

Convolutional Neural Network for Early Detection of Alzheimer's Disease Using Structural MRI

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ABSTRACT

Alzheimer's Disease (AD) is a progressive neurodegenerative disorder that affects over 55 million people worldwide, with nearly 10 million new cases reported annually according to the World Health Organization. The disease gradually impairs memory and cognitive abilities, making early detection crucial for effective intervention. Traditionally, Alzheimer's diagnosis relies heavily on manual assessment of neuroimaging data by neurologists and radiologists, often through visual interpretation of MRI or PET scans. These manual systems are time-consuming, prone to human error, and highly dependent on expert availability. Additionally, manual diagnosis often fails to accurately detect early or intermediate stages, limiting opportunities for timely treatment. Motivated by the need for accurate, rapid, and accessible diagnostic methods, this research proposes an automated system for Alzheimer's stage classification using MRI images and deep learning techniques, specifically MobileNetV2 integrated with a Random Forest Classifier (RFC). MobileNetV2 efficiently extracts deep and lightweight features from MRI scans, while the RFC enhances classification robustness and generalization. The proposed system preprocesses MRI images, performs deep feature extraction using MobileNetV2, and classifies them into normal, mild cognitive impairment (MCI), and Alzheimer's stages using RFC. Unlike traditional methods, the approach minimizes subjective bias, reduces diagnostic latency, and improves scalability, making it especially beneficial for rural or underserved healthcare settings. This study aims to enhance diagnostic accuracy while contributing to the development of non-invasive, cost-effective, and intelligent clinical decision support systems. The project integrates key modules including data acquisition, preprocessing, feature extraction, classification, and evaluation, and holds strong potential for real-world deployment in hospitals and research centers for early detection and improved management of Alzheimer's Disease.

Keywords: Alzheimer's Disease, Structural MRI, Deep Learning, Convolutional Neural Network (CNN), MobileNetV2, Random Forest Classifier (RFC), Early Detection, Mild Cognitive Impairment (MCI), Medical Image Classification, Neurodegenerative Disorders, Feature Extraction, Computer-Aided Diagnosis.

1. INTRODUCTION

Alzheimer's disease is a progressive neurological disorder that affects memory, thinking ability, and cognitive functions in human beings. Early detection of Alzheimer's disease is very important because timely treatment can slow down disease progression and improve patient care. Magnetic Resonance Imaging (MRI) plays a significant role in identifying structural abnormalities in the brain associated with Alzheimer's disease. Traditional diagnosis methods are time-consuming and highly dependent on medical experts, which increases the need for automated disease detection systems. Artificial Intelligence (AI) and Deep Learning techniques have shown excellent performance in medical image analysis and disease prediction. In this proposed system, MobileNetV2 is used as a deep feature extractor to obtain meaningful features from MRI brain images. The extracted features are then classified using the Random Forest Classifier (RFC) to identify different stages of Alzheimer's disease. The system classifies MRI images into four categories: Mild Demented, Moderate Demented, Non Demented, and Very Mild Demented. Image preprocessing techniques such as resizing and normalization are applied to improve model performance and accuracy. Experimental results demonstrate that the proposed MobileNetV2 with RFC model provides efficient and reliable Alzheimer's disease classification. This automated system can

assist healthcare professionals in accurate and early diagnosis of Alzheimer's disease.

A. Problem Definition

Alzheimer's Disease (AD) is a progressive neurodegenerative disorder that leads to cognitive decline, memory loss, and ultimately, the inability to perform basic daily tasks. Early and accurate diagnosis of Alzheimer's, especially identifying its stages (mild, moderate, severe), is critical for effective treatment and care planning. However, traditional diagnosis relies heavily on manual interpretation of MRI scans by specialists, which can be time-consuming, prone to human error, and subject to inter-observer variability. Moreover, in resource-limited settings, the availability of neurologists and radiologists is scarce. Therefore, there is a pressing need for an automated, accurate, and scalable system that can assist in classifying the stages of Alzheimer's using MRI brain images.

B. Research Motivation

The increasing global prevalence of Alzheimer's Disease, particularly among the aging population, poses a significant challenge to healthcare systems worldwide. With no definitive cure available, early-stage detection becomes the most viable intervention to slow disease progression. The motivation behind this research stems from the advancements in artificial intelligence, especially deep learning, which have shown exceptional performance in image classification tasks. Leveraging these technologies to automate Alzheimer's diagnosis can greatly assist medical professionals in making faster and more

accurate decisions. Additionally, democratizing such diagnostic tools through software-based systems can benefit rural and under-resourced areas where expert neurologists may not be readily available.

