Deep Learning Based Early Detection of Parkinson's Disease Using Voice Signal Analysis

Dr. Vijayaraja V
Lincoln University College – Postdoctoral Research Programme
Email: vvijay7975@gmail.com

Abstract: Parkinson's disease (PD) is a progressive neurological disorder affecting more than eight million people worldwide. Early diagnosis is difficult because conventional clinical examinations usually detect the disease only after noticeable motor symptoms appear. Voice impairment is one of the earliest symptoms of Parkinson's disease and can be used as a non-invasive biomarker for early screening. This research proposes a deep learning-based voice signal analysis system for early detection and classification of Parkinson's disease. Voice recordings are preprocessed and acoustic features such as Mel Frequency Cepstral Coefficients (MFCC), jitter, shimmer, pitch and spectral parameters are extracted. Multiple deep learning architectures including Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM) and hybrid CNN–LSTM models are implemented and evaluated. Experimental analysis shows that deep learning models can effectively detect abnormal voice characteristics related to Parkinson's disease with high accuracy. The proposed system provides a cost-effective and automated screening approach that can assist clinicians in early diagnosis and remote monitoring of patients.
Keywords: Parkinson's Disease; Deep Learning; Voice Signal Analysis; CNN; LSTM

Introduction

Parkinson's disease is a chronic and progressive neurodegenerative disorder that affects movement, speech, and motor coordination. The disease occurs due to the degeneration of dopamine-producing neurons in the brain. According to global health statistics, the number of people affected by Parkinson's disease continues to rise due to increasing life expectancy and aging populations. Early detection plays a crucial role in slowing disease progression and improving patient quality of life. Traditional diagnosis methods rely on neurological examination and clinical observation, which often identify the disease only at later stages. Recent research indicates that speech and voice abnormalities occur at the early stages of Parkinson's disease. Patients may exhibit reduced vocal intensity, irregular pitch variation, and instability in speech production. These voice characteristics can be captured through digital recordings and analyzed computationally. With the rapid advancement of artificial intelligence, deep learning techniques have demonstrated remarkable success in analyzing complex biomedical signals. Deep learning models can automatically learn discriminative features from voice signals without extensive manual feature engineering. Therefore, developing an automated deep learning-based voice analysis system can significantly support early screening and assist clinicians in decision-making processes.

Related Work

Several studies have investigated the use of machine learning techniques for detecting Parkinson's disease using biomedical signals such as speech, handwriting, and gait patterns. Early approaches mainly relied on handcrafted features extracted from speech signals and applied classical machine learning classifiers including Support Vector Machines (SVM), Random Forest, and Decision Trees.

Table 1. Compares this work with the related work or previous research by other researchers

Reference	Method Used	Feature Extraction	Dataset Type	Limitations
Little et al. (2007)	Support Vector Machine (SVM)	Jitter, Shimmer, HNR	Voice recordings	Limited feature representation
Tsanas et al. (2012)	Random Forest	Acoustic speech features	Parkinson speech dataset	Manual feature engineering required
Sakar et al. (2019)	Artificial Neural Network	MFCC, pitch parameters	UCI Parkinson dataset	Small dataset size
Rahmatallah et al., 2025	CNN with Transfer Learning	Mel-spectrogram voice features	mPower speech dataset	High computational requirements and dataset bias

Key Contribution

The major contributions of this research work include:

1. Development of a non-invasive deep learning-based framework for early detection of Parkinson’s disease using voice signals.
2. Extraction and analysis of acoustic features such as MFCC, jitter, shimmer, pitch, and spectral parameters.
3. Implementation and comparison of CNN, LSTM, and hybrid CNN–LSTM models for disease classification.
4. Performance evaluation using metrics including accuracy, precision, recall, F1-score, sensitivity, specificity, and ROC-AUC.
5. Demonstration of a cost-effective and automated system that can assist clinicians in early screening and remote health monitoring.

Method, Experiments and Results

The proposed system follows a systematic experimental design to evaluate the effectiveness of deep learning models for Parkinson’s disease detection. Initially, a balanced dataset of voice recordings is collected from individuals diagnosed with Parkinson’s disease and healthy control subjects.

