 70% accuracy. The model presented in

[5] is a 12-layer CNN binary classification model and used for diagnosis of Alzheimer's disease with brain MRI data. This model used OASIS dataset for training. The proposed model is compared to some current CNN models in terms of accuracy, precision, recall, F1 score, and ROC curve. This model produced 97.75 percent accuracy, which is greater than any other CNN model which uses this dataset.

They authors [6] developed a deep learning model based on CNN that detects Alzheimer's disease (AD) and mild cognitive disability that may progress to AD based on a single cross-sectional brain structural MRI scan (c-MCI). 3D T1-weighted images from ADNI and subjects recruited at thier Institute (407 healthy controls [HC], 418 AD, 280 c-MCI, 533 stable MCI [s-MCI]) were used for training the model. The model achieved 99 percent of accuracy for AD vs HC classification tests using only the ADNI dataset and achieved 100 percent for the combined ADNI + non-ADNI dataset. The author in [7] proposed novel classification algorithm Ensemble of hybrid deep learning architectures to distinguish patients with Alzheimer's disease (AD), mild cognitive impairment (MCI), and cognitively normal (CN). This model used OASIS dataset for training and produced an accuracy which outperforms over certain traditional methods.

The aim of the paper presented in [8] is to develop a Computer-Aided-Brain-Diagnosis (CABD) system diagnosing Alzheimer's disease from MRI images. This system combined multiple feature extraction techniques for classification. In this paper, comparative study was conducted with other feature extraction methods and concluded that Shearlet Transform (ST) feature extraction technique provides better results for Alzheimer's diagnosis than other methods. The proposed diagnosis tool achieved a 94.54 percent accuracy using the ST + KNN technique. In the paper [9], transfer learning model, PFSECTL was proposed and it is based on VGG-16 which is trained on the ImageNet dataset. This model used data from the Alzheimer's Disease Neuroimaging Initiative (ADNI) database and achieved an accuracy of 95.73 percent.

A new classification algorithm which is based on ensemble of hybrid deep learning architectures was proposed to extract more complete spatial features for diagnosing different stages of Alzheimer's disease. The training was carried out with OASIS dataset and produced significant improvement over some traditional methods.[10]. Three pre-trained networks, AlexNet, ResNet-18, and GoogLe Net, were revised and trained for 3000 images using the transfer learning for the classification of five stages of Alzheimer's Disease: CN, Early MCI (EMCI), MCI, Late MCI (LMCI), and AD. All the above three pre-trained networks are trained using the same dataset obtained from the ADNI database. [11].

In [12], a deep convolutional neural network (DCNN) is proposed. In this work, the structural MRIs are first pre-processed, then re-slice each volume and feed this images directly as an input to DCNN. This model produced 94.5 percent accuracy for NC versus LMCI, 96.9 percent accuracy for NC versus AD, 97.2 percent accuracy for LMCI and AD, 97.81 percent accuracy for EMCI versus AD, and 94.8 percent accuracy for LMCI versus EMCI. The model 3D multichannel convolutional neural network (CNN) architecture proposed in [13] was used to predict Alzheimer's disease using Diffusion MRI (dMRI) imaging data. This model used information in the form of images from a patient's history to improve classification accuracy. The authors in [14] developed a machine learning algorithm to extract 2D features from an MRI images. This model classified three different types of patients. This model used a generic feature extractor for 2D image, PCA+TSNE is used for reducing the dimensions and simple machine learning algorithm such as KNN or Navies Bayes Classifier is used for classification.

Their purpose of the article presented in [15] is to make a distinction so that it can separate images into three distinct categories. Critical steps in the deep learning pipeline include fine-tuning 4D fMRI images, which are 3D images that move over time. The progression measures were important

in obtaining fragments of different 2D images of Normal, EMCI, and AD for a more accurate understanding of fMRI brain scanning the most discriminatory features. The idea behind the Transfer Learning is that the use of deep pre-trained models to identify images. The advantage of this learning by building a new resolution network is that the information gained during the ImageNet Dataset training speeds up the learning process and improves accuracy.[15].

