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COMPARATIVE STUDY OF CNN MODELS FOR DETECTION OF ALZHEIMER'S DISEASE

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ABSTRACT

Early detection of Alzheimer's disease is important as the brain is the main affected organ in (Alzheimer's disease)AD. Early detection helps in minimizing the effect of AD. MRI (Magnetic Resonance Imaging) is the main method used in diagnosing AD. However, the detection of AD with this process is time-consuming. With Rapid advancement in AI technology, early detection of AD is possible using various techniques. This paper mainly focuses on detecting AD using various types of Convolutional Neural Network(CNN) models. A comparative study is done using an MRI image dataset with various CNN models to obtain the best accuracy. The dataset used in this paper is MRI images collected from the Alzheimer's Disease Neuroimaging Initiative (ADNI). This dataset was divided into 3 classes: CN, MCI, and AD. Preprocessing of the dataset was conducted to increase the effectiveness of the dataset and to obtain more accuracy. The study was done on 7 various CNN models, including LeNet, AlexNet, Inception_V3, ResNet-50, VGG16, VGG19 and DenseNet-121.The models were evaluated based on accuracy, precision, and F1 score. From the comparison study, it is observed that Dense Net achieved the highest accuracy of 96.01%, and the lowest accuracy which is 85.07% was achieved by Inception_V3.

Keywords: Alzheimer's Disease (AD), Convolution Neural Network (CNN), Mild Cognitive Impairment (MCI), Magnetic Resonance Imaging (MRI), Artificial Intelligence (AI).

I. INTRODUCTION

Alzheimer's Disease is a neurodegenerative disease that starts slowly and progressively worsens and is the cause of 60-70% of cases of dementia. It is characterized by changes in the brain that lead to certain protein deposits and shrinkage of brain cells. Of the about 55 million people worldwide with dementia, 60% to 70% are estimated to have AD. The early symptoms of this disease include forgetting recent events. Over time it progresses to serious memory issues and loss of the ability to perform everyday tasks. As a person's condition declines, they often withdraw from family and society. Gradually the functions of the body decrease, leading to death. One of the main conditions is the presence of plaques and tangles in the brain. Another condition is a loss of connection between the nerve cells, or neurons, in the brain. Doctors use various approaches for the diagnosis of AD. These approaches include medical history examinations, physical and diagnostic exams, neurological exams, and MMSE tests. These processes do not provide accurate results all the time and most of all, it is time-consuming. MRI has become the most used technique for diagnosing AD, due to its peculiar property. However, as the MRI features of MCI and AD appear to be very similar, traditional classifiers cannot distinguish between the two stages, especially in the older age group. Therefore, it is necessary to use AI algorithms to distinguish between the stages. AI algorithms use feature extraction from each class to clearly distinguish between the classes and the classification can be done more accurately.

[2]CNN stands for convolution neural network, a type of neural network used for image recognition. It processes data with a grid-like structure to extract the important features. The main advantage of using CNN is that it doesn't need much preprocessing. There are 4 layers in CNN namely the convolution layer, ReLU layer, Pooling, and fully connected layers. Image is given as an input and each of these layers processes the image, and the output is shown. A diagram showing the working of CNN is given in Fig. 1. Though CNN is used for AD detection very less models are used for this purpose. There are various types of CNN models, each with advantages and disadvantages. A comparative study is done on various models to select a better model for AD detection. The models that have been used are LeNet, AlexNet, ResNet-50, Inception_v3, VGG16, VGG19, and DenseNet-121.

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A comparative study is performed from the very oldest and simplest model (LeNet) to the latest model (DenseNet). The further section contains a related study with AD classification using CNN. The experimental setup and result analysis are explained below.

