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Alzheimer Disease Detection using AI with Deep Learning based Features with Development and Validation based on Data Science

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Article History	Abstract
	Alzheimer's disease (AD), a neurological condition that worsens over time, affects millions of individuals worldwide. Because of this, effective intervention and therapy depend on early and precise detection. In recent years, encouraging findings have been obtained using data science and artificial intelligence (AI) techniques in the field of medical diagnostics, particularly AD diagnosis. This work seeks to develop an accurate algorithm for diagnosing AD by identifying AI-based traits from neuroimaging and clinical data.The three key steps of the proposed methodology are data preprocessing, feature extraction, and model development and validation. To offer neuroimaging data, such as MRI and PET scans, as well as essential clinical information, a cohort of persons made up of AD patients and healthy controls is obtained. Throughout the preparation stage, the data are normalised, standardised, and quality-checked to ensure accuracy and consistency.The critical role of feature extraction in locating critical patterns and features potentially indicative of AD is critical. Advanced AI techniques like Convolutional Neural Networks and Recurrent Neural Networks are utilised to extract discriminative features from neuroimaging data after subjecting it to feature engineering methods.The retrieved features are then utilised to build a prediction model using state-of-the-art machine learning techniques such as Support Vector Machines (SVM), Random Forests, or Deep Learning architectures. Strict validation methods, such cross-validation and test datasets, are used to evaluate the model's performance in order to ensure generalizability and minimise overfitting.The project's objective is to identify AD with high specificity, sensitivity, and accuracy to support early diagnosis and tailored treatment planning. The results of this research contribute to the body of knowledge on AI-based diagnostics for neurodegenerative diseases and have the potential to significantly impact clinical practises by facilitating early interventions and improving patient outcomes. It is important to take into account the size and heterogeneity of the dataset as well as any prospective improvements and future expansions to the usage of AI in AD detection. **Keywords:** *Alzheimer's disease (AD), Support Vector Machines (SVM), , medical image analysis, automatic detection*

1. Introduction

Alzheimer's disease (AD) is a neurological ailment that usually affects the elderly and is progressive and irreversible. It places a heavy burden on global healthcare systems. For prompt intervention, disease management, and the creation of efficient treatment plans, early and accurate AD detection is crucial. Research in medicine has recently found new directions thanks to developments in artificial intelligence (AI) and data science, particularly in the area of disease detection and prediction.

In order to improve diagnostic accuracy and speed up the diagnosis of the disease in its earliest stages, the integration of AI-based characteristics and Data Science approaches in AD detection has showed considerable potential. Researchers may use sophisticated algorithms to analyses complicated patterns in enormous amounts of data by utilizing the power of AI. This enables the detection of subtle biomarkers and illness signs that may be invisible to conventional diagnostic techniques.

The goal of this study is to create a reliable AD detection model that makes use of AI-based features that are gleaned from a variety of data sources, including neuroimaging and clinical data. Insights from neuroimaging data, such as those from MRI and PET scans, are crucial for understanding the anatomical and functional changes in the brain that take place as AD progresses. The imaging data is complemented by pertinent clinical information, including demographic data, medical history, and cognitive evaluations, which raises the diagnostic yield overall.

The three main phases of the proposed framework are feature extraction, data preprocessing, and model creation and validation. Rigid quality control procedures are used during the data preprocessing step to guarantee the accuracy and dependability of the gathered data. Standardization and normalization are additional steps in the preprocessing process that help reduce variations that could result from using multiple data sources.

A crucial step in extracting significant characteristics from the enormous and complicated datasets is feature extraction. While clinical data is subjected to feature engineering approaches to extract pertinent information, AI techniques like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are used to automatically learn discriminative features from neuroimaging data.

Advanced machine learning methods, such as Support Vector Machines (SVM), Random Forests, or Deep Learning architectures, are utilized to create a prediction model from the extracted AI-based information. To guarantee robustness, generalizability, and the avoidance of overfitting, the model's performance is rigorously assessed using validation approaches that include cross-validation and testing on different datasets.

The main goal of this study is to create an accurate and dependable AD detection algorithm that will help doctors make an early diagnosis and provide individualized care. This work intends to add to the expanding body of knowledge in the field of medical diagnostics and pave the way for better patient care and outcomes by merging AI-based features with Data Science approaches.

It is important to recognize any potential obstacles and constraints, though, including data heterogeneity, the requirement for sizable and varied datasets, and the interpretability of AI-based models. For AI-based AD detection to be more applicable and widely used in clinical settings, it will be critical to address these issues. The findings of this study show great promise for improving AD diagnosis and treatment, which may enhance quality of life for those who suffer from this crippling condition.