The model proposed in [16] is seven layer Deep CNN binary classification model which classified two different categories among four categories of Alzheimer's disease stages with ADNI dataset. In this paper, author compared 4-layer Deep CNN model, 7-layer Deep CNN model and VGG16 based model, and concluded that VGG16 based model out performs well than other models.

3 Proposed System

The key goals of the proposed framework are to use Convolutional Neural Networks (CNN) in Deep Learning to classify Alzheimer's disease stages and to predict AD stages after training and validation using the Inception Resnet V2 Architecture.

Python was used to build this model. Python is a programming language that can be used in an Integrated Development Environment (IDE). Jupyter, Spyder, PyCharm, and Rodeo are just a few of the IDE's available. Many of these IDE's are mounted locally on the computers. Since the IDE's are local, they are not portable, so the correct files must be installed on each device. Furthermore, the IDE's speed is determined by the computer's speed, whereas Colaboratory (Colab) has numerous advantages over IDE's. Google's research led to the development of Colab. Colab is a free cloud service that allows you to write Python code using Jupyter Notebooks. It's set up for deep learning, with GPU tools available for free. It does not necessitate any prior configuration. Google Drive stores Colab notebooks, which can be shared as Google Docs.

3.1 Building CNN Model

The modules identified and implemented in the proposed system are depicted below in Fig 2 as:

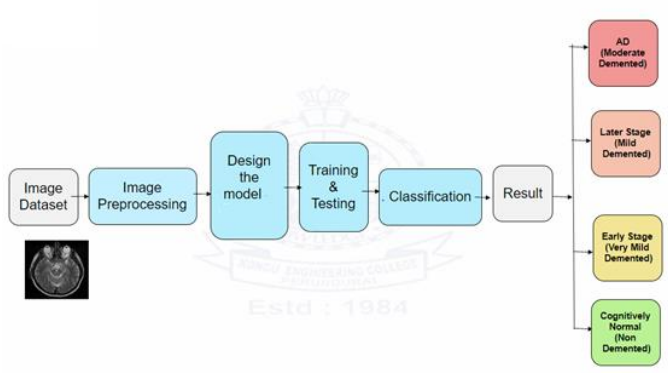

Fig. 2. Flowchart for proposed system

Dataset Description

The dataset used in these studies came from Kaagle and can be found at https://www.kaggle.com/tourist55/alzheimers-dataset-4-class-of-images. Kaggle is a data science and machine learning online community operated by Google LLC. In Kaggle, the users can use the dataset which is already available and they can also share their new dataset to others. They can use these dataset for building their model in a web-based data science environment. It allows the users to collaborate with other machine learning and data scientists, and participate in data science challenges. Figure 3 depicts the dataset description.

Train / Test	Classification	No of images	Total
For Training	Non Demented	2560	5121
	Very Mild Demented	1792	
	Mild Demented	717	
	Moderate Demented	52	
For Testing	Non Demented	640	1279
	Very Mild Demented	448	
	Mild Demented	179	
	Moderate Demented	12	
Total			6400

Fig. 3. MRI Image Dataset

Image Preprocessing

Image preprocessing is a method where it converts raw image data into a usable dataset. Since the images were derived from various sources, the dataset is not in standard form. As a result, the dataset is unsuitable for data analysis. As a result, to perform feature extraction and prediction, the image dataset must be preprocessed to create valid data.

Training the Model

A CNN model based on the Inception ResNet V2 Architecture is included in the proposed framework. The proposed architecture is based on a well-known architectural model. The Inception-ResNet-v2 is a 164-layer convolutional neural architecture that builds on the Inception family of architectures while also incorporating residual connections (replacing the filter concatenation stage of the Inception architecture).At top-5 test accuracy, the model achieves 79.12 percent on a dataset of over a hundred images divided into four classes. The Inception-Resnet V2 architecture improves on the original Inception architecture by incorporating residual connections.

The RGB image is used as the input to the conv2D layer [17,18]. The RGB image is run through a stack of convolutional layers, with the filters added in a 3:3 ratio. The Dropout layer, which helps to avoid overfitting, sets input units to 0 at random with a rated frequency at each phase during training time. Dense give the neural network a completely connected layer. Max pooling is a function that extracts high level feature value in each patch. In the case of average pooling, the feature in that patch is averaged, and in the case of Min pooling results are down sampled. The Softmax layer of the Inception ResNet V2 architecture is the final layer. In all networks, the fully connected layer configuration is the same. All hidden layers used ReLU as its activation function.

