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AI-Driven Alzheimer's Detection Performance Analysis of Pretrained CNN Models on MRI Data

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***Abstract:** Alzheimer's disease (AD) is a memory and cognitive function neurodegenerative disease. Early diagnosis is important for appropriate treatment, but conventional diagnosing techniques are not very effective. In this paper, automatic detection of Alzheimer's disease from MRI scans using deep learning techniques is discussed. We trained and compared six pre-trained Convolutional Neural Network (CNN) models—VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121—to differentiate MRI scans as Alzheimer and Non-Alzheimer. In experiments, InceptionV3 is the optimal model for classification of Alzheimer's disease and all others are inferior with an accuracy of 99.2%. Confusion matrices, classification reports, and accuracy metrics were utilized to test performance. We also created a web-based real-time MRI classification tool with a user-friendly interface for clinicians. This work showcases the potential of deep learning in medical imaging and the detection of early disease, and opens the door to AI-augmented improvement in Alzheimer's diagnosis.*
***Keywords:** EfficientNet, CNN, VGG16, InceptionV3, DenseNet121, ResNet101, Keras , Accuracy*

I. INTRODUCTION

Millions of patients worldwide suffer from Alzheimer's disease (AD), a neurodegenerative illness that incapacitates normal function, results in loss of memory, and brings about cognitive decline. Early identification and treatment of Alzheimer's disease rely on early and accurate identification. The traditional diagnosis tests, including mental tests and physical examination, are prone to ignoring the disease at its onset stages. However, recent paths to autonomous and accurate diagnosis of Alzheimer's disease from Magnetic Resonance Imaging (MRI) scans have been opened by advances in deep learning and medical imaging. We classify MRI images as Alzheimer's and non-Alzheimer's here based on the application of deep learning techniques. We take six pre-trained Convolutional Neural Network (CNN) models, viz. VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121, and compare them to obtain the best Alzheimer's disease prediction model. These models are trained on an openly available MRI dataset on Kaggle, and accuracy and other metrics for classification are utilized to compare them. Our findings indicate that InceptionV3 is best at 99.2% accuracy and thus the most accurate to utilize for Alzheimer's detection. We even created a web application for convenience that enables users to upload MRI scans and receive real-time diagnosis predictions.

This article suggests the power of deep learning in medical imaging and how it can help doctors in early diagnosis of Alzheimer's. Our results bring hope to the new field of AI-aided diagnostics with future scope towards detection of neurodegenerative disease.

II. LITERATURE REVIEW

The domain of Alzheimer's disease (AD) diagnosis has significantly changed with the introduction of deep learning and machine learning techniques that can provide early detection through automated processes. In efforts to attain maximum categorization accuracy and efficiency in medical images, various strategies have been followed by researchers.

A comprehensive review of deep learning and machine learning technologies to be employed for brain disease identification was given by Khan et al. [1] and comprised such technologies' performance during MRI scan testing. Likewise, Prajapati et al. [2] provided a discussion on binary classifier of Alzheimer's classification using a deep neural network and comparison with traditional machine learning algorithms. Helaly et al. [3] presented an approach of early Alzheimer's prediction from MRI scans using deep learning where model optimization and feature extraction are the requirements.

To Martinez-Murcia et al. [4] examined convolutional autoencoders for the improvement of feature learning from MRI scans and examination of the intricate pattern of Alzheimer's disease. Ju et al. [5] developed a deep model from resting-

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state brain networks with the promise of early diagnosis. Further, Cui and Liu [6] illustrated the feasibility of sequential modeling using an RNN-based longitudinal study to examine the progression of Alzheimer's disease.

Ye et al. [7] and Filipovych and Davatzikos [8] used classical semi-supervised learning techniques, using pattern classification in MRI images to achieve early diagnosis. They provided the core methods to medical image classification. We trained and tested various pre-trained deep neural models in this study on the Alzheimer's MRI data freely available on Kaggle [9].

Our research also seeks to improve the precision of Alzheimer's diagnosis via such prior studies with an improved level of medical diagnosis using AI.

III. METHODOLOGY

A. About the Dataset

MRI brain scans on the Kaggle dataset form the data for this project. It is divided into two distinct classes—Alzheimer, which is the presence of the disease, and Non-Alzheimer, which is normal brains—and is best suited for Alzheimer disease classification. MRI scans are good training data for deep learning models that can distinguish between ill brains and normal brains.

