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Neuro-CogniGuard: A Deep Learning Approach for Early Alzheimer's Detection

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Abstract
Alzheimer's disease (AD) is a neurodegenerative disorder characterized by progressive cognitive decline and memory impairment. This disease causes the person to suffer from memory loss, unusual behaviour, and language problems. Initial symptoms such as episodic memory impairment and patient navigation problems are typical variants. In this project, we propose a deep learning method for early and accurate detection of AD using MRI images. In the existing system, they used deep learning models such as Convolutional Neural Networks (CNN) and LeNet5 architecture to detect the disease. In the proposed system, we use The Deep Learning Model as the cellular network architecture and classify images as mild dementia, moderate dementia, non-demented, or very mild dementia. In this study, we use the ADNI dataset. Using these algorithms can achieve better accuracy for CNN and Mobile Net compared to the existing system. This can be used in the future to classify the types of different classifications that can be easily detected in the initial stages and can only be cured in the initial stages.

Keywords: Deep Learning, Convolutional Neural Networks (CNN), Mobile-Net.

1. Introduction

Alzheimer's disease (AD) represents a major global health challenge characterized by its insidious onset, progressive nature, and profound impact on cognitive function and memory. First elucidated by the seminal work of German psychiatrist Alois Alzheimer in 1906, AD predominantly affects older adults, initially showing mild cognitive impairment that escalates over time. As the disease progresses, individuals experience severe problems with memory retention, problem-solving, decision-making, and language skills, ultimately leading to a profound decline in quality of life. The urgency of early detection and intervention in AD cannot be overstated. Early diagnosis facilitates rapid access to treatment and support services, enabling individuals and their families to better manage disease progression and optimize patient outcomes. However, traditional diagnostic methods often rely on clinical assessment and cognitive tests, which can be subjective and prone to variability. In recent years, advances in medical imaging and machine learning have revolutionized AD diagnostics, offering new approaches to detect subtle brain abnormalities indicative of the disease.

Deep learning, a subfield of machine learning, has proven to be a powerful tool for analyzing medical imaging data and extracting meaningful insights. Convolutional neural networks (CNNs) have shown remarkable effectiveness in identifying patterns and features in MRI images that correlate with AD pathology. Using these advanced computing techniques, researchers have sought to develop automated systems capable of accurately classifying AD severity and predicting disease progression.

We present a comprehensive review of the current state of the art in deep learning-based approaches to AD detection and classification. We highlight recent advances in CNN architecture, including the use of lightweight models such as Mobile-Net, which offer increased computational efficiency without compromising accuracy. In addition, we discuss the critical role of large-scale datasets such as the Alzheimer's Disease Neuroimaging Initiative (ADNI) in training and validating deep learning models for AD diagnosis.

Our study aims to contribute to ongoing efforts to improve the early detection and classification of AD through MRI image analysis. By evaluating the performance of state-of-the-art deep learning models on real-world datasets, we aim to identify the most effective methodologies for accurately stratifying AD severity and predicting disease progression. We further explore the potential implications of our findings for clinical practice, including the development of automated diagnostic tools and personalized treatment strategies.

we strive to advance the field of neuroimaging and contribute to the development of innovative solutions for the early diagnosis and treatment of AD. By harnessing the power of deep learning and medical imaging analytics, we aim to provide healthcare professionals with the tools and insights needed to effectively combat this devastating neurodegenerative disorder.

2. Literature Survey

Alzheimer's disease (AD) detection and classification have been the subject of extensive research, with notable contributions from various studies:

- [SUHAD AL-SHOUKRY et al., 2020] conducted a mini-review on Alzheimer's disease detection using deep learning algorithms. They emphasized the importance of accurate diagnosis, particularly in the early stages of the disease. The review highlighted the role of Deep Learning (DL) in enabling early diagnosis and explored relevant literature in this area.
- [Ruoxuan Cui et al., 2019] Proposed a method for hippocampus analysis in Alzheimer's disease diagnosis. Their approach combines 3-D Dense Net and shape analysis to analyze the hippocampus region, a crucial area affected by AD. The method demonstrated high classification accuracy and outperformed existing techniques.
- [IEEE 15th International Symposium on Biomedical Imaging (ISBI 2018)] The symposium presented an efficient 3D convolutional network (3D Convent) architecture for automatic extraction of features from MRI brain scans and Alzheimer's Disease (AD) diagnosis. The proposed method achieved high performance in AD detection on a relatively large dataset, showcasing its effectiveness in early diagnosis.
- [TIAGO CARNEIRO et al., 2018] evaluated the performance of Google Collaboratory as a tool for accelerating deep learning applications, including those related to AD diagnosis. Their analysis focused on hardware resources, performance, and limitations of Collab, providing insights into its suitability for AD-related research.

