



# Hybrid Multimodal Data Fusion Model for Early Parkinson's Disease Diagnosis

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**Abstract:** Parkinson's disease (PD) produces motor impairments which affect both speech development and cognitive abilities. The condition remains uncured, yet research demonstrates that early diagnosis with medical treatment leads to symptom reduction. The inability to access medical centres and qualified personnel prevents doctors from diagnosing patients with PD. PD is a widespread condition which causes chronic neurological movement disorders that especially affect older adults. Multimodal data fusion shows potential to deliver additional information about PD pathophysiology. The research uses its new multimodal deep learning techniques to evaluate Parkinson's disease through its ability to differentiate between people who have PD and people who do not have PD. The study used Parkinson's progression markers which were obtained through functional magnetic resonance imaging and Public Access to the PPMI and ADNI databases. The researchers aim to develop predictive models which will identify specific brain regions affected by diseases while simultaneously determining which genetic variants contribute to Parkinson's disease (PD) risk. The study investigates how genetic elements affect both the beginning and development of PD. The results show that our multimodal approach outperforms both unimodal methods and existing multimodal techniques. The Stacked Deep Learning Classifier (SDLC) system produces outstanding results through its achievement of an F1 score measurement of 0.99 and an accuracy rate of 99.4%. Proposed method shows superior performance techniques multimodal approaches. The outcomes demonstrate how our method increases both accuracy and reliability for patient data. The study demonstrates that our proposed method shows better performance results than all other methods which we tested because it achieved higher F1 score improvements in comparison to the alternative methods. The study demonstrates how exercise provides advantages to people who participate in it. The presence of multiple modalities enables estimation to occur even when one modality is not available.

**Key Words:** Multimodal, Deep learning, Data fusion, Parkinson disease, rfMRI.

## I. INTRODUCTION

People with Parkinson's disease display multiple motor which constitute the most common disease Such symptoms of the disorder are bradykinesia, which is a delayed movement, rigidity, tremors, gait disabilities, abnormal standing, and pain [1]. Medical researchers from both the fields of medicine and science perform clinical testing for Parkinson's disease at medical facilities and research laboratories. The research team conducts a specific investigation about India the visual part of their study enables researchers to assess their current health status. The disease that patients display through their hands show extreme variations which develop according to their day activities and medication schedule and level of exhaustion [2]. The manifestations that can be displayed by the afflicted persons are similar to other health ailments hence complicating the work of medics resulting in a high misdiagnosis rate, particularly during the initial phase of the disorder. A considerable reduction in the count of nigrostriatal dopamine neurons establishes that Ron has measured Time of PD diagnosis in most individuals. The current situation shows that patients experience treatment access issues which prevent them from receiving necessary care during their initial disease stages This leads to disease progression which makes their condition worse [3]. The early identification of Parkinson's disease enables medical professionals to provide swift treatment which delivers proper patient relief after symptoms start [4]. There have been two advancements during the past ten years which include increased research and development of digital systems to monitor Parkinson's disease (PD) [5]. The Internet of Things (IoT) enables users to connect multiple sensors throughout their households which brings new possibilities for using their technology in different parts of daily activities [6].

The complete collection of sensor data which people create with their daily activities creates opportunities for continuous tracking and evaluation of PD symptoms. The research may lead to fresh insights which will enhance both PD diagnosis and treatment methods. Machine mastering a ways computers might also research, on their own, to recognize patterns in large data sets without needing to learn specific programming instructions [7]. ML has demonstrated strong growth in its ability to discover nontraditional connections among data points that have high dimensionality. Scientists have made substantial advancements in their research work during the past years using Deep Learning techniques which represent the latest developments in machine