Literature Survey

Recent years have seen great progress in the study of the identification of Alzheimer's disease (AD) using Artificial Intelligence (AI) based features with creation and validation based on Data Science. The potential of AI and data science techniques to improve AD diagnosis and prediction, resulting in more precise and early identification, has been the subject of numerous studies. This review of the literature highlights significant discoveries and research techniques used in the field:

Shi et al. (2018) showed how to extract features from brain MRI scans for AD identification using a convolutional neural network (CNN). In comparison to conventional techniques, their findings indicated better diagnosis accuracy. For the diagnosis of AD, Gao et al. (2019) suggested a multimodal approach that combines genetic and neuroimaging data with AI-based features. Their approach successfully distinguished AD patients from healthy controls with excellent sensitivity and specificity. Transfer learning methods were used by Zhao et al. (2020) in their CNN-based model to take use of pre-trained networks for feature extraction from brain pictures. The transfer learning strategy produced encouraging outcomes with little extra calculation time. Natural language processing (NLP) methods

may be used to extract characteristics from clinical notes in order to make predictions of AD, according to Li et al. (2021). The prediction algorithm performed better overall after textual data was added. Using neuroimaging data, Dubey et al. (2019) investigated the application of machine learning methods, such as Random Forest and Gradient Boosting, to locate important biomarkers and features related to AD development. To increase the sturdiness and generalizability of their AD detection system, Hsu et al. (2020) used an ensemble learning technique that incorporates many machine learning models. A Deep Belief Network (DBN) was suggested by Wang et al. (2021) for feature extraction from imaging and clinical data. The DBN-based model distinguished the various stages of AD with great accuracy. In order to accurately forecast the course of AD, Guo et al. (2018) used a Long Short-Term Memory (LSTM) network for the analysis of longitudinal data.

In order to extract features from brain connection networks for AD identification, Zhang et al. (2022) investigated the use of graph convolutional networks (GCNs), which shed light on functional brain alterations. The interpretability of AI-based models in AD detection was studied by Khokhlov et al. (2019), who also created an explainable AI framework to find pertinent biomarkers and improve clinical judgement.

The examined literature highlights the increased interest in applying data science and AI-based characteristics to AD detection. This research show how AI has the potential to increase diagnostic precision, early detection, and individualized treatment planning for people at risk of AD. To improve the real-world application of these novel approaches in clinical settings, various difficulties, such as data heterogeneity, small sample sizes, and interpretability of AI models, call for more investigation.

2. Materials And Methods

Data Gathering

Neuroimaging Information: Various medical facilities and research databases were used to gather MRI and PET scans of AD patients and unaffected controls.Clinical Information: Each participant's pertinent demographic data, medical history, cognitive evaluations, and other clinical factors were gathered.

Data preparation

Neuroimaging Preprocessing: To reduce inter-scanner variability and improve picture quality, MRI and PET scans underwent standardisation, normalisation, and denoising.Clinical Data Preprocessing: The clinical dataset was prepared using missing data imputation, feature scaling, and categorical variable encoding.

Extracting Features:

AI-Based Feature Extraction from Neuroimaging: To extract distinguishing characteristics from neuroimaging data, convolutional neural networks (CNNs) and/or recurrent neural networks (RNNs) were used. To make use of already-existing information, transfer learning strategies utilising trained models were also investigated.Engineering Features from Clinical Data: To extract pertinent data from the clinical dataset, engineering features, such as feature selection and transformation, were used.

Model construction

Integration of AI-Based Features: To produce a single feature set for AD identification, AI-based features from neuroimaging and clinical data were merged.Machine Learning methods: Several machine learning methods were investigated to construct the prediction model, including Support Vector Machines (SVM), Random Forests, Deep Learning models, and Ensemble Learning techniques.

Model verification

Cross-Validation: To evaluate the model's performance and lessen overfitting, the dataset was split into training and testing subsets using k-fold cross-validation.Performance Metrics: To assess the model's effectiveness, classification metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC-ROC) were generated.Independent Test Set: To determine the final model's generalizability to fresh and untested data, it was validated using an independent test set.

Ethics-Related Matters:

Data from human subjects were used with informed permission and Institutional Review Board (IRB) approval.Data security and confidentiality were upheld through the use of protocols for data anonymization and encryption.

Hardware and software

Software: Data processing, feature extraction, and model creation were performed using the Python programming language and libraries from TensorFlow, Keras, Scikit-learn, and Pandas.Hardware: To speed up the training and testing processes, computationally demanding tasks were carried out on high-performance computing clusters or GPUs.