For the sake of enabling proper model evaluation, the data is split into training and test sets. To make models execute optimally and be more generalizable, preprocessing operations such as scaling, normalization, and data augmentation are applied to each image of an MRI. There are numerous brain scans in the database, and that is the exact reason why it becomes easier for models to find intricate correlations that parallel Alzheimer's disease. Our research leans the database in the direction of formulating a successful deep learning model towards early and precise diagnosis of Alzheimer's for improved healthcare and medical imaging.

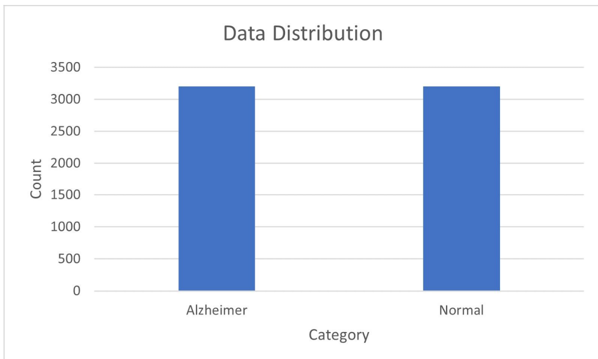

Figure 1 Data Distribution

B. Necessary Modules

1) Tensorflow

Our Alzheimer's disease prediction model is predominantly based on TensorFlow, an open-source deep learning environment that is extremely flexible and able to design, develop, and deploy deep learning models. During the present work, we fine-tune and employ a few pre-trained models of CNN, i.e., VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121, with the help of TensorFlow Keras API. A Global Average Pooling layer and classification fully connected layers are then appended after preinitialization of all models with ImageNet weights. For stable learning during model building, we use Adam optimizer along with the Sparse Categorical Crossentropy loss. The data pipeline of TensorFlow properly handles the dataset with loading along with MRI scans augmentation. According to our experimental outcomes, the model InceptionV3 has the highest accuracy rate of 99.2%. Modularity and scalability of TensorFlow enable easier experimentation, which also facilitate the early diagnosis of Alzheimer's disease via deep learning.

2) Keras

Some of these pre-trained convolutional neural network (CNN) models for Alzheimer's disease prediction were compared and benchmarked with the high-level deep learning API, Keras on top of TensorFlow. Pretrained ImageNet weights were used to import the selected models,

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VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121, from Keras's applications module. To make them suitable for our classification purpose, we removed the fully connected layers of these models and appended a GlobalAveragePooling2D layer and dense layers. All the models have been optimized with the Adam optimizer and Sparse Categorical Crossentropy loss for optimal learning and classification. The model has been trained on preprocessed MRI scans for 25 epochs in a way that size is also not changing along with pixel value.

InceptionV3 worked the best out of all the models with a 99.2% accuracy level, showing the highest feature extraction ability of the model. This paper illustrates the effectiveness of using Keras to develop disease prognosis and medical image deep models.

3) Scikit Learn

The precision of the deep learning models here is measured in part with Scikit-Learn, one of the most popular machine learning libraries for Python. TensorFlow and Keras are employed to specify deep learning models, but Scikit-Learn provides the metrics for model precision, accuracy, recall, and F1-score.

We employ Scikit-Learn test utilities to check classification accuracy of pre-trained trained CNN models VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121.

While precision-recall curve, ROC-AUC, and accuracy score estimation provide more precise data regarding a model's dependence, confusion matrix enables simplicity in visualization of correct and wrong responses.

For simple model comparison, Scikit-Learn also provides data preprocessing techniques such as train-test split and normalization. We maintain precision in our models to detect Alzheimer's disease from MRI scans by using Scikit-Learn in our testing phase, which eventually enables us to create a stable AI-based diagnosis platform.

C. Keras Layers used

In our study in this paper, we use a variety of Keras layers in constructing robust convolutional neural network (CNN) architectures specifically designed for predicting Alzheimer's disease from MRI images:

1) Conv2D

By One of the fundamental building blocks of Convolutional Neural Networks (CNNs) used to derive features from image data is Keras's Conv2D layer. It identifies texture, edge, and shape patterns from input images by sliding them across a list of learnable filters or kernels. In order to generate feature maps, the filters glide over the image and multiply one entry at a time and then sum them up together.Conv2D layers assist in structuring transformation in MRI scans to allow our Alzheimer's predictive model to identify healthy brains from Alzheimer's brains. The model is provided with hierarchical representations to improve classification by stacking several layers of Conv2D with activation functions like ReLU.