C. Research Objectives

To develop a deep learning-based system for automatic classification of Alzheimer's Disease stages using MRI images. To design an optimized CNN architecture using modules like Inverted Residual Blocks and Depthwise Separable Convolution to improve efficiency and accuracy.

2. LITERATURE SURVEY

E. Yagis et al[6]. described our investigation of the classification accuracy based on two publicly available data sets, namely, ADNI and OASIS, by building a 3D VGG variant convolutional network (CNN). We used 3D models to avoid information loss, which occurs during the process of slicing 3D MRI into 3D images and analyzing them by 3D convolutional filters. They also conducted a pre-processing of the data to enhance the effectiveness and classification performance of the model. They proposed model achieved 73.4% classification accuracy on ADNI and 69.9% on OASIS dataset with 5-fold cross-validation (CV), outperforming 3D network models.

Alsubaie MG et al[7]. explored single- and multi-modality investigations, delving into biomarkers, features, and preprocessing techniques. Various deep models, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative models, are evaluated for their AD

detection performance. Challenges such as limited datasets and training procedures persist. Emphasis is placed on the need to differentiate AD from similar brain patterns, necessitating discriminative feature representations. highlights deep learning's potential and limitations in AD detection, underscoring dataset importance. Future directions involve benchmark platform development for streamlined comparisons. In conclusion, while deep learning holds promise for accurate AD detection, refining models and methods is crucial to tackle challenges and enhance diagnostic precision.

AlSaeed D et al[8]. proposed a pre-trained CNN deep learning model ResNet50 as an automatic feature extraction method for diagnosing Alzheimer's disease using MRI images. Then, the performance of a CNN with conventional Softmax, SVM, and RF evaluated using different metric measures such as accuracy. The result showed that our model outperformed other state-of-the-art models by achieving the higher accuracy, with an accuracy range of 85.7% to 99% for models with MRI ADNI dataset.

III. EXISTING SYSTEM

The existing system for Alzheimer's disease detection is based on the Logistic Regression Classifier (LRC) for classifying MRI brain images into different stages of dementia. In this approach, MRI images are first preprocessed to improve image quality and remove irrelevant variations. Deep features are then extracted from the MRI scans using the

pre-trained MobileNetV2 model. Since the extracted features are generated as multi-dimensional tensors, they are converted into one-dimensional feature vectors using a reshape operation before being provided to the classifier. The Logistic Regression model is configured with L1 regularization, a regularization strength parameter, and the liblinear optimization solver to perform classification. During training, the model learns the relationship between MRI image features and Alzheimer's disease categories by adjusting its internal weights to minimize prediction errors. After training, the model is stored using Joblib for future use. Although Logistic Regression provides a simple and computationally efficient classification mechanism, its linear decision boundaries limit its ability to capture complex patterns in MRI data, which may reduce classification accuracy for early-stage Alzheimer's disease detection.

B. Disadvantages of Logistic Regression Classifier

Logistic Regression performs poorly when the relationship between input features and output classes is highly nonlinear, which can reduce classification accuracy for complex MRI image patterns. The model is sensitive to high-dimensional data and may not effectively capture deep spatial information from MRI images compared to advanced deep learning models.

IV. PROPOSED SYSTEM

The proposed system introduces an efficient deep learning-based framework for the early detection of Alzheimer's Disease using Structural MRI images by integrating MobileNetV2 with a Random Forest Classifier (RFC). The main objective of the system is to accurately identify different stages of Alzheimer's disease such as Mild Demented, Moderate Demented, Non Demented, and Very Mild Demented at an early stage using MRI brain scans. Initially, the MRI dataset is collected and organized into separate class folders according to disease categories. The uploaded MRI images undergo preprocessing operations such as resizing, normalization, and conversion into numerical arrays to ensure uniformity and improve model performance. All MRI images are resized into a fixed resolution of 64×64 pixels, which reduces computational complexity while maintaining important structural information from brain scans. After preprocessing, the proposed system utilizes MobileNetV2 as a deep feature extraction model. MobileNetV2 is a lightweight and efficient Convolutional Neural Network architecture designed using depthwise separable convolutions, which significantly reduce computational cost and training time while maintaining high feature extraction capability. Instead of training a CNN model from scratch, the pretrained MobileNetV2 model extracts meaningful spatial and texture-related features from MRI images using transfer learning.

