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Detecting Alzheimer's Disease Using Brain MRI

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Abstract:- A neurological condition called Alzheimer's disease causes the death of brain cells. Dementia, which is characterised by a loss of analytical skills and the ability to carry out daily duties independently, is most frequently caused by this. People of all ages are susceptible to the dementia known as Alzheimer's disease (AD). Recently, these indicators have been quickly incorporated into the signs and symptoms of Alzheimer's disease (AD) using classification frameworks that provide diagnostic tools. This study conducts a thorough review of published studies on Alzheimer's disease with a focus on computer-aided diagnosis techniques such as magnetic resonance imaging (MRI), computerised tomography (CT) scans, imaging with diffusion tensors, and PET scans (positron emission tomography). This article reviews some of the most recent research on Alzheimer's disease and discusses how machine learning (ML), deep learning (DL), and other brain imaging techniques can help with an earlier identification of theAt the conclusion of this research, a CNN model that incorporates Densenet 169, EfficientNet, and VGG-16 has been created to identify Alzheimer's disease using Magnetic Resonance Imaging (MRI) data. The Kaggle Alzheimer's dataset is used in experiments, and the results demonstrate that the suggested models had excellent accuracy.

Keywords:- *Neurogenerative illness, Dementia, Alzhiemer's detection, Deep Learning, and Machine Learning.*

I. INTRODUCTION

Alzheimer's disease is a congenital, immutable condition of brain that impairs one's ability to do basic tasks as well as memory and cognition. It can causes a large number of neurons to stop firing and synaptic connections to be broken. Alzheimer's disease is less common in those between the ages of 30 and 60. Sleep difficulties, anxiety, and difficulty performing fundamental functions such as reading and writing, as well as aggressive behaviour and poor decision-making, are all indications of Alzheimer's disease. An early brain abnormalities develop 10–20 years before symptoms appear. Over time, it reduces cognitive ability and induces memory loss.

The most frequent cause of this condition is dementia. According to a poll, dementia affects 50 million people worldwide, with the figure likely to reach 13.8 million by 2060. Dementia affectsapproximately 65 percent of people in low-income countries according to World Health Organisation.

There are two types of Mild cognitive impairment one is progressive MCI and other is stable MCI, where the former will eventually advance into Alzheimer's disease within 36 months and the latter is in a reasonably stable state without lesions. Although there is no treatment for the disease, there are some guidelines that can be followed to assist halt its growth. Therefore, a correct diagnosis will be crucial to enhancing the victim's quality of life.

The Alzheimer's disease symptoms include: inability to recall recent events or conversations, lack of interest, depression, poor judgement, unanswerable, confusion, behavioural changes in advanced stages of the disease.

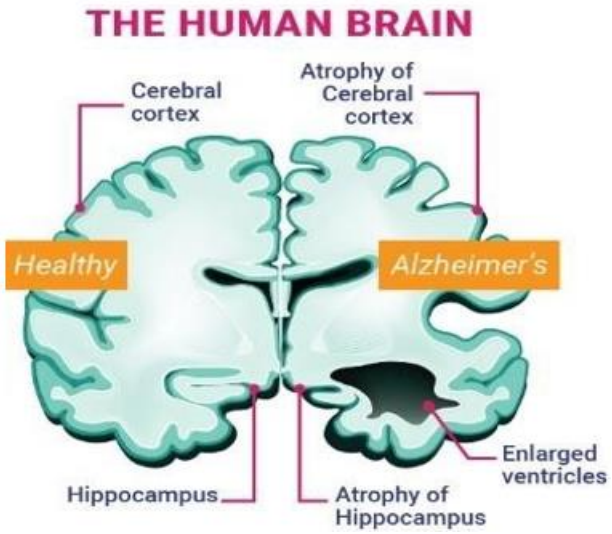

Fig 1: The progression of AD from MCI to severe AD
[image source: https://en.wikipedia.org/wiki/Alzheimer%27s_disease]

A patient suspected of having Alzheimer's disease should undergo many examinations, including a neurological examination, magnetic resonance imaging (MRI) testing, and a review of the patient's medical and family history.