learning according to recent scientific studies. Such outcomes were made possible by recent technological progress, and deep learning (DL) has become a formidable process that is capable of working with unstructured data. DNNs enable DL models to pick out salient data representations, bypassing the large amount of feature engineering and preprocessing involved [8]. These are the strategies that are particularly effective at handling complex sensor-based information gathered by the modern devices efficiently [9]. The use of DL techniques to trace and forecast progression of the Parkinson disease has become a significant topic in recent years mostly due to implementation of sensor data [10]. Some other works that use biomarker data like UTI classification assess performance using the shape features of evolved regions of interest [11]. Most recent studies have also established that by analysing breathing patterns during sleep, artificial intelligence (AI) can identify a patient with Parkinson's disease. Also, the AI algorithms have been found to be highly precise in evaluating the degree of disease severity, as well as forecasting when the disease will develop [12] compared to existing technologies through its implementation in multiple healthcare applications [13]. The multimodal data fusion method enables us to gather complete information about Parkinson's disease through the analysis of different data sources.

The combination of multiple information sources from RFMRI and gene data enables us to discover unexpected results through which we will uncover new findings about genetic inheritance and PD's development. The primary rationale is to create a superior diagnostic methodology that will overcome the limitations of the unimodal techniques besides the available multimodal procedures. Our research aims to improve Parkinson's disease diagnosis through data integration which will help us identify brain regions that correspond to the disease. The study can bring a revolution in the diagnosis of Parkinson disease as it offers a better and more effective way of detecting victims of the disease [14]. The standard datasets used for performance assessment show that traditional methods fall short of current performance standards. The results lack generalizability because the dataset did not provide sufficient variety. The entire clinical analysis process needs more time because it requires double the time needed for medical professional verification of clinical findings. The prediction accuracy becomes apparent when medical specialists conduct multiple assessments using clinic logical data. Multimodal data analysis was implemented through black box testing at this facility.

The study will be expanded through our research efforts which already exist Parkinson's disease research. Multimodal data Fusion techniques will find their application in clinical settings through this research work. The main goal of this study aims to enhance current Parkinson's disease diagnostic methods. This diagnostic procedure optimization helps doctors make better treatment decisions which leads to improved life quality for Parkinson's disease patients.

## II. RELATED WORK

The algorithms have established because they enable research work in this specific field. Researchers in the field of Diagnosis or progress monitoring have developed numerous methods which study both Parkinson's disease patients and non-PD patients according to research from [18]. The study used symptom assessment for Parkinson's disease [15] research. The previous studies selected their data sources from real-time information which they obtained through smartphone and wearable technology [16] data collection. The research used vision sensors to collect data and perform analysis according to previous studies and the current work. Various approaches have been investigated to assess. Fixed method has focused on using tablets [17] or scanners Tool for analysing handwriting [18]. The traditional study of speech analysis used microphones as the primary research tool [19]. Nix technology provides assessment services to evaluate Parkinson's disease symptoms experienced by people. The research of [20] uses a Convolutional Neural Network to study RGB data for their research. The researcher used CNN to first analyse human Pose assessment before he discovered which parts of the track his tests required. The random Forest (RF) algorithm has become a common tool because active upgrades in artificial intelligence have developed new methods. The system enables researchers to use RF to evaluate PD symptoms which they compare with non-PD symptoms. The novel approach demonstrates a high potential for enhancing PD diagnosis. The system improves both evaluation accuracy and efficiency [21]. The research used vision-based work methods to develop a convolutional neural network (CNN) which processed RGB and motion data. The CNN model provides a quantitative assessment of Parkinson's Disease symptoms. CNN models demonstrate excellent performance across various scenarios which involve different types of data. CNN models achieve success in photography classification tasks, but they have also proven their ability to function effectively in other fields.

The researchers attained exceptional outcomes through their exploration of multiple disciplines which enabled them to use CNN technology. The system allows CNN models to extract spatial and temporal dependencies for various applications. The model studied by with the Net Handwriting dataset was training on the classification of the Parkinson's disease (PD). The researchers team developed their AP solution which utilizes 3D CNN technology to separate skull material from 3D brain images. The researchers team developed a new method which uses recurrent neural additional network of independent components analysis (RNN-ICA) to study fMRI data [22]. The researchers present this model to solve problems which arise during fMRI examination. The collaborators with team, tested the Restricted Boltzmann Machine (RBM) system to verify its performance during Eden network training.

