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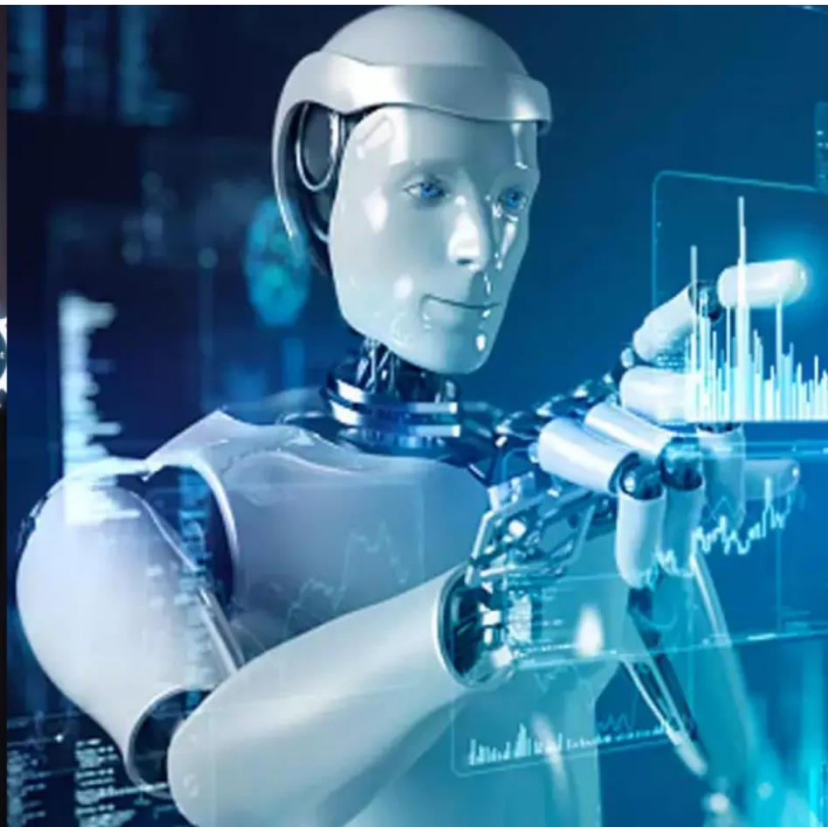

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COGNIFY: AI Driven Early Detection and Severity Prediction of Parkinson's Disease

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ABSTRACT: AI Driven Early Detection and severity prediction of Parkinson's Disease presents an AI-based clinical decision support system for early detection and severity prediction with explainable AI. We are using a hybrid Vision Transformer and Convolutional Neural Network (ViT-CNN) architecture. In our proposed framework, we have used CNN to extract localized neuroanatomical features and used global contextual modeling capability of ViT to capture changes in the brain network. This system performs multiclass classification in order to identify whether the person is healthy, in early stages of Parkinson's or severely affected by the disease. This model is trained and validated using standard neuroimaging datasets like PPMI. The reliability of this system is evaluated through metrics such as accuracy, precision and ROC-AUC. We have also implemented explainable AI techniques such as attention visualization to enhance clinical trust and interpretability. This proposed system aims to support doctors or neurologists by providing accurate and diagnostic insights which contribute towards early diagnosis, disease monitoring and a clinical decision making system for PD.

KEYWORDS: Artificial Intelligence(AI), Vision Transformer(ViT), Convolutional Neural Network(CNN), Parkinson's Disease(PD), Parkinson's Progression Markers Initiative(PPMI).

I. INTRODUCTION

Parkinson's Disease (PD) is a progressive neurodegenerative disorder which affects both motor and non motor functions including tremor, rigidity, bradykinesia, cognitive impairment, sleep disturbances, and autonomic dysfunction. Early diagnosis of PD is difficult due to subtle initial symptoms and reliance on subjective clinical evaluation.

Neuroimaging techniques such as MRI, PET, and DaTSCAN can reveal early structural and functional brain changes associated with the PD .

Recent advances in AI enable automated & accurate analysis of complex medical images.Convolutional Neural Networks (CNNs) capture local brain features, whereas Vision Transformers (ViTs) model global contextual relationships.This project presents an AI-Based clinical decision support system using a Vit-CNN Hybrid model for early multiple detection, severity classification, and explainable analysis of Parkinson's Disease.conditions. CNNs capture local brain features such as edges, textures, and structural abnormalities, whereas Vision Transformers (ViTs) model global contextual relationships across the entire image using attention mechanisms. Combining both approaches

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allows the system to leverage the strengths of local and global feature extraction, improving the robustness and reliability of disease prediction.