3. Methodology

1. **Data Collection and Preprocessing:** To ensure a representative and diverse sample, we obtain MRI images from the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset. To improve the quality

and uniformity of the images, preprocessing techniques like noise reduction, resizing, and normalization are applied.

2. **Model Selection and Architecture:** The Mobile-Net architecture is used because of its effective image classification performance and lightweight design. Mobile-Net is ideally suited for our application since it provides the benefit of quicker inference times without sacrificing accuracy.
3. **Training and Validation:** Using supervised learning, the chosen Mobile-Net model is trained on the preprocessed MRI images. To assess the model's performance and avoid overfitting, we divided the dataset into training and validation sets. Backpropagation is used to optimize the model's parameters during training.
4. **Classification:** Once the model is trained, we perform classification on unseen MRI images to predict the presence and severity of Alzheimer's disease. The model categorizes the images into specific classes, including Mild Demented, Moderate Demented, Non-Demented, or Very Mild Demented based on the patterns and features learned during training like:

- **Brain Atrophy** (loss of brain tissues)
- **Enlarged ventricles** (fluid-filled spaces b/w neurons),
- **Cortical thinning** (causes the thickness of the cerebral cortex),
- **White matter Lesions** (disruption in neural connections) confirms the presence of Alzheimer's disease.

5. **Evaluation:** We use several metrics, including accuracy, precision, recall, and F1 score, to assess how well the trained model performs. Furthermore, we examine confusion matrices to evaluate the model's accuracy in classifying Alzheimer's disease at various stages.
6. **Fine-tuning and Optimization:** We may investigate methods like hyperparameter tuning and transfer learning to further enhance the model's performance. Optimizing techniques help improve the model's robustness and generalization, while fine-tuning enables us to tailor pre-trained models to our dataset.
7. **Deployment and Integration:** After the trained model performs well, we integrate it into an intuitive application or user interface. With the help of this interface, medical professionals can quickly and automatically diagnose patients with MRI images, allowing for the early identification and treatment of Alzheimer's patients.

4. System Architecture

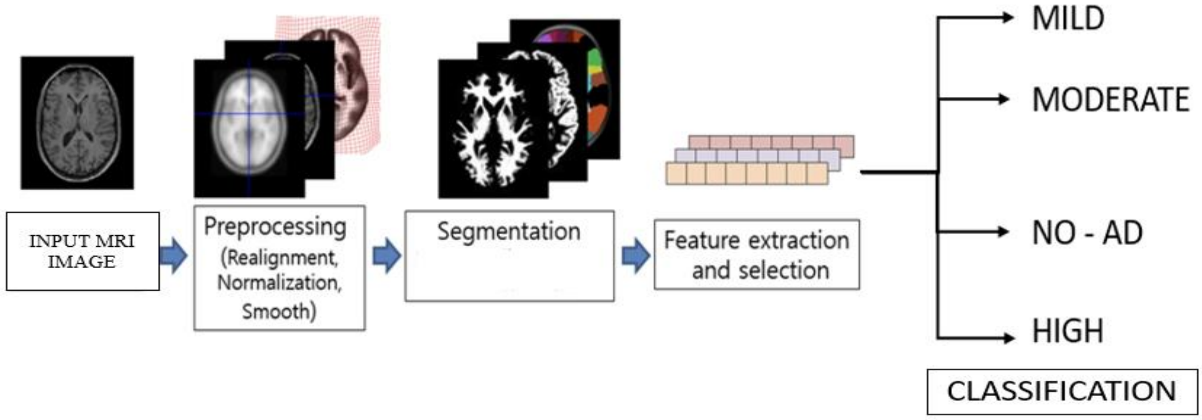


Fig1: System Architecture diagram for Alzheimer's disease classification.