The study results show that RBM can detect network activity which people can use to analyse fMRI data. The number of people who use multimodal neuroimaging assessment methods has grown because of the limitations which specific modalities encounter according to team. The current trend has resulted in the creation of databases that contain more extensive and sophisticated information. The scientific community uses Progression as a method of graph convolution in modern scientific research. All networks address these concerns above. A team developed two new approaches which medical professionals can use to diagnose Parkinson's disease according to their recent research. The researchers developed methods which use time-frequency analysis of electroencephalogram (EEG) data with deep learning techniques. The researchers developed a new method to predict multi-model features which they designed for deep learning analysis using CNN technology [23]. Rresearch group conducted of Parkinson disease conversation signals captured through the audio recordings. The team developed their entire system from its initial design phase to complete operational capacity.

The researchers applied CNN to their study of post- spectrogram audio data. The results of their study were Very promising [24]. Conversely, the UPDRS is an effective tool of assessment whereby it assesses different areas of the Parkinson disease, such as motor functionality, daily activities, and complications associated with the disease [25].

The two scales are highly used in both clinical and research and provide a standard method of measuring the severity of the disease.

The recent works on the prediction of Parkinson disease have used diverse deep learning models to enhance effectiveness [26]. Speech biomarkers are also identified as useful characteristics in predicting PD [27]. Alongside, certain studies have made use of the methods to identify Parkinson disease [28]. Sound-based PD detection achieved its highest level through improved precision and accuracy rates. The dataset cannot provide 100% assurance that PD will occur. The research extends beyond its initial data set. The article uses two datasets to establish the modal, which conducts deep learning and enhances scientific studies for patient clinical applications. The researchers used VGG16 to conduct brain tumour classification in their multimodal brain tumour detection study. The users of the model system do not find its accuracy to be satisfactory. The Eddie model handles data heterogeneity by using a heuristic initialization function which combines different data sources through its fusion framework. The proposed PD model uses its depth learning classifiers to create an advanced system for handling and understanding complex heterogeneous information [29]. The current technologies which include Explainable AI have reached a point where they cannot provide clear explanations for deep computing systems while multimodal systems show better results in brain tumour analysis.

### III. PURPOSED SYSTEM

The research uses multiple deep learning methods to assess Parkinson's disease. The study uses firm with genetic information to separate people who have PD from those who do not. This paper exploits information gathered on the PPMI and ADNI databases. This paper will seek to understand the genetic risk factors that aid the development of the disease, Parkinson, and to have a better comprehension of the disease. The research investigates fundamental mechanisms which include potential genetic factors that drive Parkinson's disease development and progression. Fig.

1. displays the overall framework which uses multiple data sources to diagnose Parkinson's disease through multimodal data fusion techniques [30]. The research team used firm data and gen data to prepare analysis work. The data undergoes multiple pre-processing steps which enable it to achieve compatibility with required output specifications. The system proceeds to the next phase which involves modal data extraction after completing preprocessing. Researchers use RFMRI data analysis to extract brain connection function from various brain connection solutions. The evaluation techniques encompass both functional connectivity networks and graph-based measurement methods. genetic data underwent a transformation process. Research has extensively studied the expression levels or selected gene characteristics believed to be associated with Parkinson's disease [31].