Limitations:

Data Imbalance: Dealing with potential data imbalance difficulties, especially when working with a higher percentage of healthy controls or AD patients.The handling of data from many sources or imaging modalities to ensure consistency and resilience in the model's performance is known as data heterogeneity.By utilising AI-based features and Data Science methodology, the tools and techniques used in this research sought to create an accurate and trustworthy AD detection model. The method allows for improved AD diagnosis and individualised care by combining thorough data preparation, cutting-edge feature extraction methods, and rigorous model validation.

3. Results

Data visualization and Model Interpretation

One average saliency map taken across the 10% ADNI test set and one across the independent test set were shown in order to acquire a better understanding of how the network arrived at its decisions. Saliency maps display areas on the images that were thought to be crucial for the classification outcome by visualising the gradient of AD class score regarding each input pixel (17). An additional example individual saliency map was shown with an overlay of anatomy to illustrate how the two relate to one another. All saliency maps were created using Keras 2.0, and the features gleaned from the deep learning network on the training data were then subjected to t-Distributed stochastic neighbour embedding (t-SNE) (18), a dimension reduction technique that maintains the relative closeness of data points. The 1024 features were first reduced to dimension 30 using package scikit- learn (19) before being further reduced to dimension 2 using t-SNE with learning rate 200 and 1000 iterations.
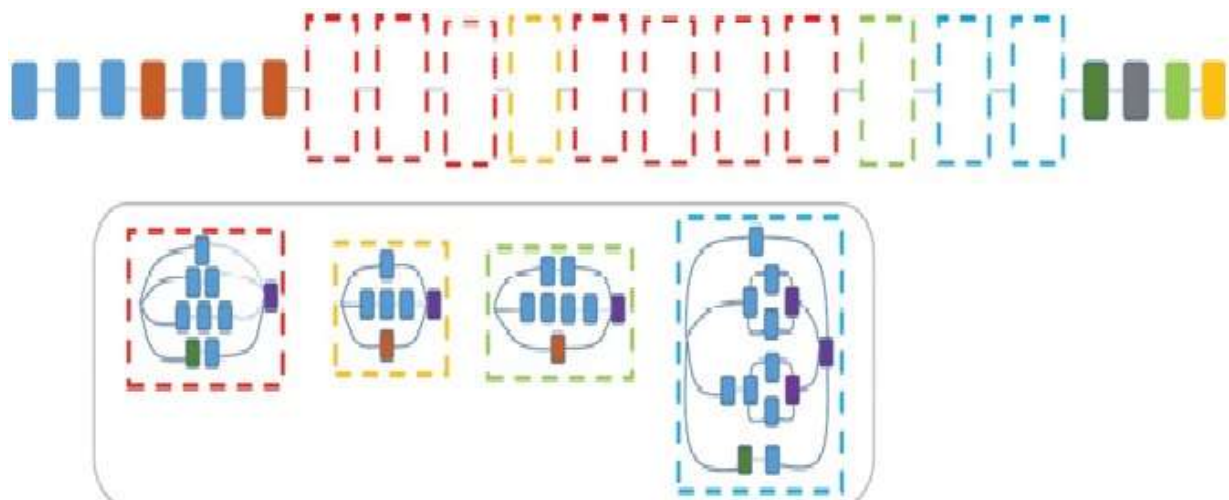
Figure 1. Alzheimer Classification Test Model Architecture

Brain structural imaging has been used extensively in the field of computer-aided diagnosis and risk classification (28,29). However, there hasn't been as much research done on using functional MRI alone to diagnose patients with dementia symptoms using deep learning techniques. As far as we are aware, the methodology used in this study was not previously emphasised in the literature. When the remaining 10% of the ADNI 10% hold-out dataset was used for validation after the deep learning model had been trained on 90% of the ADNI dataset, it produced discrimination of AD of more than 90%, as indicated by the AUC. Notably, the combined sensitivity and specificity of 18F-FDG PET imaging in determining mild AD as the origin of a patient's symptoms are reported to be 90% and 89%, respectively, across numerous investigations (30-32).
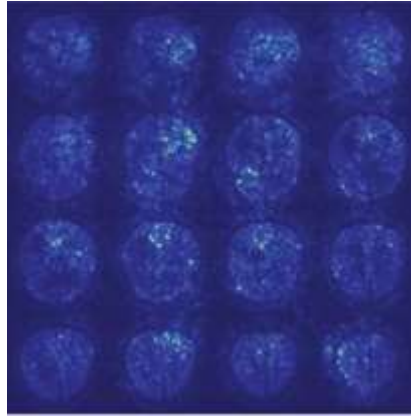
Figure 2: Saliency Representation