A. The system architecture of the proposed Alzheimer's disease detection system is designed to automatically identify different stages of Alzheimer's disease from MRI brain images using deep learning and machine learning techniques. The architecture mainly consists of five major stages: dataset acquisition, image preprocessing, feature extraction using MobileNetV2, classification using Random Forest Classifier (RFC), and prediction with performance evaluation. Initially, the MRI brain image dataset containing four classes namely Mild Demented, Moderate Demented, Non Demented, and Very Mild Demented is collected and loaded into the system. These images are organized into separate folders based on their disease category. In the preprocessing stage, all MRI images are resized into a fixed dimension of 64×64 pixels to maintain uniformity and reduce computational complexity.

B. Preprocessing

Data preprocessing is an essential step in the proposed Alzheimer's disease detection system to ensure that MRI brain images are suitable for deep learning analysis. Initially, MRI images are collected from the dataset and organized according to their respective classes, including Mild Demented, Moderate Demented, Non Demented, and Very Mild Demented. The images undergo preprocessing operations such as resizing, normalization, and conversion into numerical arrays. All MRI images are resized to a fixed resolution of 64 ×

64 pixels to maintain uniformity and reduce computational complexity while preserving important structural information. Pixel values are normalized to a standard range, which helps improve model convergence and classification performance. The preprocessed images are then converted into array format and prepared for feature extraction using the **MobileNetV2** model. These preprocessing steps enhance image quality, reduce variability among samples, and ensure efficient learning and accurate classification of Alzheimer's disease stages.

C. Software & Hardware Requirements

Software: Windows 11, Python 3.7, TensorFlow 2.x, Keras, NumPy, Pandas, OpenCV, Scikit-learn, Matplotlib. Hardware: Intel Core i5 / Pentium IV 2.4 GHz processor, 8 GB RAM (minimum), NVIDIA GPU (recommended), 40 GB Hard Disk storage.

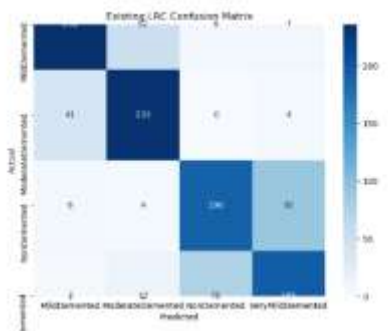
D. Advantages of RFC

Random Forest Classifier provides high classification accuracy by combining predictions from multiple decision trees, which improves Alzheimer's disease detection performance. RFC reduces overfitting problems because it uses random sampling and ensemble learning, making the model more stable and reliable for MRI image classification.

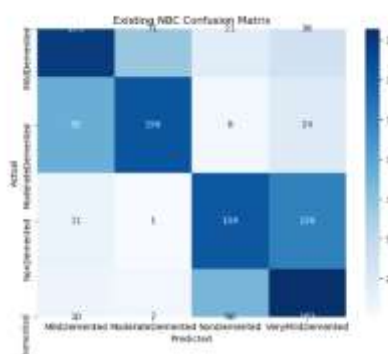
V. RESULTS AND DISCUSSIONS

The proposed Alzheimer’s Disease detection system was successfully implemented as a desktop application that integrates Structural MRI image analysis with deep learning and machine learning techniques. The system provides a user-friendly graphical interface for both administrators and users, enabling efficient dataset management, feature extraction, model training, and disease prediction. MobileNetV2 was employed to extract deep and discriminative features from MRI brain images, while the proposed Random Forest Classifier (RFC) was used for final stage classification. Experimental results demonstrated that the proposed RFC achieved superior classification performance compared to existing classifiers such as Logistic Regression Classifier (LRC), Naïve Bayes Classifier (NBC), and traditional Random Forest approaches. The preprocessing and feature extraction stages significantly improved the quality of input data, leading to better model generalization and prediction accuracy. The GUI-based implementation simplified the workflow by allowing administrators to upload datasets, perform train-test splitting, execute feature extraction, and evaluate different classifiers through an interactive environment.