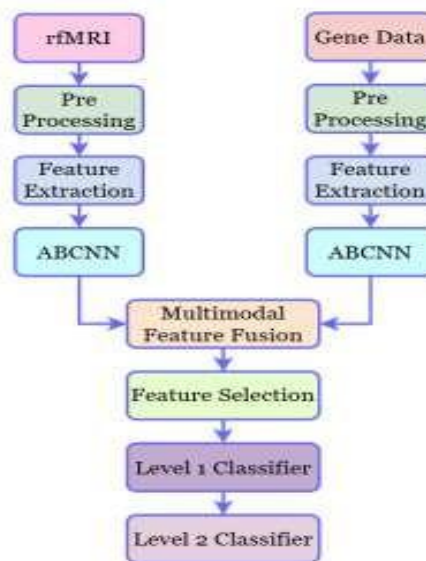


Fig. 1. Purposed Structure of Parkinson's Disease Diagnosis

The system creates joint function representation through the process which combines features from both modalities into one unified system. Deep neural network architectures that handle multimodal fusion operate through the process of fusion technology. The implementation of feature selection methods on fused features helps to enhance model interpretation abilities while improving their performance across different scenarios. The approach works to decrease feature space dimensions which preserve essential contextual details needed for precise analytical prediction. The model achieves superior interpretative capacity and general performance through the selection of its most valuable features. Research studies have extensively utilized regularization-based methods which include L1 regularization known as LASSO for the process of feature selection. The research used stacked deep learning models to identify functional patterns for Parkinson's disease classification purposes. Machine learning practitioners use stacked models which machine learning practitioners call ensemble models to combine multiple distinct classifier systems through their multiple classifier systems. The method aims to improve prediction accuracy through the combined knowledge from multiple classifiers in the stacking system. The method enables the system to discover intricate connections between various features which results in better classification outcomes. Stacked deep learning classifiers require training through

specific algorithms that include back-propagation as one of their training methods. The system optimizes its parameters during training in order to achieve the lowest possible value of the loss function [32].

### A. Data Storage

The PPMI databases hold medical history of patients with Parkinson's disease and associated neurological diseases, and of the Michael J. Fox Foundation runs a large clinical research initiative, which is concerned with the biological markers of the progression of the wellbeing of the Parkinson disease by means of comprehensive examinations, including sophisticated imaging research, gathering of biological samples, diagnostic equipment, and evaluation of patient conduct. The PPMI database contains data on patients with Parkinson's disease (PD) who were diagnosed with related disorders ( $n = 55$ ; 18 women; 37 men; mean age = 66.9s.  $d = 4.5$  years) while the healthy controls (HCs) database includes data on 49 individuals with 25 women and 24 men who had an average age of 69.3s.  $d = 4.5$  years. The study included 35 HC and 14 HC from the ADNI database PPMI database). Each sample includes secured firm data together with its associated gene data. The mental and physical attributes of the samples match the typical characteristics observed in

healthy people. The databases use strict criteria for both data collection and processing which ensure that two record sets maintain their structural integrity. The subjects provided their written consent which confirmed their understanding of the study while the healthy controls showed no evidence of other medical issues. Something that can cause disturbances in the nervous system. PPMI and ADNI permit the use of multiple data types and research articles that appear in this section [33]. The data usage follows all applicable regulations.

### B. Multimodal Data Fusion

The research uses integrated data which includes resting- state fMRI results and genetic information to create a CNN model that functions with an attentional system. The research needs to process both firm data and gene data because the analysis needs complete information about both data sets. The pre-processing step establishes information accessibility which enables researchers to conduct their studies. The proper technical procedures enhance data quality which leads to correct and significant results. The appropriate normalization techniques should be used to maintain data quality while enabling data comparison through scaling and standardization methods. The analysis process requires these steps because they enable data preparation for modelling activities. Normalization converts data into a standard measurement range that typically extends from 0 to 1 to remove bias which results from different variable size[39].