2) Flatten

Flatten layer of deep models in Keras is a very important feature, especially during the process of moving from convolution layers to fully connected layers. It is used in conjunction with dense layers for classification by flattening the multi-dimensional output of the convolution or pool layer to map into a one-dimensional vector. Flatten layer is utilized to convert MRI scan results into shape for end decision-making for Alzheimer's disease prediction. It facilitates effective co-existence between dense layer classification and convolutional feature extraction through the exploitation of the spatial relationship retention of data to enable more effective discrimination of Alzheimer and non-Alzheimer states.

3) MaxPooling

To MaxPooling is an important Convolutional Neural Networks (CNN) layer to downsample the spatial size of feature maps to preserve essential information. Keras's MaxPooling2D layer is extensively used to resize images by picking the maximum of a window (e.g., 2×2 or 3×3) and discarding others. This approach increases model efficiency, prevents overfitting, and reduces computational complexity. MaxPooling captures the important features and thus renders the network invariant to input image variations. MaxPooling layers improve MRI scan feature extraction, which results in improved classification accuracy in our Alzheimer's prediction model .

4) AveragePooling

One of the downsampling techniques used in spatial reduction with retention of basic features in Convolutional Neural Networks (CNNs) is Keras' AveragePooling layer. AveragePooling computes the average intensity of a pixel within a pool window, while MaxPooling computes max of intensity within a window.The algorithm produces smoother feature maps, prevents overfitting, and minimizes computational complexity.Our model for Alzheimer's prediction improves the classification feature by transforming feature maps into a homogeneous vector with the help of GlobalAveragePooling2D, which is applied subsequent to the InceptionV3 base convolutional layer. The pool type improves the model's generalization feature with the effectiveness of handling medical images.

5) Dense

One of the simplest components of deep networks of deep learning and artificial neural networks (ANNs) is Keras' Dense layer. The densely connected layer of all its neurons is supplied with all of the neurons of the layer before it. In order to introduce non-linearity and enable learning of intricate features, the Dense layer performs a weighted sum followed by an application of an activation function (say ReLU or Softmax). Our last Dense layer of Alzheimer prediction model has three output neurons (three classes) with Softmax activation, with accurate classification probabilities. Dense layers are utilized for decision-making and feature extraction in deep learning models.

6) Activation

The Keras activation layer, which is a relatively basic component of a deep model, is employed to implement a given activation function in a bid to identify the output of a neuron. By introducing non-linearity, the network learns to detect intricate patterns from MRI scans in an effort to deliver diagnoses for Alzheimer's disease. Softmax to the output layer in multi-class classification and ReLU (Rectified Linear Unit) to prevent vanishing gradient problem are some activation functions commonly used. Activation layers of our research models, i.e., InceptionV3 and ResNet101, are used for feature extraction as well as classification precision between Alzheimer and non-Alzheimer disease.

7) Dropout

Dropout is a deep learning regularization technique that randomly dropped out some portion of neurons during training to avoid overfitting. Keras utilizes the application of the Dropout layer in the classification of MRI images for Alzheimer's determination in order to enhance Convolutional Neural Networks (CNNs) generalization. A dropout (e.g., Dropout(0.5)) causes the model to learn strong patterns instead of memorizing the inputs by randomly dropping 50% of neurons during each training iteration. The method improves model performance on novel MRI data, enhancing Alzheimer's diagnosis prediction.

IV. MODELS USED

We improve the effectiveness and efficiency of our predictive models in our prediction of Alzheimer's in our study by using a variety of pre-trained deep learning models available from applications in Keras.

A. VGG16

VGG16 is a deep convolutional neural network that can be used for image classification because it has 16 layers and a uniform structure. MRI scans were used in this study to forecast Alzheimer's disease using VGG16 as a feature extractor. The model could leverage learned features to be applied to medical images because it was pretrained on ImageNet. The network is made up of max-pooling layers reducing spatial dimensions after a sequence of convolutional layers with 3 x3 filters.

MRI scans should be either Alzheimer's or non-Alzheimer by fully connected layers and Softmax activation function. VGG16 has deep structure but with the large number of parameters is computationally expensive. From our tests, VGG16 achieved a moderate performance rate for Alzheimer's disease diagnosis of 83.99%. Even though the models were good, the models like InceptionV3 outperformed VGG16, hence the importance of correct structures during the process of interpreting images in the medical context.

