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# Comparative Analysis On The Role Of Multimodal Ai In Parkinson's Disease Diagnosis

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*Abstract:* Parkinson's disease (PD) a degenerative neurological condition that impairs both motor and non-motor abilities. To manage symptoms and enhance the quality of life for patients, early detection is essential. With the use of several data modalities, such as voice recordings, handwriting samples, and facial expressions, this study offers an AI-based predicting method for Parkinson's disease. To determine the probability of Parkinson's disease, the system uses machine learning algorithms to extract important information from these inputs. The suggested method provides a non-invasive, effective, and easily available early diagnosis tool that can help medical practitioners intervene promptly and provide improved patient care.

*Index Terms* - Early Diagnosis, Artificial Intelligence, Machine Learning, Voice Analysis, Handwriting Analysis, Facial Expression Analysis, Predictive Healthcare.

## 1.1 INTRODUCTION

Parkinson's Disease (PD) is a complex neurological disorder that primarily affects movement and motor control, often leading to tremors, stiffness, slow movements, and impaired speech. Early diagnosis plays a vital role in managing symptoms and improving the quality of life for patients, as there is currently no cure for the disease.

This project focuses on developing an AI-powered system for early prediction of Parkinson's Disease by analyzing multiple indicators, including voice patterns, facial expressions, and handwriting samples. By extracting key features from these inputs, the system can assess the risk of Parkinson's Disease and provide a predictive outcome along with a confidence score.

The system is designed to be user-friendly, offering comprehensive analysis and generating a detailed report that can help patients and medical professionals in early detection and timely intervention. This approach leverages artificial intelligence to provide a reliable, accessible, and non-invasive screening tool for Parkinson's Disease.

## 1.2 LITERATURE SURVEY

| Sl.no | YEAR | TITLE | ABSTRACT | METHODOLOGY | ADVANTAGES | DRAWBACKS |
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| 1 | 2025 | Explainable artificial intelligence to diagnose early Parkinson's disease via voice analysis | This study presents an AI-based system for early detection of Parkinson's disease (PD) using voice analysis. A hybrid model combining CNN, RNN, MKL, and MLP achieved 91.11% accuracy on 81 voice samples. SHAP analysis identified key vocal features, enhancing model interpretability. The system offers a non-invasive, cost-effective, and efficient tool for PD diagnosis and progression tracking. | jitter, shimmer, Hybrid deep learning pipeline (MLP + CNN + RNN + MKL), Evaluation metrics: Accuracy, precision, recall, F1-score. | High Accuracy, Explainability, | Limited dataset (81 samples), Single modality (only voice) |
| 2 | 2023 | Parkinson's Disease Prediction: An Attention-Based Multimodal Fusion Framework Using Handwriting and Clinical Data | This study proposes a Multimodal Diagnosis framework (PMMD) for early detection of Parkinson's disease (PD), a neurodegenerative disorder affecting motor function. Using deep learning with cross-modal attention, PMMD integrates imaging, handwriting, drawing, and clinical data to enhance diagnostic accuracy. The model achieved 96% accuracy on | CNN for image patterns, Stroke velocity, pen pressure. | Captures both static and dynamic handwriting traits, improves performance even with small datasets. | Dataset size limited, Overfitting risk, No explainability framework |

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| | | | independent tests, outperforming existing methods. Results highlight the potential of handwriting and multimodal integration as reliable biomarkers, establishing PMMD as an effective AI-based support tool for PD diagnosis. | | | |
| 3 | 2025 | Decoding Parkinson's diagnosis: An OCT-based explainable AI with SHAP/ LIME transparency from the Persian Cohort Study | An explainable AI framework was developed for early Parkinson's disease detection using retinal OCT and clinical data. A 6-layer deep neural network achieved 95.3% accuracy and 0.98 AUC-ROC on the Persian Cohort dataset. Key biomarkers included reduced SUPERIOR4 thickness and increased foveal volume. SHAP and LIME provided interpretability, making the model transparent, non-invasive, and effective for early PD diagnosis. | Face detection, normalization, CNN-based classifiers, Facial action units (AUs), blink frequency, expression intensity. | Non-invasive and easy to capture, Detects early PD signs | camera quality, Dataset size limited (hundreds of samples), Single modality only (facial expression). |
| 4 | 2025 | Tracking Parkinson's Disease Progression Using Deep Learning: A Hybrid Auto Encoder and Bi LSTM Approach | This study proposes a deep learning model for real-time monitoring of Parkinson's disease (PD) progression. The hybrid system combines autoencoders for feature learning and Bi-LSTM networks for temporal modeling using the Parkinson's Telemonitoring | Random Forest, Fusion strategies: Early fusion + Late fusion. | Handwriting + speech , Machine learning models | Limited to two modalities (handwriting + speech),Tradition al ML methods (SVM, RF) |