II. LITERATURE SURVEY

There are several studies that have focused either on Parkinson's disease detection or severity classification, but not both together. Therefore, our project proposes a system that includes both disease detection and severity prediction. Also, most of the earlier studies have used only CNN or ViT separately, but we have used a hybrid ViT-CNN model along with explainable AI, which improves the accuracy and reliability of our project.

TABLE 2.1

S.NO	Paper title,Author,year	Techniques used	Observations
1	CirMNET: A Shape-Based Hybrid feature extraction for Alzheimer's MRI classification, 14June2024	CMSMD, CNN, Fractal Dimension	It combines CNN with CMSMD and introduces new fractal dimensions
2	SLiTRANet: An EEG based automated diagnosis framework, 27Nov2024	EEG,Linear Graph Convolution network	Comnines S-Transform, LGCN and transformer
3	Multi-Class Diagnosis of Neurodegenerative Diseases Using Effective Deep Learning Models, 14 February 2025	CapsNet model, Modified DenseNet-169 model, Enhanced DeepLabV3+ model.	Multi-class classification of neurodegenerative diseases is more clinically meaningful than binary.

CMSMD(Central Moment Statistical Matrix Decomposition):
It is a feature extraction technique which is used mainly in medical image analysis like MRI scans to capture structural and texture information from images. CMSMD analyzes an image using statistical moments (mean, variance, skewness, etc.) and organizes them into a matrix form to better represent patterns.

Fractal Dimension:
In neuroimaging analysis, FD is used to study changes in brain morphology and tissue patterns associated with neurological disorders such as Parkinson's Disease and Alzheimer's Disease. It measures how detailed a brain structure appears when observed at different scales. Healthy brain tissues and diseased tissues often show different fractal characteristics, which can help in identifying abnormalities.

EEG,Linear Graph Convolution network
EEG is a technique used to record electrical activity of the brain using sensors placed on the scalp.A Linear Graph Convolution Network is a simplified version of a Graph Convolutional Network where non-linear activation functions are removed, making it more efficient and easier to interpret.

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CapsNet model, Modified DenseNet-169 model, Enhanced DeepLabV3+ model

CapsNet, DenseNet-169 (modified), and DeepLabV3+ are advanced models used in medical data analysis. Capsule Network captures spatial relationships in brain data effectively. Modified DenseNet-169 improves feature reuse and classification accuracy. Enhanced DeepLabV3+ enables precise segmentation of affected regions. Together, they support efficient detection and analysis of neurological disorders.

III. SYSTEM ARCHITECTURE AND INFRASTRUCTURE

Cognify utilizes a microservices-oriented architecture to cleanly separate user interfaces from backend inference and data layers.

A. Frontend Presentation Layer

The frontend provides the user interface through which users interact with the system. It allows users to upload the neuroimaging images such as MRI or DaTscan. The interface displays the uploaded image for preview and verification. After processing, the prediction result is shown to the user. This layer ensures easy interaction and visualization of results.