The complete analysis requires scaling which necessitates extraction of specific functions through separate processing of both firm data and gene data. This method allows us to investigate potential links and how these two systems interact. The process of relevant function extraction from firm data requires the detection and measurement of various functions. The research finds connection patterns through network connection strength measurements and nodal centrality assessments and graph-theoretic calculations. The features provide understanding about how the system maintains its overall structure. RfMRI data enables the extraction of various functions through the analysis of connectivity metrics and network-based metrics. Parkinson's disease researchers study gene expression levels from multiple genes which show links to the disease through their research. Researchers need to combine features from both modalities before they can proceed with their work. Researchers obtain complete incident information using multiple feature sets derived from different available sources.

The process creates an integrated representation through the combination of essential functions from multiple modalities which reveals fundamental patterns and connections [34]. This is a strategy which is applied to produce a combination of features appended along a definite axis to create one entire representation. The combination of the representation is then inputted into the CNN model in this study. Researchers propose to use a meditation mechanism which will help CNN systems identify their most important components. The associated representation includes the complete information. By using attention in CNNs, the system can determine which parts of input data require more attention because they contain critical details. The technology will enhance the network's ability to concentrate on critical elements, and it will boost efficiency across all activities. Fig. 2. shows the network construction method that CNN uses to build their system. We use the VGG19 network as our model base to create general models which will protect our system from overfitting while we develop our machine learning models. The removal of all fully connected layers will enable us to reach our objective of constructing a model which delivers optimal performance while handling basic overfitting concerns. The meditation blocks of VGG19 network system operate with their third network element to achieve their full operational capability through their fourth and fifth teams[40].

The final phase of the process required merging all output results from three distinct attention blocks. The process creates a final feature vector through this operation. Attention mechanisms work to enhance classification performance by allowing models to concentrate on essential areas and specific genes. The system enables the model to determine which genetic traits and areas should receive special attention because they will contribute to successful classification. The model improves its decision-making process and classification accuracy by directing its attention towards genetic areas and specific genes. The classification model uses attention mechanisms for selective focus because they help determine which regions or genes should receive more attention during the classification process. The model uses attention mechanisms to identify which elements of information about people with disabilities research should be considered most important. The method provides researchers with tools to enhance their system performance while maintaining system visibility to users. CNN technology has emerged as a major solution for tackling various computer vision tasks since its inception. Researchers have studied how to improve CNN performance through attentional mechanisms because it leads to better network designs.

The system requires network recovery capabilities to retrieve essential data from user input because it needs to protect specific system fields and user-defined attributes. The researchers present a convolutional neural network design for their study. The system requires input through its meditative mechanism which processes merged function representation data. The system

achieves connected feature representation through the combination of multiple feature maps together with different feature vectors from both layers and modalities. The network uses the fusion process to extract different information types, which helps it better distinguish between various elements in the attention system. The system uses weight assignment to different components of the convolutional neural network in our proposed architecture. The deep learning system includes convolutional layers for feature extraction and aggregation layers. Meditation techniques use multiple methods for dimensionality reduction, with self-meditation serving as one of the methods [35].

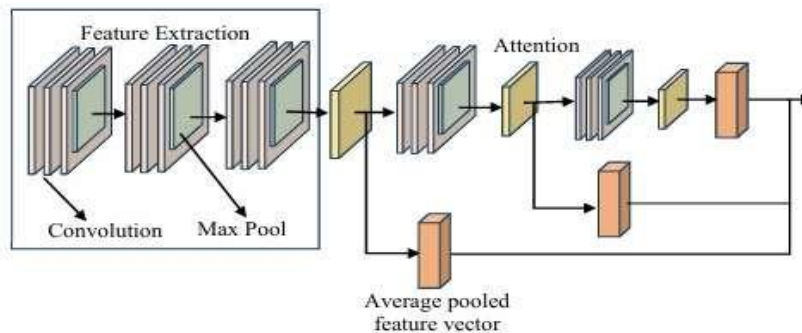


Fig. 2. Attention based CNN (ABCNN) architecture

**C. Function Selection**

Various techniques exist for selecting deep learning model features because different data characteristics and specific problem requirements determine which methods to use. The embedded methods or integrated feature selection techniques enable deep learning models to conduct feature selection during their training process. The model requires feature selection which these methods used to identify essential features that should be learned by the system. The system automatically selects useful features through this integration which helps to boost its performance and ability to generalize. Embedded methods simplify deep learning feature selection through their built-in feature selection process which eliminates the requirement for distinct selection tools. This punishment makes the model concentrate on the most informative features and downplay the contribution of less relevant features, which results in the selection of sparse features. Moreover, regularization of dropout is used in the training to improve the performance of the model. Through this approach, neurons are randomly disabled and thus the network will not rely on particular features.