In order to ascertain whether a patient with memory or cognitive issues has Alzheimer's disease, doctors use a number of tests and technology. In order to diagnose Alzheimer's disease, doctors may interrogate the patient about their overall health, medication use, diet, prior medical issues, and ability to perform daily duties. It is recommended to perform a brain scan using a computed tomography, magnetic resonance imaging, or positron emission tomography machine. Similar tests may be administered again in the future by medical professionals to evaluate how the memory and other cognitive abilities have evolved of a patient. Other possible causes of memory loss. Some of these conditions can be treated and even reversed. Every six to twelve months, people with memory issues should see a doctor. The only way to detect if someone had Alzheimer's disease before the early 2000s was to do an autopsy, which is a post-mortem operation.

The following is how this paper is organised: The introduction, background, and stages of Alzheimer's disease are covered in Section I. The relevant research and assessment in the field are covered in Section II, and the various techniques for diagnosing and classifying Alzheimer's disease are also covered in this section. In Section III, the datasets used to identify Alzheimer's disease are described. Section IV discusses methodology and V discusses methodology. In Section VI, future aspects and conclusions are reached.

II. RELATED WORK

A number of studies have recently used imaging data to aid in the development of medicines that target the underlying brain alterations at each stage. The Alzheimer's disease neuroimaging initiative is a data resource that provides researchers with datasets such as MRI, DTI, CT and PET pictures. MRI is a technique for imaging the anatomy of the brain, and it is one of several picture data formats. MRI can be used to diagnose atrophy by measuring the amount of grey and white matter in the brain.

A. Some brain imaging techniques for Alzheimer's Disease are as follows :-

➢ *Computerized Tomography (CT) Scan*

According to the findings, the characteristics-based categorization criterion provides promising results in terms of detecting the condition and assisting clinical development. It's probable that Alzheimer's patients' cerebral atrophy is caused by disease processes rather than the brain's natural ageing process. As the condition worsens, the degree of atrophy also gets worse. In this clinical stage, the cortical atrophy is already apparent. Later on, however, the ventricular dilatation becomes more apparent.

➢ *Positron Emission Tomography (PET)*

PET scanning is a way of producing a 3D brain image at the anatomical and sub anatomical levels using a volumetric subatomic illustration method. During PET scanning, a radioactive isotope that is administered or breathed is referred to as a tracing agent or radiotracer. This serves as the subject's positron-emitting standard. The scanning apparatus then finds the radiotracer. The radiotracer is then distributed throughout the body of the individual in a digital image produced by the scanner (illustration). The kind of radiotracer employed determines the type of the PET scan.PET scanning has become more expensive due to the use of cyclotron agents, which are required in the manufacturing of radiotracers. It can beargued from the fact that brain function is dependent on blood sugar consumption. The PET scan has a unique potential to predict Alzheimer's disease even with modest symptoms. PET scanning is a veryeffective diagnostic tool, but it is not a healthy diagnostic technique for the reasons described above.

➢ *Magnetic Resonance Imaging (MRI)*

MRI is the main method used by humans to examine brain tissues (MRI). It is helpful in the Alzheimer's disease detection and has the capacity to accurately depict the inner workings of the brain. The diagnosis of diseases using MRI data is a frequent practice. During the MRI procedure, the area that needs to be imaged is assaulted with magnetic radiation.