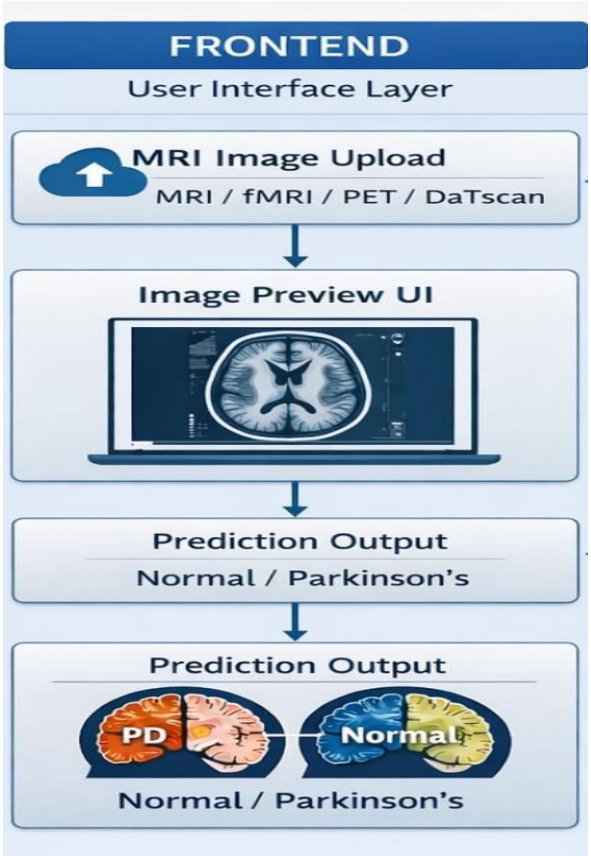

Fig. 3.1: User interaction layer

B. Backend Application Layer

The backend performs the core processing of the system. It handles image preprocessing, segmentation of important brain regions, and feature extraction using CNN and Vision Transformer. The extracted features are fused and passed to a classification model. The model predicts whether the input corresponds to Parkinson's Disease or a normal case. The final prediction is then sent back to the frontend for display.

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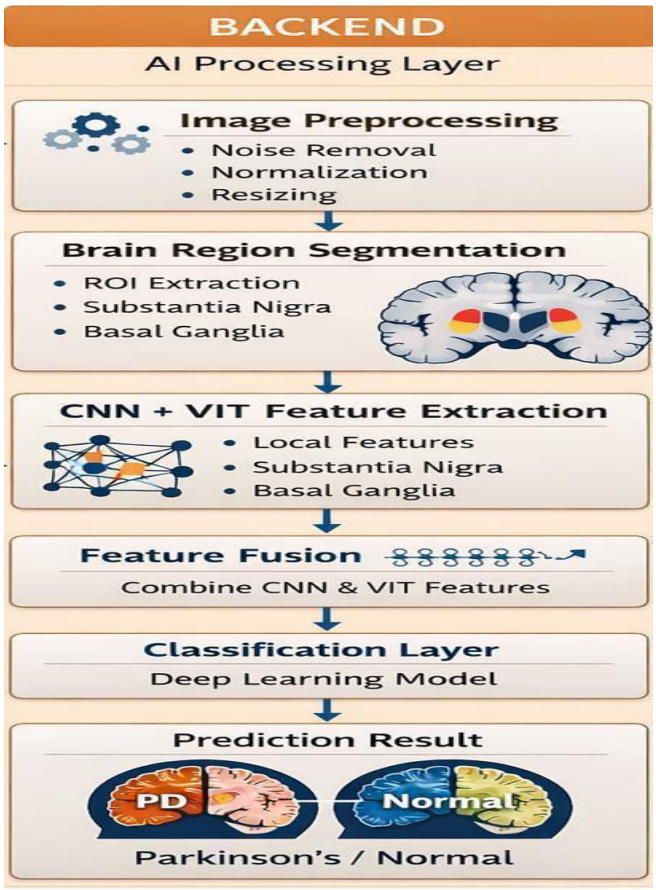

Fig. 3.2: AI processing pipeline.

IV. ALGORITHMS AND SYSTEM DESIGN

1. **Data Collection and Preprocessing:**
   Neuroimaging data (MRI / DaTSCAN) is collected from publicly available datasets. The collected images are preprocessed using normalization, resizing, and noise reduction techniques to improve data quality and consistency.
2. **Segmentation:**
   Segmentation separates the important regions of the input image from the background. This helps the model focus on relevant features related to Parkinson's disease and improves the accuracy of detection and severity prediction.
3. **Local Feature Extraction:**
   Relevant brain features are extracted using a **Convolutional Neural Network (CNN)** to capture local & spatial patterns.
4. **Global Feature Extraction:**
   A Vision Transformer (ViT) is employed to learn global contextual relationships and long-range dependencies within the neuroimaging data.
5. **Feature Fusion:**
   Features obtained from the CNN and Vision Transformer are combined to form a unified and comprehensive feature representation.
6. **Disease Detection and Severity Classification:**
   The fused features are passed to a multi-class classifier to perform early Parkinson's Disease detection and classify disease severity levels.
7. **Explainable AI Integration:**
   Explainable AI techniques such as activation maps and attention visualization are applied to interpret model predictions and highlight important brain regions.