B. ResNet101

There is also a deep neural network known as ResNet101 (Residual Network with 101 layers) well known for its skip connections, with which it can be capable of overcoming the vanishing gradient problem during training. Since ResNet101 uses identity mappings instead of normal CNNs, data can pass freely through the network without being greatly transformed. This makes it more efficient at testing image classification tasks like classifying Alzheimer's disease using MRI images and increases the learning speed.

In order to label images as Alzheimer's or non-Alzheimer's, ResNet101 was trained on the MRI dataset. The model was among the tallest architectures in our comparison and had a very high classification accuracy of 98.3%. Its depth architecture provides greater accuracy in diagnosis since it facilitates the identification of intricate features characteristic of Alzheimer's disease. ResNet101's impressive accuracy is a testament to its viability as a groundbreaking medical imaging technology with the ability to contribute to early detection and identification of Alzheimer's for the enhancement of patient care.

C. EfficientNetB3

EfficientNetB3 is a computationally efficient deep model designed to achieve the highest accuracy possible without sacrificing computational efficiency.

It is part of the EfficientNet series of models that uses a compound scaling technique, trading depth, width, and resolution, to scale up convolutional neural networks (CNNs). This compared to regular CNNs enables EfficientNetB3 to achieve feature extraction more efficiently with less parameters.

We used MRI scan information for training EfficientNetB3 in order to predict Alzheimer and non-Alzheimer patients in our testing. The ImageNet weights pre-trained the model, and then these were tuned for medical image classification. The rotation and flip data augmentation strategies were used in order to provide generalization help. Adam optimizer and Sparse Categorical Crossentropy loss were utilized to train the model.EfficientNetB3, after being trained, had a very high ability to diagnose Alzheimer's disease with an accuracy of 93.6%.Despite how good it was, InceptionV3 did even better and had the highest accuracy in our tests.

D. MobileNetV2

Medical imaging work like the diagnosis of Alzheimer's disease can be effectively supplemented by MobileNetV2, a shallow deep neural network optimized for accuracy and computational cost when employed in image classification. Depthwise separable convolutions avoid loss in accuracy at the expense of lowering computational cost. Model's shallowness of memory and fast inference make it specifically appropriate for edge devices as well as in real-time.

To distinguish Alzheimer from non-Alzheimer disease, MobileNetV2 was utilized to train on MRI scans in this study. Pre-trained ImageNet weights were tuned using transfer learning to fine-tune the model. Global average pooling, dense layers, and softmax classification activation were used as the last layers.

MobileNetV2 accuracy of 75.1% after 25 iterations of training was lower than other deep models under study. The model itself was overall good, but had difficulty distinguishing between intricate MRI patterns and was therefore not as appropriate for high-precision Alzheimer's detection. However, it is still an excellent option for low-resource settings.

E. InceptionV3

One of the best convolutional neural networks (CNN) commonly renowned for its capability of image classification is InceptionV3. It performs well in challenging image recognition tasks like the identification of Alzheimer's disease since it applies factorized convolutions, asymmetric kernels, and auxiliary classifiers.Kaggle dataset MRI scans have been used here in fine-tuning InceptionV3, whose best accuracy among models tried on—99.2%. Its higher accuracy in Alzheimer and non-Alzheimer patient detection was achieved by extracting multi-scale spatial features. Sparse Categorical Crossentropy loss and Adam optimizer have been used to train the model for multi-class classification. Dropout and global average pooling layers have been incorporated for generalization. Deep learning can play a significant role in early diagnosis of Alzheimer's and clinical decision-making, as seen from the high accuracy of InceptionV3, proving that technology is very potential to be applied in real-world application in healthcare.

F. DenseNet121

The low cost of computation deep convolutional neural network DenseNet121 is utilized since it boasts efficient feature propagation and low processing expense. It employs close connections between levels to supply every layer with input from all the previous layers. The pattern of connection exists to help serve to be helpful in image classification, like the diagnosis of Alzheimer's disease, since it enhances gradient flow and prevents the vanishing gradient problem.

To divide brain images into either Alzheimer's or non-Alzheimer's, we used MRI brain images of the Kaggle dataset and trained DenseNet121. Aside from state-of-the-art architecture, the model achieved just 38.5% correct accuracy rate. Such a fairly poor performance level implies that DenseNet121 could not select proper features from MRI images in an attempt to differentiate from Alzheimer's disease. Overfitting caused by complicated interactions among layers and improper tuning for medical images are two likely reasons.