Author	Methodology	Dataset	Images	Accuracy
"F. Nazir et al."[31]	TransferLearning	OASIS	MRI	92.85%
"Y. Shen, et al." [32]	Transfer Learning	OASIS	MRI	90.6%
"D. Shen et al." [33]	Multi-DomainTransfer Learning	ADNI	MRI	94.7%
"L. Guibas et al."[34]	ImageNetTransfer Learning	ADNI	MRI	83.5%
"F. Nazir et al." [35]	TransferLearning	OASIS	MRI	98.41%
"S. Wang et al."[36]	SVM	OASIS	MRI	80%
"J. Ramirez etal."[37]	SVM	PET	MRI	96%
"N. Kodikara etal."[38]	CNN	ADNI	MRI	96%
"Cui et al."[39]	RNN	ADNI	MRI	89.7%
"Liu et al."[42]	3D CNN	ADNI	MRI, PET	91.40%
"Nawaz etal."[43]	Alexnet	OASIS	MRI	92.85%

Table 1: Comparison of different brain imaging techniques used for AD's detection

B. To detect Alzheimer's disease, various Machine Learning and Deep Learning techniques are employed.

The research indicates that the characteristics-based categorization criterion offers promising results for diagnosing the illness and improving therapeutic care. Deep learning, Bayesian, K-Nearest Neighbor, and Support Vector Machine are the classifiers that are most frequently used to diagnose AD.

The author used support vector machines in [1] to draw out the most significant high-level features from MRI scans and pinpoint the different stages of Alzheimer's disease.

The authors of [3-5] combined the prediction algorithms Random Forest, k-Means and Region Growing. The k-Means algorithm was used to cluster the MRI images. Using the region Growing approach, the white and grey matter were separated from the clustered pictures. The condition was categorised as having neuro-anatomical constraints or not using the data collected and the Random Forest approach.

In order to overcome the constraints of the machine learning approach, the author of article [6] developed a deep learning method for recognising AD that uses a softmax output layer and stacked auto-encoder. The suggested

approach successfully distinguished Alzheimer's disease from mild cognitive impairment and other types of dementia.

During research phase of this study, a literature review was conducted using reputable publications from portals such as Springer, Elsevier, IEEE, MDPI, and others. From a pool of roughly 40 papers published in the recent five years, 16 have been picked for their relevance, quality, and easy of comprehension in our chosen field. The table below contains a list of them.

S No.	Author	Approach
1	" Islam et al" [16]	Create a trio of slightly different deep convolutional neural network setups as an ensemble.
2	"R. Cui etal" [20]	By stacking the input block, Conv block, fully connected block, and Softmax layer, the 3D deep CNN is created.
3	"L.V.Fulton et al" [17]	Keras is used for creating models and uses ResNet with50 layers.
4	"Latha R Set al" [22]	With the use of CNN and the VGG16 model, six alternative categorization models are applied for the various stages of AD.
5	"Atif Mehmood et al" [11]	CNN based approach is used which is inspired by VGG-16.In the VGG-16 model insert one extra convo layer and check its effectiveness
6	"M.Dua et al"[18]	Uses the ensemble learningmodel by combing the algorithms like CNN-RNN-LSTM .
7	"Katzourou, I. Ket al" [45]	A systematic approach (PRISMA) is used, Twelve studies were found to meet the requirements for inclusion.
8	"M. Tanveer et al"[3]	The main machine learning techniques they employed were support vector machine, artificial neural network, deep learning, and ensemble methods.
9	"T.Jo et al" [28]	Without pre-processing for feature selection, deep learning algorithms like CNN and RNN are employed with neuroimaging data.
10	"S. Sarraf et al" [26]	The researchers used fMRI and MRI pipelines, as well asa decision-making algorithms.
11	"Khan A et al"[48]	The model starts with a pre-processing stage and then moves on to imperative attributes. Association rule mining is used to achieve selection and categorization.
12	"Oscar Darias Plasencia al" [51]	The state of the art of medicalimage analysis and AD with AI, until early 2019, has been analyzed and summarized.
13	"Crous-Bou et al" [50]	They discuss the emergence of public–private partnershipsfor disease prevention after summarising the information on several AD risk variables.
14	M.Maqsoo et al"[31]	By optimising a pre-trained convolutional network using an efficient transfer learning method, the proposed system recognises the images. AlexNet.
15	"S. Afzal et al"[35]	They use the OASIS dataset and a transfer learning method with the help of data augmentation for 3D magnetic resonance imaging views.
16	"Y. Zhang et al"[36]	Atlas-registered normalisation was used as a preprocessing step on three dimensional MRI images.