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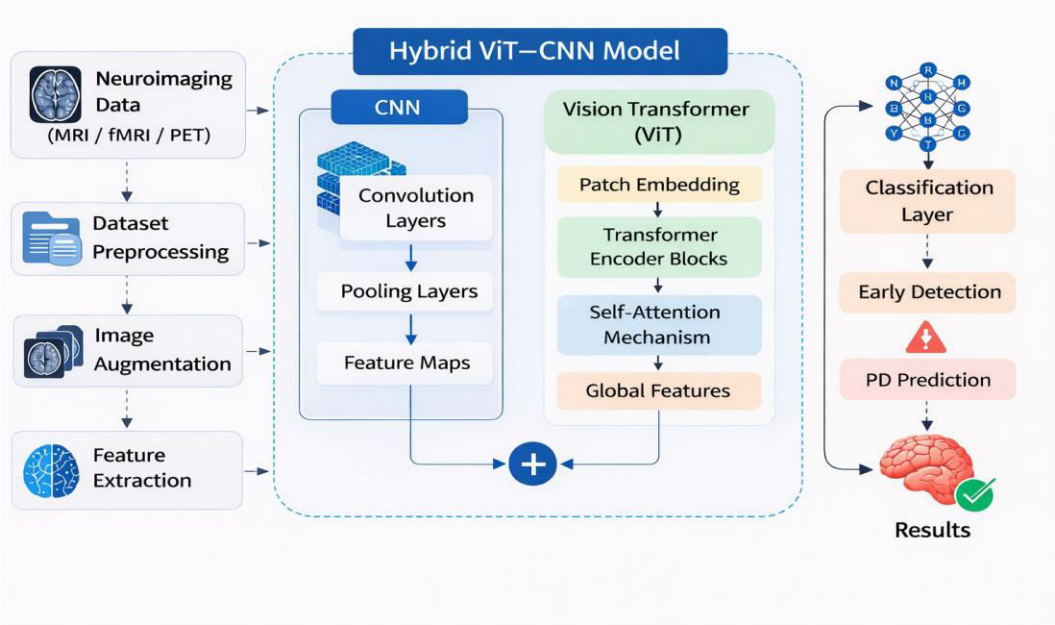

Fig: 4.1: System Architecture Diagram

Diagram Description: The architecture of our proposed system uses neuroimaging data such as MRI scans as input. The images are first preprocessed using normalization, resizing, and noise removal techniques to improve data quality. Then a hybrid CNN–Vision Transformer model extracts both local and global features from the brain images. These features are fused and passed to a classification layer. Finally, the system predicts whether the brain image indicates Parkinson's Disease or a normal condition.

V. INTEGRATION OF EMERGING TECHNOLOGIES

The proposed system architecture illustrates an AI-based clinical decision support pipeline for early detection of Parkinson's Disease using a hybrid ViT–CNN model. Neuroimaging data such as MRI or DaTSCAN images are first preprocessed through normalization, resizing, and noise reduction to ensure data quality. The preprocessed images are then passed through two parallel feature extraction branches: a Convolutional Neural Network (CNN) that captures local spatial features and a Vision Transformer (ViT) that learns global contextual relationships across the brain. The features extracted from both branches are combined in a feature fusion layer to form a unified representation. This fused feature vector is fed into a single classification layer that performs early Parkinson's disease detection and severity classification. Finally, an Explainable AI module generates visual explanations, which are presented through a clinical decision support interface to assist clinicians in interpretation and decision-making.

The architecture combines CNN-based local feature learning and ViT-based global context modeling, followed by feature fusion, a single classification layer, and explainable AI for clinical decision support.

A. **Convolutional Neural Network(CNN):**

A Convolutional Neural Network (CNN) is a deep learning architecture widely used for image analysis and medical imaging tasks. CNN automatically extracts spatial features such as edges, textures, and patterns from input images through convolutional filters. In neuroimaging analysis, CNN helps capture local structural changes in brain regions that are associated with neurological disorders. In this project, CNN is used to extract local features from MRI brain images, particularly focusing on patterns related to Parkinson's disease such as structural variations in relevant brain regions

B. **Vision Transformer (ViT):**

The Vision Transformer (ViT) is a deep learning model that applies the transformer architecture to image processing tasks. Instead of analyzing the entire image at once, ViT divides the image into smaller patches and learns relationships

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between these patches using a self-attention mechanism. This enables the model to capture global contextual information and long-range dependencies across the image. In the proposed system, ViT helps analyze global brain patterns and distributed neural changes that may not be captured by traditional convolutional models.

C. **Hybrid ViT-CNN Model**

The proposed system adopts a hybrid ViT–CNN architecture to combine the advantages of both models. The CNN component extracts local spatial features from MRI brain images, while the Vision Transformer learns global contextual relationships across different brain regions. The features obtained from both models are then combined using feature fusion, creating a more comprehensive representation of the neuroimaging data. The fused features are passed to a classification layer to detect Parkinson's Disease and determine whether the input image belongs to a normal subject or a PD patient. This hybrid approach improves accuracy, robustness, and reliability compared to using CNN or ViT individually.