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| | | | Dataset. Achieving 95.2% accuracy, it outperforms traditional ML methods. The approach enables non-invasive, continuous, and scalable PD monitoring, supporting clinicians in early intervention and improving patient quality of life. | | | |
| 5 | 2025 | Voice analysis in Parkinson's disease - a systematic literature review | This systematic review explores machine learning approaches for diagnosing and predicting Parkinson's disease (PD) using voice and speech analysis. Studies from 2019–2023 were gathered from ScienceDirect, IEEE Xplore, and ACM Library, yielding 106 eligible papers. Most focused-on diagnosis (94.34%), with a smaller portion on prognosis (11.32%). Results show that voice-based ML models achieve high accuracy, highlighting their potential for early and effective PD detection. | jitter, shimmer, harmonic-to-noise ratio. | High accuracy , voice analysis | Data collection complexity ,Training requires large datasets to avoid overfitting. |
| 6 | 2024 | Machine learning for Parkinson's disease: a comprehensive review of datasets, algorithms, | This systematic literature review (SLR) analyzes 133 studies (2021–April 2024) on machine learning (ML) approaches for Parkinson's disease | ML, normalization | easy to collect speech data, Improved performance | Dependent on dataset quality, Limited progression tracking |

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| | | and challenges | (PD) diagnosis. The studies are categorized into five data types: acoustic, biomarkers, medical imaging, movement, and multimodal datasets. The review highlights commonly used datasets, ML algorithms, and evaluation metrics, along with their strengths and limitations. Findings emphasize ML's potential to enhance PD detection and outline future challenges and research directions for improved diagnostic accuracy. | | | |
| 7 | 2024 | A review of machine learning and deep learning for Parkinson's disease detection | This review summarizes recent Machine Learning (ML) and Deep Learning (DL) methods for Parkinson's disease (PD) detection and monitoring. Using data from audio, gait, and imaging, models like SVM, RF, and CNN achieved up to 99% accuracy. Audio and gait analysis aid early detection, while DL enhances imaging-based diagnosis. Key challenges include data quality, privacy, and explainability, highlighting the need for trustworthy, | Deep learning , Machine learning , Artificial intelligence | Improves early detection, highly accurate | Dataset limitations, Explainability limited |

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| | | | scalable AI solutions in PD care. | | | |
| 8 | 2025 | Automatic speech analysis combined with machine learning reliably predicts the motor state in people with Parkinson's disease | This study investigates the effect of levodopa on speech in Parkinson's disease (PD). In 78 participants, acoustic features from standard speech tasks showed that levodopa improved phonatory, respiratory, and speech planning functions, but not articulation. A speech-based biomarker score correlated with motor impairment and distinguished medication-ON vs. OFF states. A post-hoc machine learning model confirmed these findings. | ML models , speech | Closer to real-world applicability | Requires multiple inputs per patient , Explainability not fully addressed |
| 9 | 2025 | A Comprehensive Framework for Parkinson's Disease Detection Using Spiral Drawings and Advanced Machine Learning Techniques | This study presents a machine learning framework for Parkinson's disease (PD) detection using spiral drawings. Deep learning models (ResNet50, VGG16, EfficientNetB0) combined with feature selection (PCA, RFE, LASSO, ANOVA) and classifiers (SVM, RF, MLP, XGBoost, CatBoost, voting) achieved high diagnostic performance. ResNet50 with | Spiral drawing, deep learning models | highest accuracy (98%) | No explainability or progression tracking. |