Table 2: Comparison of several Machine Learning and Deep Learning methods for Alzheimer's disease detection

III. DATASET DESCRIPTION

Online datasets are available for free. For research on Alzheimer's disease, ADNI and OASIS datasets are incredibly helpful. These datasets produce appealing, freely usable reverberation images of the brain. This study looked into using deep learning to detect Alzheimer's illness using the Alzheimer's dataset, which consists of four classes of photographs. Two files, Training and Testing, make up the dataset, with a combined total of about 5000 photos in each file, each categorised according to the degree of Alzheimer's. The dataset includes MRI pictures in the following four categories: mildly, very mildly, not at all, and moderately demented.

IV. METHODOLOGY

The dataset used in this test was obtained from kaggle. The dataset contains about 5000 images consisting of four classes (Moderate Demented, Mild Demented, Very Mild Demented, and Nondemented or normal). However, the data is very unbalanced.Therefore, there needs to be augmentation for classes where there is still little data.

In general, the pipeline in this test can be seen in Figure 2. Initially, there was loading and re-dividing the dataset. The dataset is divided into "train", "val", and "test" with ratio of 70:15:15. After that, there is a process of augmentation of data to balance the dataset. Then, there is an importation of the model from tensorflow as well as the addition of layers and optimizers. We've tested some additional layer combinations so that the layers used in the final result are already quite good. After that, the data that has been processed earlier goes to the training. The output of this training is the data and plot of the training history as well as the final model obtained. Next, there is an evaluation whose output is the matrix.

The discussion here includes things that were done during testing. In testing, the initial step is of course to enter the data. Next, several functions from various modules are imported, mainly from tensorflow modules.