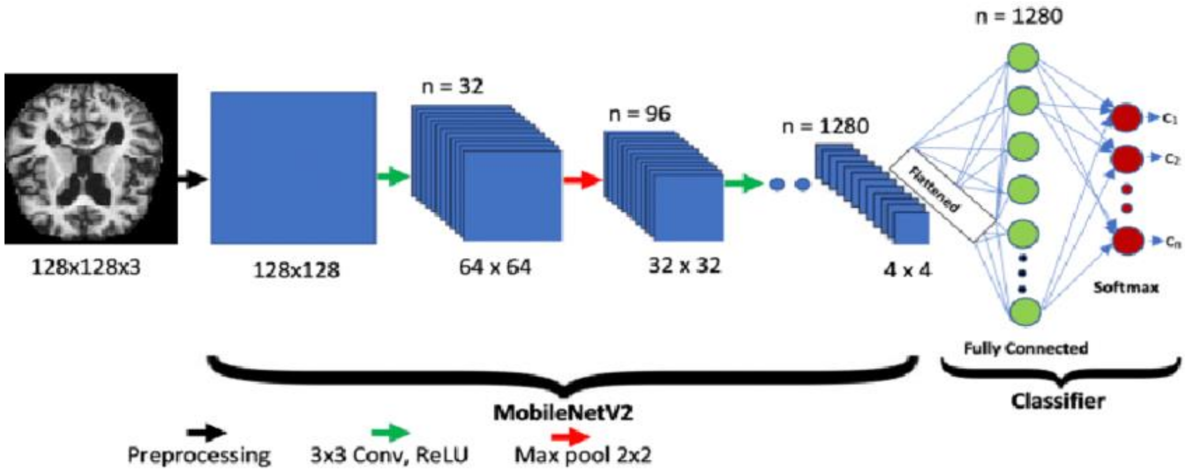


Fig2: Architecture of MobileNetV2 implemented in this project

5. Result

Alzheimer's disease detection using deep learning algorithms and MRI image analysis yielded promising results, demonstrating the effectiveness of our proposed methodology:

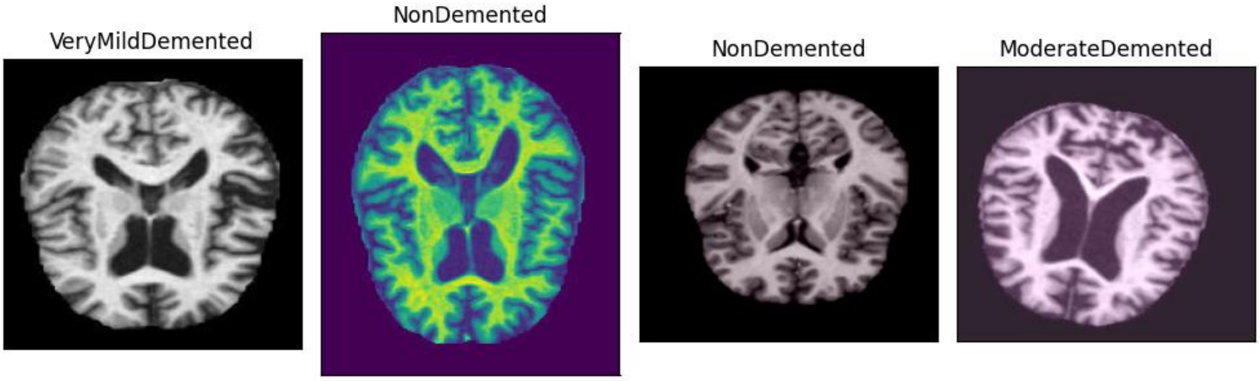


Fig 3: Displaying some random MRI images classified into respective classes from the ADNI dataset

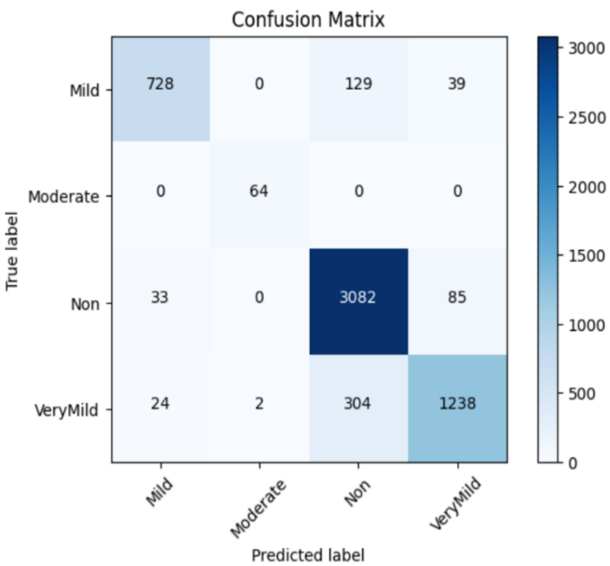


Fig 4: confusion matrix provides a detailed summary of a classification model's performance