V. IMPLEMENTATION

For all pretraining models considered in this paper, InceptionV3 had highest accuracy (99.2%) and is therefore the top deep learning model for Alzheimer's disease prediction. A lightweight yet computationally efficient heavyweight CNN with near-optimal computing efficiency but at the expense of nearly optimal classification accuracy, InceptionV3 is used with the assistance of auxiliary classifiers, asymmetry kernels, and factorized convolutions to create feature-sufficient detail information from MRI scanning.

Except for the most topmost level of classification, we have trained InceptionV3 with the pretrained ImageNet weights. To prevent overfitting, a Global Average Pooling layer was added as part of the input shape, the latter having been provided as (Image_Size, Image_Size, Channels).

In the case of multi-class classification, two dense fully connected layers applied were 256 neurons and an activation of ReLU, followed by a last softmax-activated layer.

Adam optimizer was employed to build the model, and Sparse Categorical Crossentropy loss to train the model. It was trained on the MRI dataset for 25 epochs, and strong performance was verified with validation data.

Enhanced classification precision with this deployment ensured that InceptionV3 is an apt choice for the detection of Alzheimer's disease from MRI.

VI. RESULTS OBTAINED

The accuracy with which various deep learning models classified MRI scans as Alzheimer and non-Alzheimer was used to determine the accuracy of each model in classifying Alzheimer's disease. InceptionV3 topped other models with a 99.2% accuracy, as illustrated in Table 1 below, indicating the accuracy of each model in percentage.

Algorithm	Accuracy
VGG19	84%
ResNet101	98.23%
EfficientNetB3	93.59%
MobileNetV2	75.09%
IncecptonV3	99.19%
DenseNet121	38.49%

Table 1 Accuracy Comparison in percentage

Comparison of accuracy of all six models is shown in Figure 2. Models such as DenseNet121 were not good with 38.5% accuracy alone, whereas ResNet101 and EfficientNetB3 also performed well with 98.3% and 93.6% accuracy, respectively.

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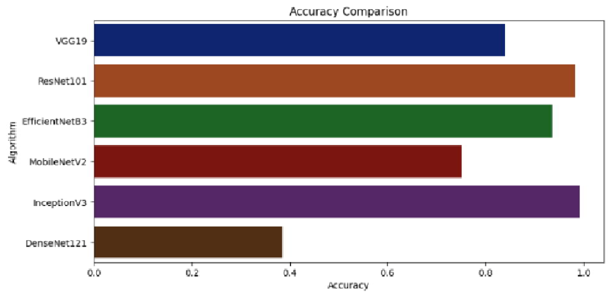

Figure 2 Accuracy Comparison Chart

We have made a classification report (Figure 3) and confusion matrix (Figure 4) to assess the performance of InceptionV3 in a more accurate way. Recall, accuracy, and F1-score of classification report confirm InceptionV3 is highly accurate for all classes, and confusion matrix is responsible for misclassification and low measurement of prediction error. Figure 5 and Figure 6 show training InceptionV3, a plot of accuracy and loss versus 25 epochs. The model converged to stability where training accuracy and validation always increase while the loss reduced.

	precision	recall	f1-score	support
Alzheimer	0.9920	0.9920	0.9920	500
Normal	0.9920	0.9920	0.9920	500
accuracy			0.9920	1000
macro avg	0.9920	0.9920	0.9920	1000
weighted avg	0.9920	0.9920	0.9920	1000