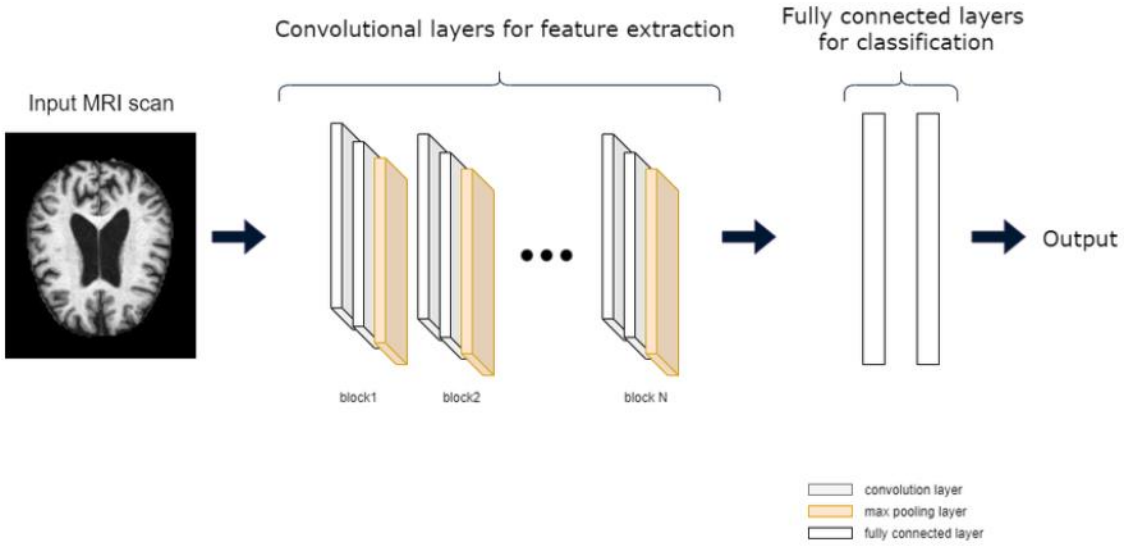

Figure 1: The basic working of a CNN model.

II. LITERATURE REVIEW

[6]Deep learning (DL) has become a powerful classification and big data analytics tool. One of the major reasons is its ability to learn from the surroundings and to improve its prediction accuracy. Many methods have been published in Deep learning(DL) since 2013. In 2017, researchers understood the importance of using CNN and DL in the detection of Alzheimer's disease. These technologies are used in every sector nowadays. The very first model for early detection of Alzheimer's disease was introduced by Odusami et al.. He used a modified ResNet18 model for this purpose. Later on, Pradhan et al. proposed the detection of different stages of Alzheimer's disease using VGG19 and DenseNet 169 architecture. Liu et al. proposed a classification model using Convolution and Recurrent neural networks. Sarang et al. proposed a Hybrid AI model for AD detection using Transfer learning and permutation-based machine learning. Amir et al.made an AD detection model using LSTM. Ruhul et al. did an experimental analysis with various deep learning-based models for Alzheimer's disease detection. Wei Feng et al. did a comparison of 2D CNN and 3D CNN for the detection of Alzheimer's disease. Amir Ebrahimi-Ghahnavieh et al. made a transfer learning model for the detection of Alzheimer's disease from MRI Images. Ekin Yagis et al. did the detection of Alzheimer's disease using 3D CNN. Xin Bi et al. did Alzheimer's disease detection using deep features and Extreme Machine learning.

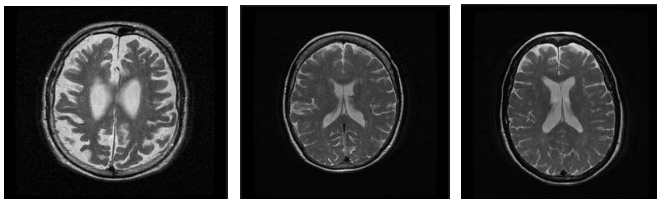

Figure 2: MRI images of AD, MCI, and CN patients respectively.