**D. Stacked Classifier**

The combined use of MRI data from different sources enables researchers to study Parkinson's disease through its various diagnostic modalities. The different data sources can be effectively merged through the implementation of deep learning classifiers using stacking techniques [36-38]. To reveal too complicated relationships in the data. The common approach to classify sequential or temporal data combines the use of CNNs with long-term memory (LSTM) models. This mixture enables acquire information of part acquires the sequence of events in the data stream. The first stages of the model are CNN layers aimed at extraction of spatial features that allow the system to identify patterns that appear in certain areas of the input. The stacked deep learning classifier of Parkinson's disease classification is described in Fig. 3.

The technique of ensemble averaging bases its operation on the assumption that different models will make distinct errors when they encounter fresh, new data. The research demonstrates that an ensemble model produces more precise results than single models because it decreases forecast uncertainty. The main benefit of this method stems from its straightforward execution requirements. The system successfully utilizes the complete error range of its base models while it maintains operational efficiency without needing extra training on extensive individual prediction data.

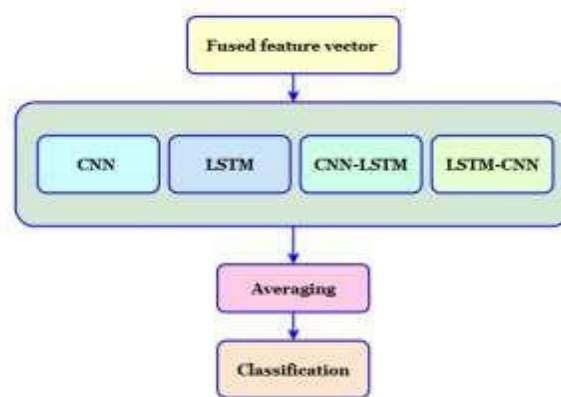


Fig. 3. Stacked deep learning classifiers

#### IV. RESULTS AND DISCUSSION

Machine learning uses cross-validation as a standard method to measure model performance and scalability. The 6-fold cross-validation method divides the data set into six equal-sized sections which researchers call "folds". The training process uses all folds for evaluation while one-fold serves as the validation set which gets used once for each of the five training cycles. The above method has the advantage of making every sample of data used in both training and validation, so that one can determine model performance with respect to distinct subsets of the data. The model's accuracy improves when tested on multiple data subsets because more testing methods such as 10 different tests and leave-one-out make the model's performance predictions more dependable. The process of training and evaluating the model results in substantial increases to computing expenses. The training process requires three or five validation folds which results in decreased computation time. The validation data subset needs more diverse elements because its current state restricts accurate performance assessment of the model. Six-fold cross-validation balances these factors. The system achieves operational performance through its combination of fast processing speed and accurate processing speed measurement. The system tests different model operations by using various data sets while maintaining low processing requirements.

It presents the results of the evaluation assessment. The analysis investigates both standard models and models that detect PD (Parkinson's disease) classification. The base CNN model successfully identified 97 percent of all normal cases. The total class exhibits an accuracy rate of 0.98 which demonstrates an exceptional success rate in identifying true positive cases. The model achieved a recall score of 0.97 which means it successfully identified 97 percent of all positive occurrences. An F1 score of 0.96 was achieved by the general class which denotes high balance between precision and recall.