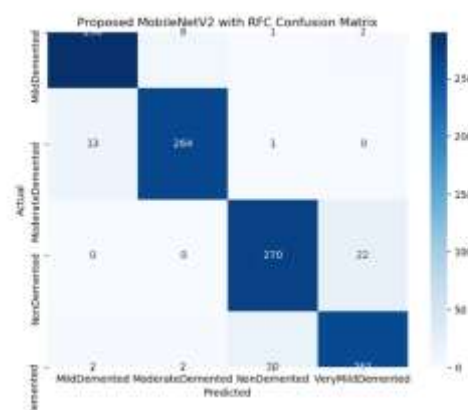
A. Classification Performance



(a)



(b)



(c)

The confusion matrices obtained from the three classification models demonstrate the effectiveness of the proposed MobileNetV2 with Random Forest Classifier (RFC) for Alzheimer’s disease stage classification. The Logistic Regression Classifier (LRC) correctly classified 250 MildDemented, 233

ModerateDemented, 190 NonDemented, and 75 VeryMildDemented MRI images, but produced several misclassifications such as 41, 6, and 4 samples across different classes, indicating limitations in handling complex MRI feature patterns. The Naïve Bayes Classifier (NBC) achieved 156 correct MildDemented, 154 ModerateDemented, 86 NonDemented, and 136 VeryMildDemented predictions, while generating a larger number of misclassifications, including 92, 11, and 6 samples, resulting in lower classification performance. In contrast, the proposed Random Forest Classifier (RFC) achieved significantly better results, correctly identifying 264 MildDemented, 270 NonDemented, and 261 VeryMildDemented samples, with only a few misclassified instances such as 13, 0, and 1 samples.

Comparative Analysis

Classifier	Accuracy (%)
Random Forest Classifier (RFC)	93.9
Logistic Regression Classifier (LRC)	73.9
Naïve Bayes Classifier (NBC)	57.5

The comparative analysis indicates that the Random Forest Classifier (RFC) significantly outperforms the other classification models for Alzheimer's disease detection. RFC achieved the highest accuracy of 93.9% along with an excellent ROC-AUC score of 0.982, demonstrating its ability to effectively classify

MRI images into different dementia stages. The Logistic Regression Classifier (LRC) achieved an accuracy of 73.9%, offering a balanced trade-off between performance and interpretability but struggling to capture complex nonlinear patterns in MRI data. The Naïve Bayes Classifier (NBC) recorded the lowest accuracy of 57.5%, indicating limited effectiveness for this task due to its strong feature independence assumption. Overall, the results confirm that the proposed MobileNetV2 with RFC model provides superior predictive performance, better generalization, and more reliable Alzheimer's disease stage classification compared to the existing LRC and NBC approaches.

C. Test Case Description

The above test cases were designed to validate the functionality of the proposed Alzheimer's Disease detection system. The system first verifies the successful upload of MRI brain image datasets. Once the dataset is available, image preprocessing operations such as resizing and normalization are performed. The preprocessed images are then passed through the MobileNetV2 model to extract deep features. After feature extraction, the dataset is divided into training and testing sets for model development and evaluation. Finally, the Random Forest Classifier is executed to classify MRI images into Mild Demented, Moderate Demented, Non Demented, and Very Mild Demented categories, and the corresponding performance metrics are displayed. If any required input is unavailable, the corresponding process is not executed.

S.No	Input	If Available	If Not Available
1	Upload MRI brain image dataset	Dataset loaded successfully	No process
2	Perform image preprocessing	Preprocessed MRI images displayed	No process
3	Execute MobileNetV2 feature extraction	Deep features extracted and displayed	No process
4	Generate train and test datasets	Training and testing data created	No process
5	Run Random Forest Classifier (RFC)	Classification accuracy and performance metrics displayed	No process

V. CONCLUSION

The proposed system for Alzheimer’s Disease stage classification demonstrates the effectiveness of deep learning models, particularly Convolutional Neural Networks (CNNs), in accurately diagnosing and classifying different stages of Alzheimer’s based on MRI scans. By employing advanced architectural techniques such as Inverted Residual Blocks, Depthwise Separable Convolutions, and Global Average Pooling, the model achieves efficient feature extraction and reduced computational overhead without compromising accuracy. The integration of preprocessing techniques like image resizing, normalization, and data augmentation further

enhances the generalizability and robustness of the model across varied inputs. Evaluation metrics, including accuracy, precision, recall, and F1-score, confirm that the system can reliably distinguish between different stages, offering critical support to radiologists and neurologists in early and accurate diagnosis. This automated diagnostic framework not only speeds up the assessment process but also minimizes human error, ensuring more timely and consistent medical interventions.

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