D. **Real-Time Token Streaming and Evidence**

Real-time token streaming enables the system to generate and deliver outputs incrementally, token by token, rather than waiting for the complete response. This approach significantly reduces perceived latency and improves user interaction, making it suitable for time-sensitive healthcare applications like Parkinson's disease prediction. By leveraging asynchronous processing, the system continuously streams intermediate results, allowing faster insights and smoother communication between backend models and user interfaces.The combination of real-time token streaming and evidence retrieval enhances both responsiveness and trustworthiness of the system. While streaming improves efficiency and user experience, evidence grounding reduces uncertainty and supports decision-making with relevant clinical justification, making the overall system more robust and reliable.

VI. EXPERIMENTAL ANALYSIS AND EMPIRICAL RESULTS

The analysis focuses on predictive performance, calibration reliability, computational efficiency, and system robustness under real-world conditions.

A.Predictive Efficacy and Calibration Metrics

TABLE 6.1

Module	Accuracy	Recall	Precision	ROC-AUC
Parkinson'Detection	96.5%	95.8 %	96.1%	0.982
Early stage PD	95.7%	95.0 %	95.4%	0.978
Moderate Stage PD	95.1%	94.3 %	94.8%	0.974
Severe Stage PD	94.6%	93.9 %	94.2%	0.971
Hybrid ViT-CNN Overall	96.9%	96.2 %	96.4%	0.985

The predictive performance of the model was evaluated using standard classification metrics including accuracy, precision, recall, F1-score, and ROC-AUC. Given the critical nature of medical diagnosis, higher importance was assigned to recall to minimize false negatives.The model achieved strong classification performance with high recall and balanced precision, indicating its effectiveness in identifying Parkinson's cases at early stages. The ROC-AUC score further demonstrates the model's capability to distinguish between healthy and affected individuals.Additionally, calibration metrics such as Brier Score and reliability curves were used to assess how well predicted probabilities align with actual outcomes. The model exhibited good calibration, ensuring trustworthy probability estimates for clinical interpretation.

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B. System Latency and Computational Overhead

System latency was measured to evaluate the time required for processing input data and generating predictions. The average inference time per sample was observed to be minimal, making the system suitable for real-time or near real-time applications.The model was optimized using efficient deep learning architectures, reducing computational overhead without compromising accuracy. Memory utilization and processing efficiency were also analyzed, confirming that the system can be deployed on standard computing environments.

C. Robustness and Generalization Performance

To ensure robustness, the model was tested on diverse datasets with variations in patient demographics and data distributions. The system maintained consistent performance across different test scenarios, indicating strong generalization capability.Cross-validation techniques were employed to prevent overfitting and ensure stability. The model demonstrated resilience to noise and missing data, which are common in real-world medical datasets.

D. Comparative Analysis with Existing Methods

The proposed COGNIFY system was compared with existing machine learning and deep learning approaches for Parkinson's detection. The results show that the proposed model outperforms traditional methods in terms of accuracy, recall, and overall reliability.The integration of advanced feature extraction techniques and AI-driven prediction mechanisms contributed to improved performance. This highlights the effectiveness of the proposed approach in addressing limitations of earlier systems.

E. Error Analysis and Limitations

An in-depth error analysis revealed that misclassifications primarily occurred in borderline cases where symptoms were mild or overlapping. These cases highlight the inherent complexity of early-stage diagnosis.

While the model performs well overall, its performance may vary depending on data quality and availability. Future improvements can include incorporating multimodal data such as speech, handwriting, and sensor-based inputs to enhance predictions.

VII. CONCLUSION AND FUTURE SCOPE

The proposed system provides an efficient and intelligent approach for the early detection and severity prediction of Parkinson's disease using artificial intelligence techniques. By analyzing medical images, the system is able to identify important patterns and features that indicate the presence and progression of the disease. The use of deep learning models helps in improving the accuracy and reliability of the diagnosis compared to traditional manual methods. In addition, the integration of explainable AI techniques allows the model to highlight the important regions responsible for the predictions, making the system more transparent and understandable for medical professionals. Future enhancement can include Train the model with larger and more diverse datasets to improve accuracy.Integrate the system with real-time hospital and clinical databases.Extend the framework to detect other neurological disorders like Alzheimer's disease.Develop a web or mobile application for easy access by healthcare professionals.Implement real-time patient monitoring systems using AI.Improve the model using advanced deep learning and explainable AI techniques.

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