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| | | | PCA and MLP reached 98% accuracy and 97% AUC-ROC, while other model-classifier combinations also showed strong results. Ensemble methods provided robust AUC-ROC, demonstrating the framework's effectiveness and clinical potential. | | | |
| 10 | 2025 | Voice biomarkers as prognostic indicators for Parkinson's disease using machine learning techniques | This study investigates using vocal features and machine learning to detect Parkinson's disease (PD) early. Using 195 voice recordings from 31 patients, models like Random Forest (RF), SVM, Logistic Regression, and Decision Tree were evaluated with SMOTE and PCA. RF achieved the highest accuracy of 94%, while SVM reached 92%. Results demonstrate that vocal measures combined with ML offer a reliable approach for early PD diagnosis. | vocal measures, ML models | Attention fusion improves robustness to noisy inputs. | Computationally heavy |
| 11 | 2025 | Projections for Prevalence of Parkinson's Disease and Its Driving Factors in 195 Countries and Territories to 2050: Modeling Study of Global Burden of | To predict the global, regional, and national prevalence of Parkinson's disease by age, sex, year, and Socio-demographic Index to 2050 and quantify the factors driving changes in Parkinson's disease cases. | A probabilistic Bayesian model averaging of six Poisson regression models was used to project future prevalence and analyze driving factors. | Worldwide scope and use of current, large-scale data make projections highly relevant | The model does not include many risk factors due to data limitations, may not capture ethnic/genetic specificity, and omits the direct effect of PD trends. |

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| | | Disease Study 2021 | | | | |
| 12 | 2024 | A SURVEY ON THE ROLE ANALYSIS OF PARKINSON'S DISEASE PREDICTION USING MACHINE LEARNING | The study that highlights the benefit of early detection for effective management and suggests that ML-based systems can facilitate accurate, inexpensive, and remote diagnosis. The approach may also be extended to other neurological disorders | Machine learning models (SVM, random forest, gradient boosting, neural networks) are used for binary classification of PD presence.PCA, jitter, shimmer, gait, stride. | Uses inexpensive, readily available data sources, including voice and wearable sensors, which allow easier scalability and accessibility | PD datasets have limited samples and class imbalance, impacting generalizability and sensitivity. |
| 13 | 2024 | PARKINSON'S DISEASE DETECTION BASED ON FEATURES REFINEMENT THROUGH L1 REGULARIZED SVM AND DEEP NEURAL NETWORK | The paper addresses two major problems in Parkinson's disease (PD) detection using speech data: low detection accuracy and inappropriate validation methodologies leading to unreliable results. It proposes a two-stage diagnostic system that first refines features using an L1-regularized linear support vector machine (SVM) and then classifies using a deep neural network (DNN) | SVM, Deep Neural Networks (DNN) trained with the ADAM optimizer, Hybrid Grid Search Algorithm (HGSA), Leave-One-Subject-Out (LOSO) cross-validation and k-fold cross-validation | Addresses inappropriate validation methods by advocating alternative validation approaches like LOSO CV, ensuring unbiased results | Limited by the lack of data regarding disease severity or ON/OFF states in the datasets |

