Early Alzheimer's Detection

Deep Learning on OASIS MRI Images

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1 MOTIVATION

As the primary caregiver for my 87-year-old grandmother diagnosed with Alzheimer's, I've witnessed firsthand the critical importance of early detection and accurate staging of the disease. Motivated by this personal experience and my decade in healthcare, I aim to apply deep learning techniques, specifically convolutional neural networks (CNNs), to classify MRI brain images into four categories reflecting Alzheimer's progression stages. Utilizing the extensive OASIS MRI dataset of 80,000 images, this project seeks to explore how effectively CNNs can detect and differentiate subtle brain changes in early Alzheimer's stages. By investigating whether a multi-class CNN model can improve early detection compared to traditional binary classification, I hope to uncover new patterns or indicators that might enhance diagnostic accuracy. Ultimately, this research aims to contribute to improved patient care and treatment strategies, potentially benefiting families like mine who are affected by Alzheimer's.

2 LITERARY SURVEYS

Oh, K. et al (2019) developed a deep convolutional neural network (CNN) model to classify Alzheimer's disease stages using structural MRI data. Their model achieved high classification accuracy by automatically learning relevant features from the MRI images without manual feature extraction. They employed visualization techniques to highlight the brain regions that contributed most to the classification decisions, enhancing the interpretability of the model. The results demonstrated that the CNN could effectively identify patterns associated with Alzheimer's disease progression.

Islam, J & Zhang, Y (2018) presented an ensemble approach using deep convolutional neural networks for the diagnosis of Alzheimer's disease from brain MRI scans. They constructed multiple CNN models and combined their predictions to improve diagnostic accuracy. The authors utilized data augmentation and transfer learning techniques to address the limited availability of medical imaging data. Their ensemble system showed superior performance compared to individual CNN models, achieving higher accuracy in classifying patients with Alzheimer's disease versus healthy controls.

Korolev, S et al (2017) compared the performance of plain and residual convolutional neural networks for classifying Alzheimer's disease using 3D brain MRI data. They explored how deeper network architectures could improve classification accuracy by capturing complex features from volumetric data. The study found that residual networks, which incorporate shortcut connections to mitigate vanishing gradient problems, outperformed plain CNNs in this task. Their results demonstrated that using 3D CNN architectures with residual connections could enhance the detection of Alzheimer's disease from MRI scans.

Bassaia, S. et al (2019) developed an automated system using deep convolutional neural networks to classify Alzheimer's disease and mild cognitive impairment (MCI) from single structural MRI scans. They designed a 3D CNN model that could process whole-brain images without the need for region-of-interest segmentation. The model achieved high accuracy in distinguishing between Alzheimer's patients, MCI individuals, and healthy controls. By using a single MRI scan, their approach offers a practical solution for clinical settings where additional imaging modalities may not be available.

Wen, J et al (2020) provided a comprehensive overview of convolutional neural network applications for Alzheimer's disease classification using MRI data. They conducted a reproducible evaluation of various CNN architectures and training strategies to assess their effectiveness. The study emphasized the importance of standardized evaluation protocols to ensure fair comparisons between models. By making their code and models publicly available, the authors aimed to improve transparency and reproducibility in the field.

3 PROPOSED WORK

This project aims to develop a multi-class convolutional neural network (CNN) model for early Alzheimer's detection using the OASIS MRI dataset. The work will begin with data exploration to understand the dataset's structure and characteristics, followed by basic preprocessing steps including pixel normalization and image resizing. A simple custom CNN architecture will be developed, consisting of 2-3 convolutional layers with max pooling, 1-2 fully connected layers, and an output layer with softmax activation for multi-class classification. The model will be trained on the preprocessed dataset, with basic hyperparameter tuning and dropout regularization implemented to optimize performance and prevent overfitting. If time permits, a pre-trained model such as VGG16 or ResNet50 will be fine-tuned for comparison with the custom CNN.

Evaluation of the model will focus on calculating key performance metrics including accuracy, precision, recall, and F1-score for each class. A confusion matrix will be created and analyzed to understand model misclassifications, and learning curves will be plotted to assess potential overfitting or underfitting issues. The project will also include visualization of sample predictions to gain insights into model performance. This approach differs from previous works by focusing on multi-class classification of Alzheimer's stages, demonstrating how beginner-level practitioners can approach complex medical imaging tasks within time constraints. By balancing the complexity of multi-class Alzheimer's detection with practical limitations, this project aims to contribute valuable insights into early Alzheimer's detection while serving as a learning experience in applying CNN techniques to medical imaging problems.

4 DATA SET

My project utilizes the OASIS MRI dataset, a comprehensive collection of 80,000 brain MRI images specifically curated for Alzheimer's disease research. Available on Kaggle at https://www.kaggle.com/datasets/ninadaithal/imagesoasis/data, this 1.3 GB dataset consists of .jpg images converted from original .nii format MRI scans of 461 patients. Each patient's MRI was sliced along the z-axis, with 60 slices selected per patient to create 2D images suitable for deep learning applications. The images are classified into four categories based on Alzheimer's progression: non-demented, very mild demented, mild demented, and demented, using metadata and Clinical Dementia Rating (CDR) values. This preprocessed dataset provides a solid foundation for exploring various neural network models and achieving optimal results in early Alzheimer's disease detection and analysis.

5 EVALUATION METHODS

To evaluate our model, we will employ a comprehensive set of metrics including accuracy, precision, recall, and F1-score for each of the four classification categories. We will generate confusion matrices to visualize the model's performance across all classes and use ROC curves with AUC to assess its ability to distinguish between stages. For model interpretability, we'll implement Grad-CAM to highlight influential regions in the MRI images, potentially uncovering new patterns or indicators of early Alzheimer's stages. To ensure robustness, we'll use k-fold cross-validation and compare our multi-class CNN model against a baseline binary classification model to quantify improvements in early detection capabilities. Finally, we'll conduct error analysis on misclassified images, particularly focusing on cases where the model confuses adjacent stages, to identify areas for future improvement.

6 TOOLS

This project will primarily utilize Python as the programming language, leveraging its extensive ecosystem for machine learning and image processing. Key libraries include TensorFlow and Keras for building and training convolutional neural networks, OpenCV for image preprocessing, and Pandas and Matplotlib for data handling and visualization. Development will be conducted in Jupyter Notebooks, with

Google Colab providing access to GPU resources for computationally intensive tasks. Version control will be managed through Git and GitHub.

7 MILESTONES

The project will be executed in four phases, with key deadlines for a progress report on October 28 and the final report on December 9. Phase 1, concluding with the progress report, will encompass exploratory data analysis, implementation of data preprocessing steps, and the initiation of basic data augmentation techniques. We will also begin designing a simple custom CNN architecture during this phase. Phase 2 will focus on finalizing and implementing the custom CNN architecture, commencing initial model training, and beginning basic hyperparameter tuning. Phase 3 will continue with model optimization and evaluation, implementing key metrics and generating confusion matrices. If time permits, we will also start fine-tuning a pre-trained model for comparison. The final phase will be dedicated to advanced analysis techniques, including the implementation of Grad-CAM for model interpretability and conducting error analysis on misclassified images. This phase will culminate in the documentation of project findings and insights, leading to the preparation of the comprehensive final report due on December 9.

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