The original CNN model had a 98 percent accuracy on the prediction of the cases of Parkinson disease, which means they made the majority of predictions correctly having PD-positive cases. It also gained a recall rate of 96 wherein it was able to detect 96 percent of the patients with Parkinson disease. The model had an F1 score of 0.96 as the values of precision and recall of the PD class were equal. The precision score of 0.96 shows that the system achieves accurate true positive results for general situations. The model identified 97 percent of normal events through its 97 percent recall capability. The LSTM model attains an accuracy rate of 95 percent in identifying the disease of Parkinson (PD). Its value of precision (0.95) shows that it is correct to display the predicted PD cases to a large extent. Also, the 95% recall rate of the model indicates that it is effective and can identify 95% of PD patients. The PD class achieves equal performance through its 0.94 F1 score.

The basic model can be improved using CNN-LSTM and LSTM-CNN. The CNN-LSTM model achieved 98% accuracy when it classified normal and PD cases. The proposed model demonstrates strong performance through its precision and recall and F1 scores which both exceed 90%. LSTM-CNN yields 96 percent on general samples and 95 percent accuracy on the cases with the Parkinsonian disease (PD) thus is as good as the baseline model. LSTM-CNN achieves excellent performance through its high precision and recall and F1 score. The proposed Stacked Deep Learning Classifier (SDLC) model reaches 99.4% accuracy for general case classification. The system successfully identifies all positive instances with a precision and recall range between 0.99 and 1.00. The F1 score of 0.99 shows that the system maintains most of its precision while maintaining a lower rate of recall loss. The SDLC model achieves 99% accuracy for PD classification. The system demonstrates high accuracy through its 0.99 accuracy rate for PD predictions. The PD class shows balanced precision and recalls results which produce an F1 score of 0.99.

The accuracy of the LSTM-CNN model is 96 percent which shows that the results are rather high in terms of classification, yet not equal to CNN or CNN-LSTM algorithms. The Stacked Deep Learning Classifier (SDLC) model will provide overall best results with a prediction of PD of 99.4% and classifying almost all the cases of PD. Even though CNN-LSTM and SDLC have the highest accuracies, the other models are not that bad in their performance either as CNN, LSTM, and LSTM-CNN also yield high accuracy rates of between 95-97 percent.

#### V. CONCLUSION

Parkinson's disease is a neurodegenerative disorder that gradually worsens over time and affects a person's ability to move and think and remember things. The most effective way to handle Parkinson's disease symptoms involves identifying the disease in its early stages and starting treatment right away. The process of diagnosing this condition becomes extremely difficult because medical resources and personnel are not available in sufficient amounts. The research developed a solution to this problem through the creation of new deep learning methods which analyse multiple data types to distinguish between people who have Parkinson's disease and those who do not. The study obtained data from PPMI and ADNI databases through the analysis of firm and genetic information. The research focused on predicting which brain regions would experience disease-related changes through the identification of Parkinson's disease and its associated risk genes. The research team aimed to achieve its main research goal by conducting extensive data analysis to understand the basic systems and genetic factors that cause Parkinson's disease to develop and progress. The research study results demonstrate that the multilateral approach shows better performance than both single modal systems and existing multimodal approaches. Stacked Deep Learning Classifier method demonstrated high performance and gave high F1 scores and good accuracy scores. The SDLC method achieved its best performance through its F1 score which reached 0.99 and its accuracy metric which reached 100%. The approach used in the study proves the efficiency and possibility of the given method to work efficiently in patient diagnosis and increase the quality of the data analysis. The research results demonstrate that different experiments show an average F1 score increase which maintains consistent performance across all tests. The research study results demonstrate that training across multiple modalities leads to better results during estimation when one training modality remains inaccessible. This work uses modern multimodal deep learning techniques to advance the research conducted by Parkinson's Disease. The exploration results deliver essential knowledge about fundamental biological mechanisms and genetic elements that cause Parkinson's disease (PD), which leads to improved methods for future diagnosis and treatment.

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