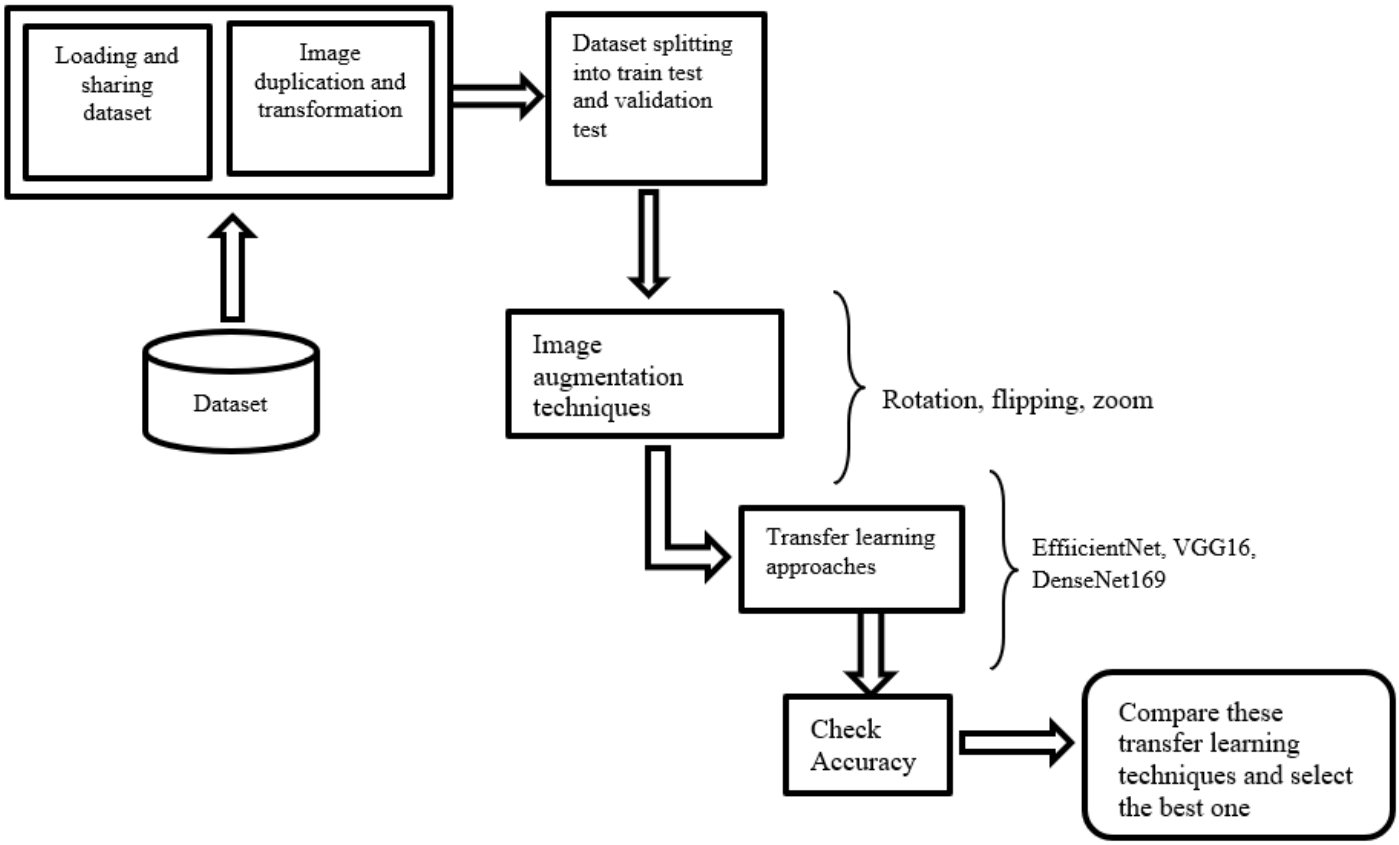

Fig:2 Proposed methodology for Alzheimer's Detection

After those various initializations, there is a preliminary definition. This includes defining the values of important parameters used in the test, such as data split ratios, parameters for Image transformation, the number of epochs and batch sizes, and parameters for the optimizer.

The defined functions are functions for plot training history and storing its data, functions for model evaluation, as well as functions for creating matrices and storing them. Then, a random re-division of the dataset is carried out using a specific function. In addition, there is a process of duplicating image files so that many of the files reach a certain number. The existing image files are duplicated in order until they can be sufficient. If it is not enough, then the process is repeated from scratch. This duplication process is only done for "training" data that requires class balance. These splits and duplications are done before Image Transformation. If the data is transformed first and then shared, there will be a very similar image in the train and test data so that the testing is unfair.

The next step is Image Loading and Transformation. Initially, there was a definition for load and transform images via Image Data Generator. The image goes into the generator to be randomly transformed so that there is no longer an exact duplicated image. That way, the class can be more balanced with data that remains diverse. The next part is testing with Densenet169, EfficientNet and VGG16 models. Previously, it was necessary to import the initial model from tensorflow. Imported models already have pretrained weights for image processing. Next, there is the addition of several layers. The activation function used is relu. What layers need to be added are the result of several tests and literature reviews.

V. RESULT AND ANALYSIS

The transfer learning method produces the most accurate results, but it necessitates a substantial amount of labelled data and demanding computer capabilities. Deep network models that have already been trained and validated for transfer learning include Densenet, VGG, and EfficientNet. The main crux of different model is summarized below.