III. MODELING AND ANALYSIS

Dataset

[3]This research paper mainly focuses on comparing some of the CNN models for the detection of Alzheimer's disease. The Dataset was taken from the Alzheimer's Disease Neuroimaging Initiative(ADNI).ADNI is a widely recognized dataset in Alzheimer's disease research and is publicly available. [1]The Dataset was available in DICOM format so it was converted to JPEG format. The Dataset contains 2315 training images and 580 testing images of T2-weighted patients divided into 3 classes namely AD, MCI, and CN. In training data, AD, MCI, and CN contain 597,1031 and 687 images respectively. Meanwhile, in testing data AD, MCI, and CN contain 150,258 and

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172 respectively. Some images of the data from the three classes are given in Fig 2. These images are of patients ranging from age of 50 to 80 years.

Data preprocessing

Data preprocessing was done on the dataset to obtain more accuracy. The dataset was divided into training and testing data with 80% of training data and 20% of testing data. The images were then resized as per the input image sizes of various models. Normalization was performed to bring all the pixel values to a standardized range. The grayscale dataset was converted to an RGB dataset and data augmentation was also performed on the dataset. After preprocessing the dataset is trained and tested on various CNN models.

CNN Models

Seven models were compared to get the best accuracy. The original architecture was built for each model with the necessary modifications. Also, hyperparameter tuning was performed on each model like changing the batch size, and learning rate to optimize the performance. A detailed description and the accuracy that was obtained after the training of each model are given below.

LeNet: Lenet also referred to as Lenet-5 is a type of convolutional neural network discovered by LeCun et.al. It is one of the earliest and the oldest models. As it is the first model this model has the simplest architecture. The input image size of this model is 32*32 pixels. Except for the input layer, all other layers can train parameters. The accuracy received after the training of the dataset is 94.31% with a precision of 94.55% and an F1 score of 94.37%.

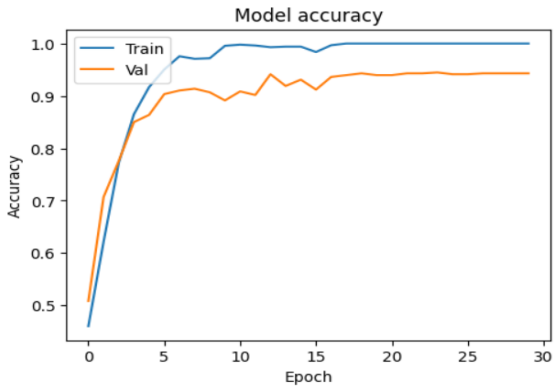

Figure 3: Accuracy of Lenet Model

AlexNet: Alexnet was designed by Alex Krizhevsky .Alexnet competed in the Large Scale Visual Recognition Challenge by Imagnet in 2012. Alexnet has 8 layers with various parameters. This model additionally includes dropout layers to prevent overfitting. The input image size of this model is 227*227. The accuracy received after training the dataset is 88.62% with a precision of 88.67% and an F1 score of 88.58%.

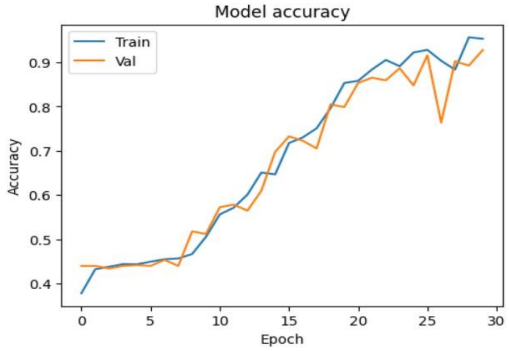

Figure 4: Accuracy of Alexnet Model.

Inception_V3: Inception_v3 is the third version of Google's Inception Convolutional Neural Network. Inception helps in the classification of Objects in the world of computer vision. This model has deeper networks as compared to Inception_v1 and Inception_v2. This model also has higher efficiency and is less expensive. There are 42 layers in this model. The input image size of this model is 299*299. The accuracy received after training this model is 85.07% with a precision of 85.69% and an F1 score of 84.81%.