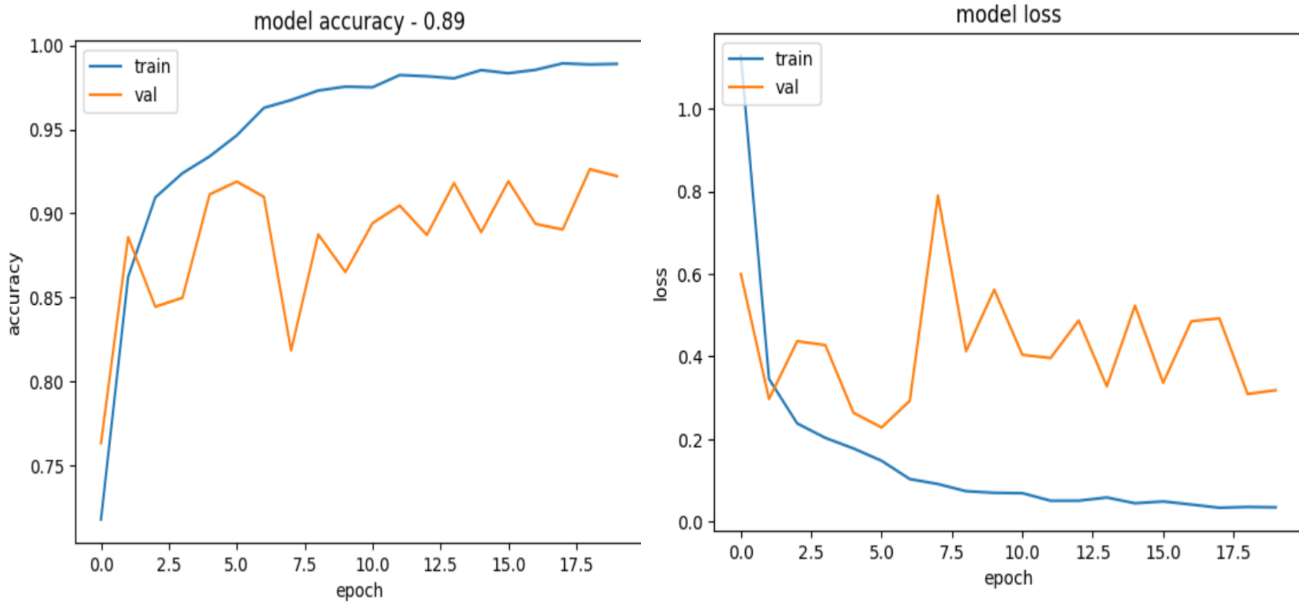
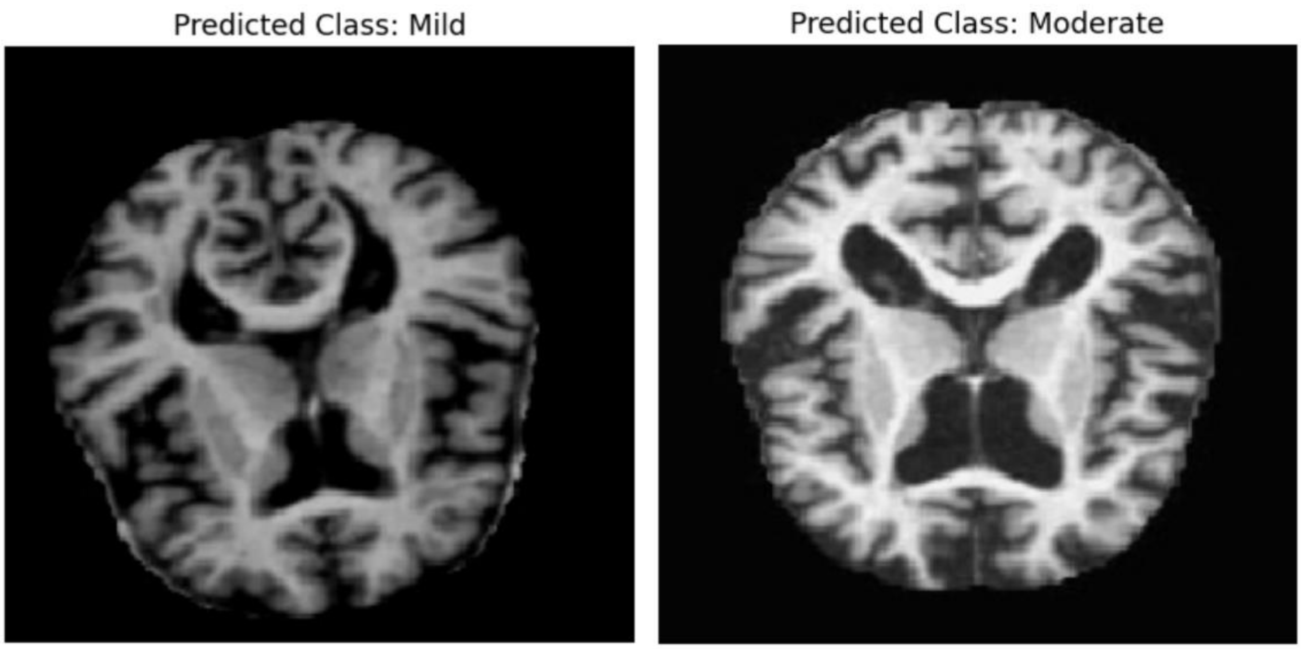
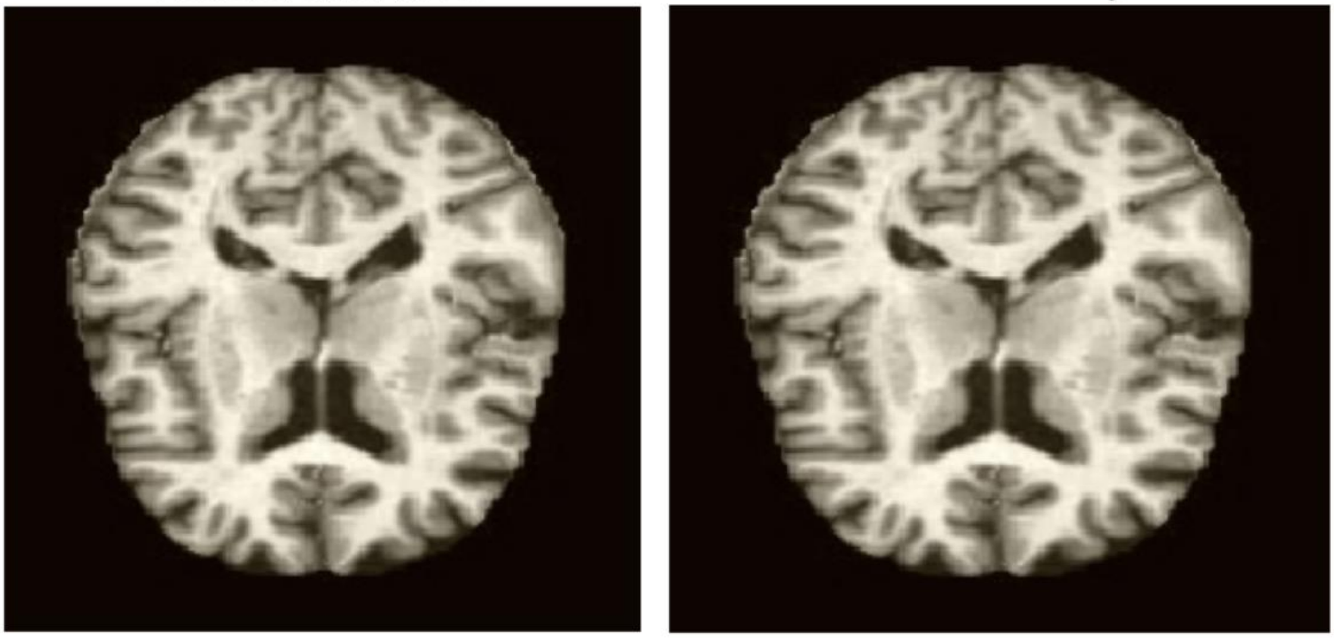