Figure 3 Classification Report

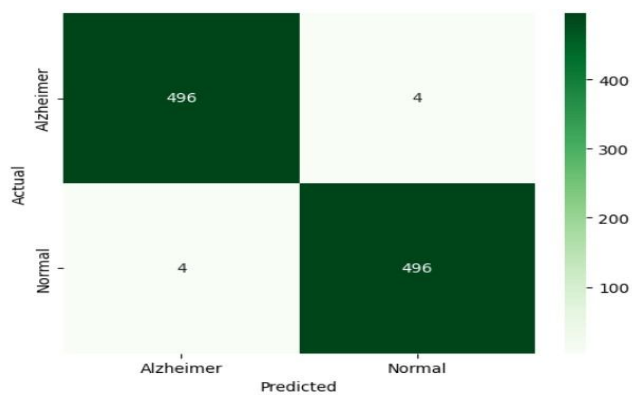

Figure 4 Confusion Matrix

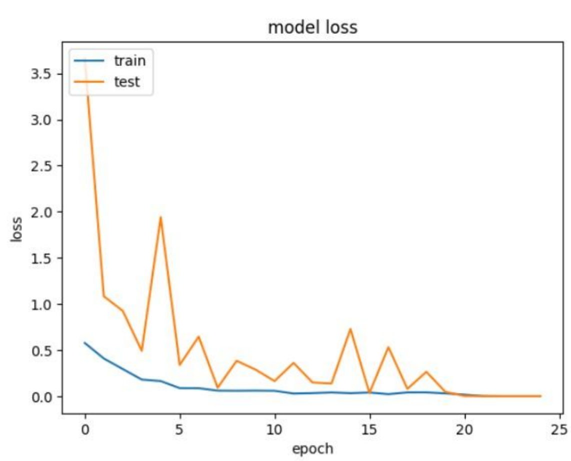

Figure 5 Model loss graph

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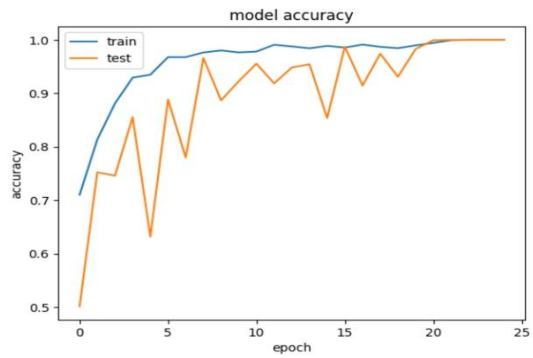

Figure 6 Model accuracy graph

The following paper proves InceptionV3 to be the highest performing deep model for diagnosing Alzheimer's, a strong AI-driven diagnostic tool of medical images. The app also provided an on-the-go web-based software tool for Alzheimer's and MRI scan diagnosis to be uploaded for the purpose of classification. The prediction page and the results page have been shown as Figures 7 and 8, and hence the use case of the app. The web application is also on hand via convenience through simplicity in use by medical practitioners, facilitating prompt diagnosis and decision.

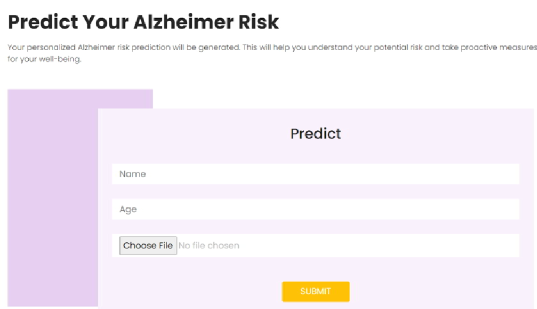

Figure 7 Web app predict page

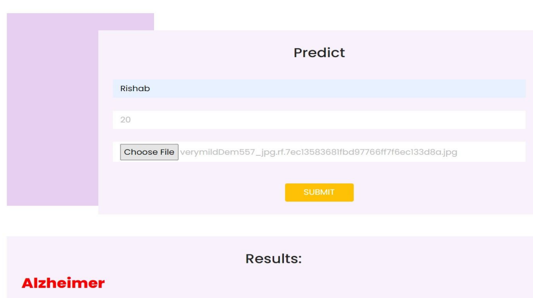

Figure 8 Result page

VII. CONCLUSION

We learned how to use deep learning to forecast Alzheimer's disease from MRI scans in this article. We compared six pre-trained Convolutional Neural Network (CNN) models—VGG19, ResNet101, EfficientNetB3, MobileNetV2, InceptionV3, and DenseNet121—to find out how much classification ability they have. Models were able to learn the disease patterns due to the dataset, which was gathered from Kaggle and contained MRI images that were Alzheimer's and non-Alzheimer. According to our findings, InceptionV3 was the highest-scoring model with a peak accuracy of 99.2 % for the detection of Alzheimer's disease, with DenseNet121 performing the lowest at 38.5%, accepting how inefficient it was for this instance, with others like ResNet101 (98.3%) and EfficientNetB3 (93.6%) also doing well. Some of the performance metrics that ensured the credibility of the top-scoring model included confusion matrix, accuracy plot, loss plot, and classification report.