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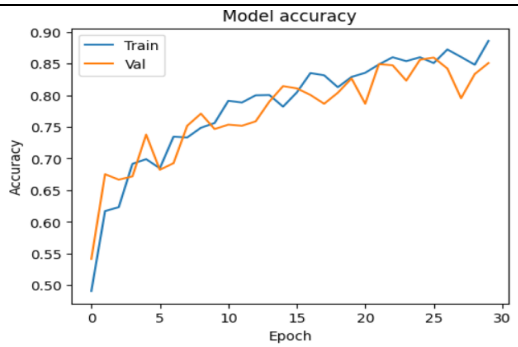

Figure 5: Accuracy of Inception_v3 Model.

ResNet-50: Resnet-50 stands for the Residual model and is a variant of the Resnet model. This model has 50 layers. It is a deep neural network that is used for various computer vision tasks such as object detection. The input image size of the ResNet model is 224*224. The accuracy received after training the model with the dataset is 85.94% with a precision of 37.73% and an F1 score of 37.65%.

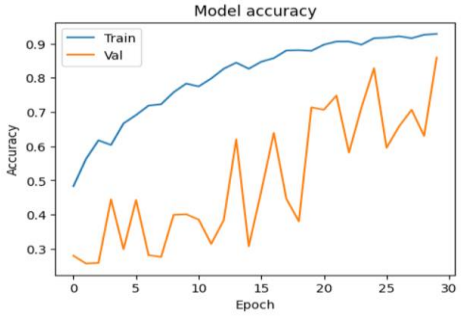

Figure 6: Accuracy of ResNet-50 model.

VGG-16: VGG-16 is one of the significant innovations in the field of computer vision. It is a CNN model proposed by Karen Simonyan and Andrew Zisserman. This model was called VGG after the visual geometry group at the University of Oxford. This model uses a 3x3 filter throughout the network lesser than previously discovered networks like Alexnet. The input image size of this model is 224*224. The accuracy received after training the model with the dataset is 93.4% with a precision of 35.49% and an F1 score of 35.8%.

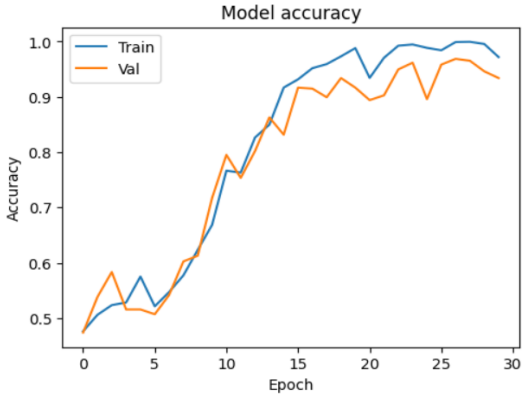

Figure 7: Accuracy of VGG-16 model.

VGG-19: It is a deep neural network that contains 19 layers and is used to classify images.VGG-19 is used for facial recognition tasks. This model can also be used for many custom datasets. This model is one of the pioneering architectures in deep convolutional neural networks for image classification. Even though this model is not computationally efficient this model is a baseline of comparison with modern architectures. This model is designed to work with an input image size of 224*224. After training the model it achieved an accuracy of 95.7% followed by a precision of 35.88% and an F1 score of 35.95%.

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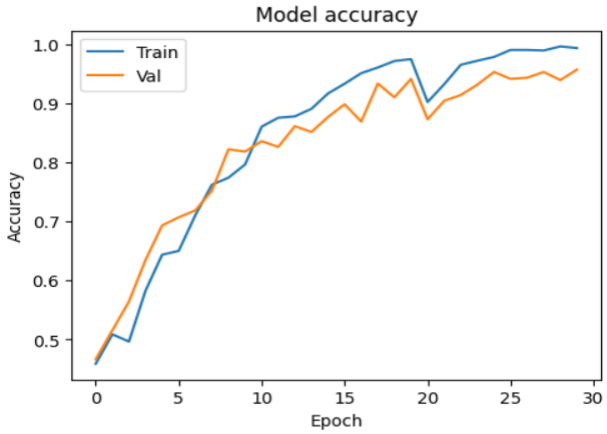

Figure 8: Accuracy of VGG-19 model.