ModelName	Train_Acc	Precision	Recall	Auc
DenseNet	0.9840	0.9739	0.9619	0.9982
EfficientNet	0.7401	0.4616	0.2373	0.7527
VGG16	0.9694	0.9450	0.9320	0.9951

Table 3: Final result of all three models

The table above provides some conclusions. that the best classification accuracy was received by Desnset169 having categorical accuracy of 98% followed by VGG 16 with a categorical accuracy of 96 % and EfficientNet model accuracy of 74% .

➢ *Confusion Matrix*

The previous result are actually enough to show the performance of the model. However, to better understand how the model deals with existing data, a confusion matrix can be used. The matrix for all three models can be seen in Figure 3

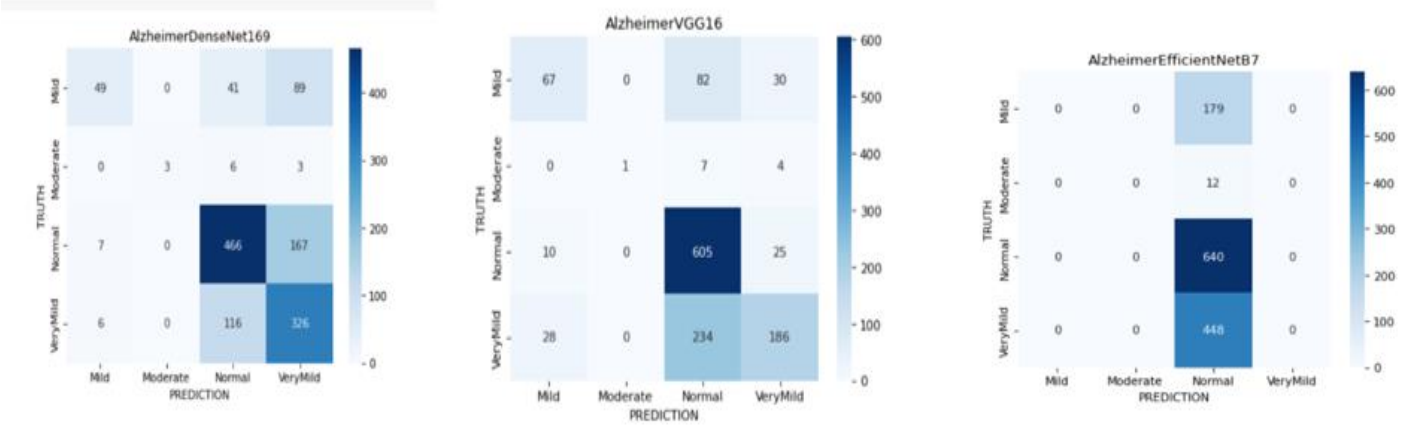

Fig 3: Confusion matrix of all models used

This matrix demonstrates how the model categorises already-existing data before comparing it to the label. The better the model, the higher the diagonal part's value in relation to the other components. This is so because the diagonal portion displays the situation at the time the prediction and actuality match.

VI. FUTURE ASPECT AND CONCLUSION

To properly treat Alzheimer's disease, early detection is essential. Because the number of cases of Alzheimer's disease is rising at an alarming rate, advanced technology is needed to treat the disease. Many biomarker, proteome, and genomic studies have been conducted in recent years and will continue to be conducted in the future. Despite these research, there remain a number of challenges to overcome. To battle the disease, technology alone will not suffice, standardisation of procedures and approaches is essential for maintaining consistency and reaching a high level of reliability. In this study, we discussed Alzhiemer's disease, its stages in detail. This study focuses on brain imaging approaches for alzheimer's illness, Machine Learning, and Deep Learning methods for alzheimer's detection. When it comes to classification and detection approaches, CNN is the most commonly utilised models in this area. For testing our proposed method, we have explored the Alzheimer's Dataset freely available on Kaggle. Exploratory data analysis has been performed on it. A comparative study has been done using Transfer Learning models. The best classification accuracy was achieved by DenseNet169 when compared with other transfer learning models (EfficientNet, VGG16).

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