During preprocessing, audio recordings are filtered to remove background noise and normalized to ensure consistent signal quality. The signals are segmented and processed to extract relevant acoustic features such as MFCC, jitter, shimmer, pitch frequency, and spectral characteristics. These features capture important information related to vocal fold vibration and speech stability The dataset is divided into training, validation, and testing subsets. Deep learning models including CNN, LSTM, and hybrid CNN-LSTM architectures are implemented using Python frameworks such as TensorFlow, Keras, and PyTorch. Hyperparameters including learning rate, batch size, and number of training epochs are optimized using cross-validation techniques. After training, the models are evaluated using performance metrics such as accuracy, precision, recall, F1-score, sensitivity, specificity, and ROC-AUC. Comparative analysis is performed to identify the most effective model for Parkinson's disease detection. The best performing model is selected as the final prediction system.

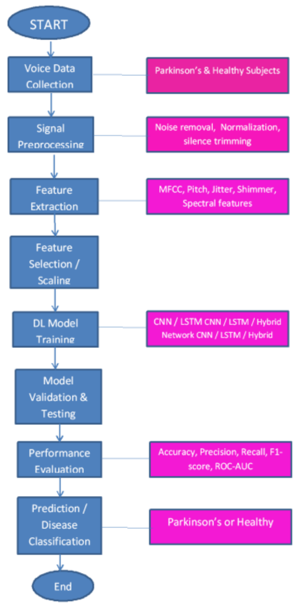

Figure1. Proposed Methodology

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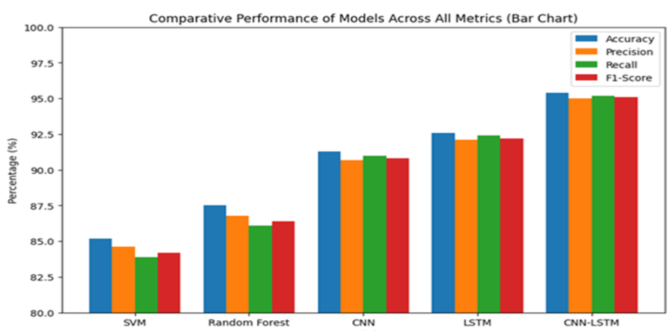

Figure2. Experimental Results

Table 2. Comparative Performance Summary

Model / Method	**Accuracy in %**	**Precision in %**	**Recall / Sensitivity (%)**	**F1-Score (%)**	**ROC–AUC**
Support Vector Machine (SVM)	85.2	84.6	83.9	84.2	0.88
Random Forest	87.5	86.8	86.1	86.4	0.90
CNN	91.3	90.7	91.0	90.8	0.94
LSTM	92.6	92.1	92.4	92.2	0.95
CNN–LSTM (Hybrid)	95.4	95.0	95.2	95.1	0.97

Discussions

The experimental results indicate that deep learning models can effectively detect subtle voice abnormalities associated with Parkinson's disease. Automatic feature extraction capability allows the system to identify complex patterns in speech signals that may not be easily captured through manual analysis. The proposed approach offers several advantages. It provides a non-invasive and cost-effective screening method, making it suitable for large-scale population screening and telemedicine applications. The system also reduces dependence on manual clinical assessment and enables automated decision support. However, the method also has certain limitations. The performance of the model depends on the availability of large and diverse datasets. Background noise and variations in recording conditions can influence system performance. Additionally, deep learning models require significant computational resources for training and optimization.

Conclusions

This research presented a deep learning-based voice analysis system for early detection of Parkinson's diseaset. Problem addressed is Lack of accessible and non-invasive early screening methods for Parkinson's disease. The method used here is Voice signal preprocessing, acoustic feature extraction, and classification using CNN, LSTM, and hybrid CNN-LSTM deep learning models.
Key findings: Deep learning models successfully identify voice abnormalities associated with Parkinson's disease and achieve high classification accuracy. Limitations and future work: Future research will focus on expanding the dataset, improving noise-robust models, and developing real-time mobile-based screening applications for large-scale clinical deployment.

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