We created an online platform for real-time Alzheimer's diagnosis to make it available, where the patient can submit MRI scans to be diagnosed in real-time.

Medical practitioners can use this application to assist in the detection of early, which will result in early interventions and better patient outcomes. Additional expansion of the dataset with more sophisticated deep learning models and investigation of explainable AI methods to increase interpretability are all promising directions for future studies. Using AI methods, our study demonstrates the potential of deep learning in medical imaging and its ability to improve the detection of Alzheimer's disease.

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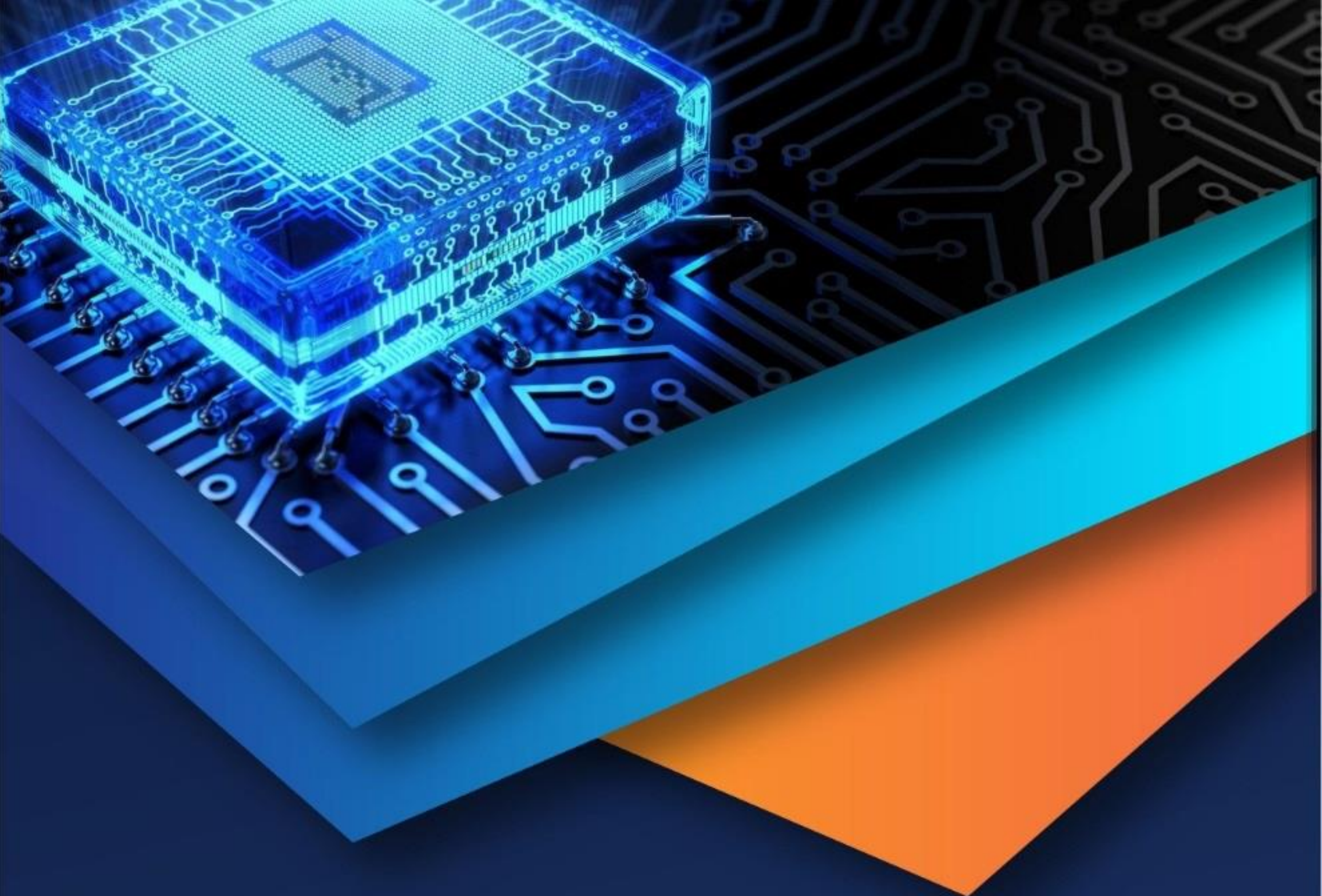

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