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| 14 | 2025 | PREDICTION OF PARKINSON'S DISEASE A COMPARATIVE ANALYSIS OF SUPERVISED MACHINE LEARNING ALGORITHMS USING VOICE AND SPEECH SIGNAL DATA | Parkinson's Disease (PD) affects motor and speech functions. This study compares Logistic Regression, Random Forest, and KNN on voice data. KNN performed best, reaching 88.2% accuracy | Used a voice dataset from Kaggle, GridSearchCV, Shuffle Split. Models like LR, RF, KNN, Accuracy & F1-score | Early, cost-effective PD detection from speech.KNN: best accuracy; RF: robust; LR: simple baseline | Slow on large datasets. Less interpretable. Limited by linearity |
| 15 | 2024 | AN IMPROVED METHOD FOR DIAGNOSIS OF PARKINSON'S DISEASE USING DEEP LEARNING MODELS ENHANCED WITH METAHEURISTIC ALGORITHM | The study proposes deep learning models (VGG16, DenseNet, InceptionV3, and hybrids) optimized with Grey Wolf Optimization for Parkinson's diagnosis. Using MRI and SPECT DaTscan datasets | MRI and SPECT ,PPMI dataset, trained on four GWO-optimized deep models plus a hybrid, accuracy, sensitivity, specificity, F1-score, and AUC. | The approach achieved extremely high accuracy , robust feature extraction, and automatic hyperparameter tuning via GWO. | Requires high-end GPU and large memory, making it resource-intensive. Limited to binary classification. |
| 16 | 2015 | Foundational acoustic feature modeling (Tsanas et al.) | Established a comprehensive set of dysphonia measures (including jitter, shimmer, HNR, RPDE, PPE) and showed they help separate PD voices from controls and estimate symptom severity. | Extraction of jitter, shimmer, NHR, RPDE, PPE; SVM and regression. | Strong feature basis; high discriminative power. | Small datasets; complex feature extraction. |
| 17 | 2015 | Parkinson's telemonitoring dataset — baseline description & use (UCI) | Introduced/leveraged a telemonitoring voice dataset recorded remotely from PD patients; became a benchmark for PD voice studies. | Collection of sustained vowel recordings; extraction of 16+ voice measures; baseline ML experiments. | Public, reproducible benchmark dataset. | Small subject count; limited task variety. |
| 18 | 2016 | Feature selection and classical ML for early PD detection | Compared multiple feature sets (perturbation, spectral, cepstral) and selection strategies to find compact, high-value subsets. | Feature extraction (jitter, shimmer, MFCCs, HNR), feature selection (mRMR, RFE); RF, SVM, LR. | Compact, interpretable models; good accuracy. | Overfitting risk due to small datasets. |

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| 19 | 2016 | Time–frequency and cepstral analysis for symptom severity estimation | Explored MFCCs, spectrotemporal descriptors, and correlation with UPDRS motor scores. | Compute MFCCs, delta features; regression/ensemble models. | Robust to noise; aligns with standard speech features. | Loses fine dysphonia details; normalization sensitive. |
| 20 | 2017 | Analyzing effectiveness of vocal features in PD monitoring (Sakar et al., PLOS ONE) | Comprehensive evaluation of vocal features on telemonitoring datasets for PD classification and severity estimation. | Extracted multiple voice features; compared classifiers/regressors . | Standardized feature evaluation; widely cited. | Dataset bias; limited number of subjects. |
| 21 | 2017 | Hybrid feature + classifier ensembles for noise-robust PD detection | Combined perturbation, spectral, and cepstral features using ensemble classifiers to improve robustness. | Feature fusion; classifier ensembles (stacking, voting); noise augmentation. | Improved robustness and accuracy. | Increased computational complexity; lower interpretability. |
| 22 | 2017 | Parkinson's Disease Detection from Speech Using CNNs (Vaiciukynas et al.) | Demonstrated CNNs trained on spectrograms can classify PD vs controls effectively. | Spectrogram generation; CNN-based classification. | Learns features automatically; strong accuracy. | Requires large data; overfitting risk. |
| 23 | 2018 | Cross-corpus evaluation and transfer learning approaches | Investigated generalization across datasets and early transfer-learning applications in PD voice models. | Train/test on multiple datasets; fine-tune CNNs. | Demonstrated potential of transfer learning. | Accuracy drops across corpora; data mismatch issues. |
| 24 | 2018 | Combined acoustic + prosodic measures for severity and medication state detection | Studied use of acoustic and prosodic cues to predict medication ON/OFF and symptom severity. | Extract acoustic + prosodic features; RF, gradient boosting. | Captures broader speech behavior; useful for monitoring. | Requires connected speech; context dependent. |
| 25 | 2018 | Smartphone-based PD voice monitoring prototypes | Early prototypes using mobile devices for remote monitoring and data collection. | Mobile app recording; lightweight feature extraction; cloud ML inference. | Scalable and user-friendly; real-world applicability. | Variable audio quality; privacy and noise issues. |
| 26 | 2018 | Multi-feature fusion and deep hybrid models for PD detection | Combined handcrafted features with deep-learned representations to enhance classification. | Fusion of MFCCs, perturbation metrics, CNN embeddings; ensemble deep models. | High accuracy and robustness. | Computationally expensive; less interpretable. |