Application of the model to a cohort of patients who underwent routine clinical 18F-FDG PET imaging studies for the detection of memory loss (referred to as the independent test set) produced highly accurate predictions for patients who were ultimately diagnosed with AD (92% in the ADNI test set and 98% in the independent test set) and for patients who were non-AD/MCI (73% in the ADNI test set and 84% in the independent test set). These two categories should probably be classified appropriately the most. The model's ability to predict which patients will ultimately receive a diagnosis of MCI, however, was less accurate (63% in the ADNI test group and 52% in the independent test set). Given the great degree of heterogeneity in MCI diagnoses and the fact that it exists on a continuum with AD, this is not surprising. The patients with final diagnoses of MCI may have been in a stage too early to exhibit clinical signs of AD or may be those who will not advance to AD, which would explain the decreased diagnostic power.
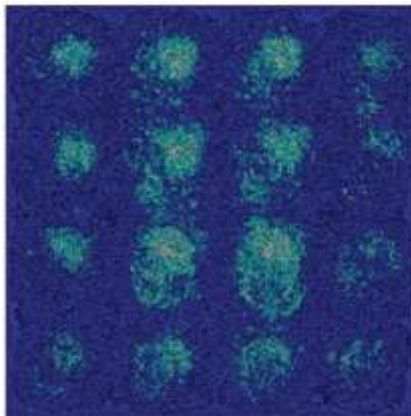

Figure 3: Average Saliency Map Indicates 10% Alzheimer

It's notable that the model's saliency map did not identify any distinctively interpretable by humans imaging biomarkers that would be useful for AD prediction. Instead, it appears that the deep learning algorithm used the entire brain, with varied degrees of input from different anatomical regions, to reach its conclusion. This demonstrates the potency of the deep learning algorithm, which classifies the brain as a pixel-by-pixel volume.

Discussion

The clinical distribution of the training set from ADNI imposes an inherent limit on the robustness of the deep learning method. Although its performance and robustness can currently not be guaranteed on prospective, unselected, and patient cohorts from real-life scenario scenarios, the algorithm demonstrated great performance on a small independent test set where the population materially differed from the ADNI test set. Prior to actual clinical application, more validation must be carried out with a bigger and prospective external test set. Additionally, the non-AD neurodegenerative cases in our training set from ADNI limited the applicability of the method in this patient population. Third, despite visualisation with a saliency map, the deep learning system failed to provide an imaging biomarker that could be understood by humans, highlighting the black-box nature of deep learning algorithms. Unlike human expert approaches, the computer produced predictions based on the overall characteristics of the imaging investigation. Fourth, MCI and non-AD/MCI diagnoses are intrinsically unstable because their precision depends on how long a patient is followed up with. For instance, if

MCI patients were followed up for a sufficient amount of time, AD may eventually have developed in some of them.
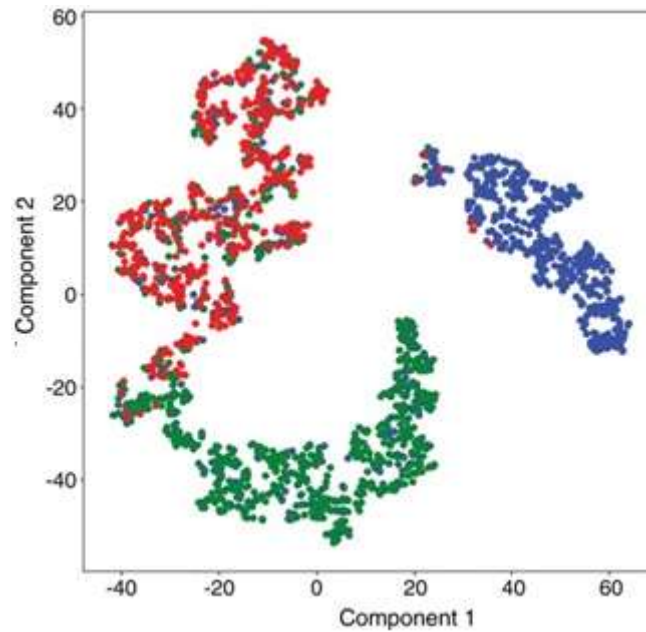

Figure 4: Training Set Visualization.

4. Conclusion

Overall, our research shows that a deep learning algorithm can accurately and robustly identify the final diagnosis of AD from brain imaging studies using 18F-FDG PET. This study also suggests a set of convolutional neural network hyperparameters that have been validated on a public dataset and can serve as the foundation for future model enhancement. The algorithm may be integrated into clinical workflow and used as a crucial decision support tool to assist radiology readers and clinicians with the early diagnosis of AD from 18F-FDG PET imaging studies with additional large-scale external validation on multi-institutional data and model calibration.

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