Fig 5: Graphical representation of the model accuracy & model loss.

- Predicted Images corresponding to their respective severity levels are as follows:

(Mild, Moderate, No-AD, Very Mild)





6. Conclusion

Alzheimer's disease (AD) poses a significant challenge to global healthcare due to its progressive nature and devastating impact on cognitive functions. Our project employs state-of-the-art deep learning techniques, particularly the Mobile-Net architecture, to address the early and accurate classification of AD using MRI images. By leveraging the ADNI dataset, we have demonstrated promising results in classifying MRI images into specific categories, including Mild Demented, Moderate Demented, Non-Demented, or Very Mild Demented. This underscores the potential of deep learning to improve the early detection and management of AD, ultimately advancing healthcare technology and patient care.

Our study underscores the potential of deep learning algorithms in enhancing the accuracy and efficiency of AD diagnosis, enabling early intervention and treatment. By paving the way for future applications in medical imaging analysis, our project contributes to advancing healthcare technology.

7. Future Work

In our future research, we aim to explore more advanced deep-learning methods to better understand Alzheimer's disease. We will investigate using different types of neural networks to analyze MRI data over time, helping us spot changes in the brain more accurately. We also plan to combine MRI with other medical tests to improve diagnosis. Additionally, we will adapt our model to work with different groups of people and healthcare settings. By making our predictions easier to understand, we hope to collaborate closely with doctors to ensure our research benefits patients directly.

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