3.2 Prediction and Classification

The Confusion Matrix is the simplest way to evaluate the efficiency of a classification problem with two or more types of output. A confusion matrix is nothing more than a two-dimensional table. True Positives (TP), True Negatives (TN), False Positives (FP), False Negatives (FN) are all present in both the real and expected dimensions (FN) The precision values, accuracy, recall, and F-measure are all calculated using the confusion matrix. The softmax activation function is used to categorize the findings into the various phases of Alzheimer's disease.

4 Result and Discussion

4.1 Performance Metrics

Accuracy, Precision, Recall, AUC, and F1 Score are the metrics used to test a classification model. This model achieved 79.12% Accuracy, 70.64% Precision, 28.22% Recall, 81.9%AUC, 39.91% F1 Score.

4.2 Result Analysis

In this work, we have performed hyper parameter turning for the proposed hybrid model Inception ResNet V2 by varying the parameters Learning rate(0.1, 0.01, 0.001) and Optimizers(Adam, SGD, RMS Prop). We have achieved good performance for the model with Adam optimizer and Learning rate of 0.01. The performance of this model is illustrated in fig.4 for 5 epochs. Number of epochs can be increased to improve the performance this model.

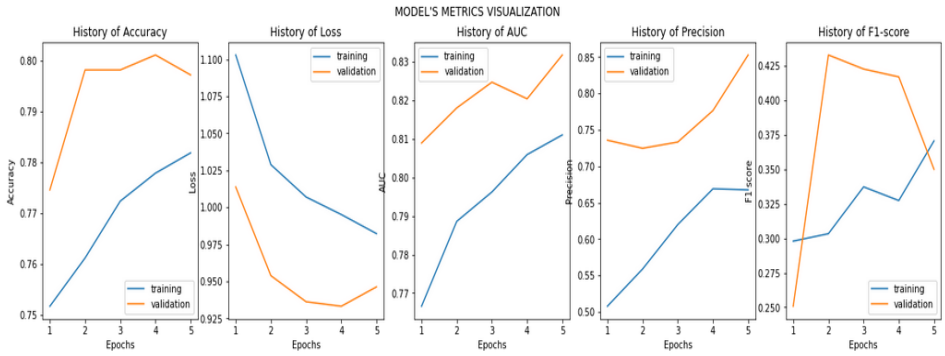

Fig. 4. Performance of Inception ResNet V2 with optimizer : Adam, Learning rate:0.01

The same hybrid model with optimizer : Adam, Learning rate:0.001 produced the following result shown in fig.5 for 5 epochs. Performance of this model is somewhat lesser than the model with the learning rate of 0.01.

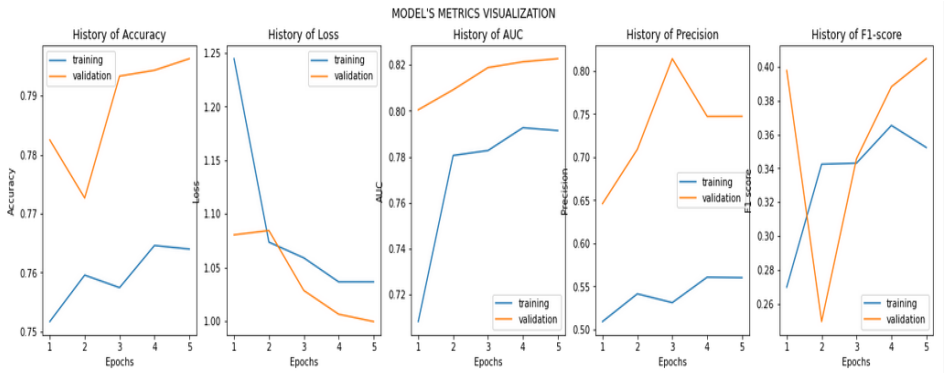

Fig. 5. Performance of Inception ResNet V2 with optimizer : Adam, Learning rate:0.001

The same model with optimizer : SGD, Learning rate:0.001 produced the following result for 5 epochs depicted in fig.6.