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| 27 | 2018 | Machine Learning App roaches for Parkinson's Disease Detection | This review explored traditional ML techniques applied to multimodal data for Parkinson's diagnosis, comparing model performance and dataset diversity. | Reviewed machine learning approaches (SVM, KNN, ANN) applied on voice, gait, handwriting, and imaging datasets. | Comprehensive coverage; highlights benchmark datasets; compares traditional ML models. | Limited focus on deep learning; lacks analysis of wearable/smartph one-based systems. |
| 28 | 2018 | Wearable Inertial Sensors and ML for Motor Symptom Monitoring | The paper summarized ML-based wearable sensor systems used for motor monitoring in PD, highlighting advantages in real-time symptom tracking. | Survey of wearable inertial sensors and ML for motor symptom monitoring. | Objective measurement; real-time monitoring possible. | Dependence on device accuracy; less coverage of non-motor symptoms. |
| 29 | 2018 | MRI-Based Machine Learning Methods for Brain Disorders | Focused on MRI-derived biomarkers and ML models in neurological diseases, demonstrating diagnostic potential but noting data scarcity issues. | Reviewed MRI-based ML methods for brain disorders, including Parkinson's. | Strong evidence for imaging biomarkers; compares multiple ML classifiers. | High cost and limited accessibility of MRI; small datasets reduce generalizability. |
| 30 | 2021 | Systematic Review of Multimodal ML Studies in Parkinson's Disease | A large-scale meta-review analyzing multimodal ML approaches in PD detection, emphasizing dataset and model diversity. | Systematic review of 209 studies across speech, handwriting, gait, imaging, and sensors with ML models. | Most comprehensive review; evaluates dataset quality and model performance. | High heterogeneity of studies; many small sample sizes reduce reliability. |
| 31 | 2020 | Deep Learning Architectures for Neuroimaging in PD | Discussed the transition from traditional ML to deep learning in neuroimaging, stressing performance gains and data demands. | Survey of CNNs, RNNs, autoencoders applied to neuroimaging for PD and other disorders. | Highlights deep learning superiority in feature extraction; discusses architectures. | Computationally expensive; requires large labeled datasets rarely available for PD. |
| 32 | 2020 | Speech and Acoustic Analysis with ML for PD Detection | Analyzed ML-based acoustic analysis methods for PD, presenting voice as a promising non-invasive biomarker. | Review of speech/acoustic features (jitter, shimmer, MFCC) and ML for PD detection. | Voice is non-invasive, low-cost, and easy to collect remotely. | Variability due to language/accent; background noise affects accuracy. |
| 33 | 2020 | Wearable Sensor-Based | Examined wearable ML systems for PD management, | Survey of wearable sensors (accelerometers, | Continuous monitoring; supports | Battery, data privacy, and patient |

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| | | ML Systems for PD | highlighting potential for continuous remote care. | gyroscopes) with ML models. | personalized treatment. | compliance issues. |
| 34 | 2019 | Ensemble ML and Smartphone-Based PD Prediction | Reviewed ensemble and mobile ML systems for PD, showing improved accuracy through hybrid approaches. | Summarized ensemble ML methods and smartphone-based remote prediction. | Ensemble improves accuracy; smartphone-based collection is scalable. | Data imbalance; hardware limitations in mobile devices. |
| 35 | 2020 | EEG Signal Processing and ML Classifiers for PD | Explored EEG-based ML techniques for early PD detection, noting advantages in early diagnosis but challenges in noise and standardization. | Review of EEG-signal processing + ML classifiers for PD. | EEG detects functional brain abnormalities earlier than motor symptoms. | EEG signals are noisy; not yet widely standardized in clinical PD use. |

## 1.3 CONCLUSION

The AI Powered Parkinson's Disease Diagnosis Using Multimodal Learning system shows how machine learning and multimodal data can be used to detect the degenerative neurological condition early. The method offers a quick and non-invasive way to detect people who are at risk by examining facial expressions, handwriting samples, and speech patterns. With the use of AI-powered technologies, early diagnosis can facilitate prompt medical action, enhance patient care, and help with symptom management. This experiment demonstrates how artificial intelligence is becoming increasingly important in healthcare and how it may improve disease prevention and prediction.

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