DenseNet-121: DenseNet-121 is a convolutional neural network architecture that is known for its dense connections between layers. It is a traditional feed-forward CNN. DenseNet resolves the gradient problem by modifying the standard CNN architecture and simplifying the connectivity between the layers. It has 121 layers in total and has been used for various tasks like image classification. The input image size of the model is 224*224. After training the model it achieved an accuracy of 96.01% followed by a precision of 33.83% and an F1 score of 33.97%.

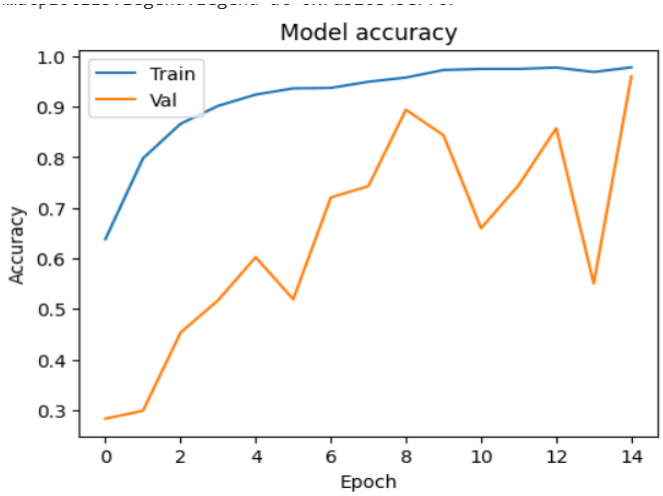

Figure 9: Accuracy of DenseNet-121 model.

IV. RESULTS AND DISCUSSION

From the comparative study of various CNN models in the detection of Alzheimer's disease a significant variation in their performance metrics was observed. The LeNet model demonstrated high accuracy with impressive precision and an F1 score. Alexnet and Resnet-50 followed with a pretty good accuracy. However, it is observed that Inception_v3 has the least accuracy of all the seven models.VGG-16 and VGG-19 demonstrated a competitive accuracy but their precision and F1 score were notably lower.DenseNet-121 outperformed all models with the highest accuracy, although it had the lowest precision and F1 score. This raises a critical point in AD detection: while high accuracy is desirable, it should not come at the expense of precision, especially in a medical context where false positives can have significant consequences. This limitation in the research may be caused by the imbalanced dataset or the smaller data size etc.. However, the LeNet and DenseNet121 models, despite their simplicity and complexity, outperformed other models in the experiments. As DenseNet121 achieved the highest accuracy, researchers and clinicians must weigh this against its lower precision and F1 score. However, the choice of the model should be made on the specific requirements of diagnostic tasks and the acceptable level of false positives. The below table represents the results of the experiments.

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Table 1. Experimental results of all models

Model Name	Accuracy	Precision	F1-Score
LeNet	94.31%	94.55%	94.37%
AlexNet	88.62%	88.67%	88.58%
Inception_V3	85.07%	85.69%	84.81%
ResNet-50	85.94%	37.73%	37.65%
VGG-16	93.4%	35.49%	35.8%
VGG-19	95.7%	35.88%	35.95%
DenseNet-121	96.01%	33.83%	33.97%

V. CONCLUSION

The main aim of this research was to make a comparative study of various CNN models for the detection of Alzheimer's disease using the ADNI image dataset of AD, CN, and MCI patients. This experiment leads to valuable insights into the performance of CNN models for this critical medical application. The findings revealed that the model selection plays an important role in AD detection. Models, like LeNet and DenseNet-121, exhibited great accuracy, the precision and F1 score of DenseNet-121 came out to be very low. Models, like AlexNet and Inception_V3, gave a very good accuracy with a relatively better balance between precision and F1 score. In the pursuit of AD detection model complexity alone does not guarantee superior performance. Simpler models, such as LeNet, can excel when appropriately optimized, hyperparameter setting and data preprocessing techniques. Future work could focus on fine-tuning hyperparameter refinements in model architecture and optimization techniques for each model to increase its performance with larger datasets. In conclusion, this research contributes to the ongoing efforts to develop accurate and reliable tools for early AD detection.

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