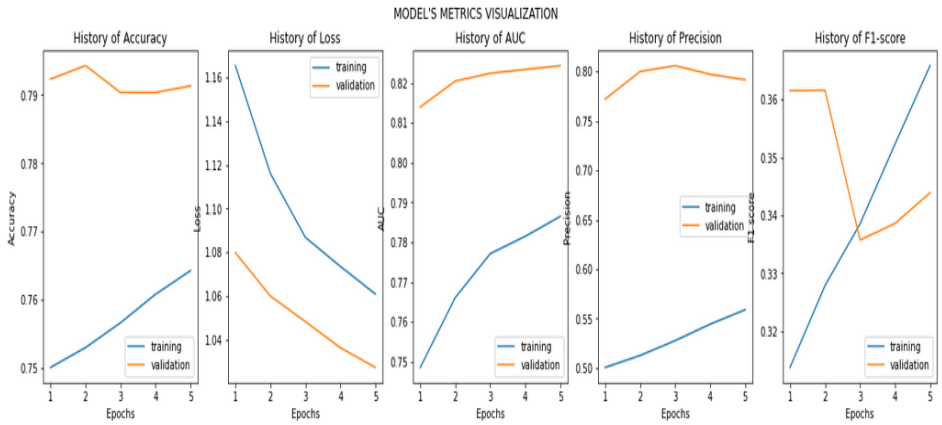

Fig. 6. Performance of Inception ResNet V2 with optimizer : SGD, Learning rate:0.001

Fig.7 shows the performance comparison of Inception V3 and ResNet-50 with Inception ResNet V2 Architecture. From the graph, it shows that Inception ResNet V2 has higher accuracy, recall, f1-score for all the same kaggle dataset, when compared to Inception V3 and ResNet-50 model.

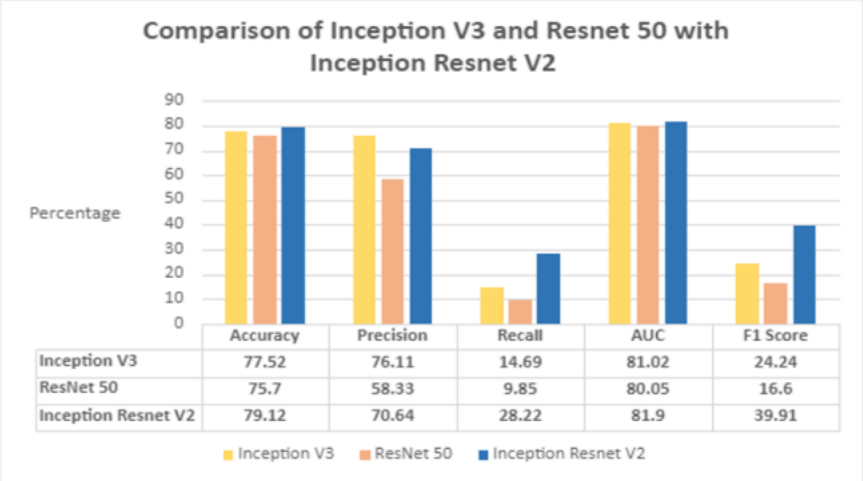

Fig. 7. Performance Comparison of Inception ResNet V2 with existing models .

5 Conclusion and Future Work

Alzheimer's disease is the most common cause of dementia, which is a broad term for memory loss and other cognitive abilities that interfere with daily life. To capture the high level feature using the MRI input images, this paper proposed a classification model based on a combination of Inception and ResNet V2 architecture. According to the experimental findings on the Kaggle dataset, the suggested approach outperformed well than the other architectures in terms of classification accuracy, precision, F1-score and recall.

The CNN model's efficiency will be improved in the future. The accuracy of the model can be achieved by increasing the number of samples used for training and validation, as well as fine-tuning the CNN model. The sagittal view of T1-weighted MRI images was the subject of this study. Other views, such as coronal and axial views, may be added in the future to help in the detection of disease landmarks by integrating Inception and ResNet V2 architecture.

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