



SPEECH SIGNAL PROCESSING FOR AUTOMATED DETECTION OF BRAIN DISORDERS

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ABSTRACT

Speech is a complex physiological and cognitive process that reflects the functional state of the human nervous system. Neurological disorders such as Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis often manifest through subtle changes in speech patterns, including variations in pitch, articulation, fluency, and voice quality. This project focuses on the analysis of speech signals to detect early signs of such neurological conditions using advanced signal processing and machine learning techniques.

The proposed system involves collecting speech samples from individuals and extracting relevant acoustic features such as Mel-Frequency Cepstral Coefficients (MFCC), pitch, jitter, shimmer, and formant frequencies. These features are then analyzed using machine learning algorithms including Support Vector Machines (SVM), Random Forest, and Deep Learning models to classify and predict the presence of neurological disorders. The system aims to identify patterns and anomalies in speech that are often imperceptible to human listeners but indicative of underlying neurological impairments.

Keywords: Speech Signal Processing, Neurological Disorder Detection, Parkinson's Disease, Alzheimer's Disease, Machine Learning, Deep Learning, Voice Analysis, Acoustic Feature Extraction, MFCC (Mel-Frequency Cepstral Coefficients), Jitter, Shimmer, Speech Biomarkers, Pattern Recognition, Artificial Intelligence in Healthcare, Non-Invasive Diagnosis



I. INTRODUCTION

Speech is one of the most natural and efficient modes of human communication, involving the coordinated functioning of the brain, vocal cords, respiratory system, and articulatory organs. Any disruption in the neurological system can significantly affect speech production, making it a valuable indicator for diagnosing various neurological disorders. Conditions such as Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis often lead to noticeable as well as subtle changes in speech characteristics, including reduced vocal intensity, monotonic pitch, slurred articulation, and irregular speech rhythm.

In recent years, advancements in speech signal processing and artificial intelligence have opened new possibilities for early detection and monitoring of neurological conditions. Traditional diagnostic methods for these disorders are often expensive, time-consuming, and require specialized medical expertise. In contrast, speech-based analysis offers a non-invasive, cost-effective, and easily accessible alternative. By analyzing speech signals, it is possible to detect early signs of neurological impairment even before severe clinical symptoms become apparent.

This project focuses on the analysis of speech signals using modern signal processing techniques and machine learning algorithms. The system extracts important acoustic features such as Mel-Frequency Cepstral Coefficients (MFCC), pitch, jitter, shimmer, and formant frequencies, which provide insights into the quality and structure of speech. These features are then used to train predictive models capable of distinguishing between healthy individuals and those with neurological disorders.

II. LITERATURE REVIEW

The analysis of speech signals for detecting neurological disorders has gained significant attention in recent years due to its non-invasive and cost-effective nature. Various researchers have explored different techniques in speech processing and machine learning to identify early symptoms of disorders such as Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis.

Early studies primarily focused on identifying acoustic abnormalities in patients' speech. Researchers observed that individuals with Parkinson's Disease exhibit symptoms such as reduced vocal intensity, monotonic pitch, and increased jitter and shimmer. These findings



led to the development of feature extraction techniques such as Mel-Frequency Cepstral Coefficients (MFCC), which became a standard method for representing speech signals in computational models.

Subsequent research introduced machine learning approaches for classification tasks. Support Vector Machines (SVM) and k-Nearest Neighbors (k-NN) were widely used to distinguish between healthy and affected individuals. These models showed promising results, achieving high accuracy when trained on carefully extracted speech features. Random Forest and Decision Tree algorithms were later applied to improve robustness and interpretability of the results.

With the advancement of deep learning, more sophisticated models such as Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) have been utilized for speech-based neurological disorder detection. These models can automatically learn complex patterns from raw or minimally processed speech data, reducing the dependency on manual feature extraction. Studies have shown that deep learning models outperform traditional machine learning techniques, especially when large datasets are available.

In the context of Alzheimer's Disease, researchers have focused not only on acoustic features but also on linguistic and semantic aspects of speech. Natural Language

Processing (NLP) techniques have been integrated with speech analysis to detect cognitive decline through vocabulary usage, sentence structure, and speech coherence.

III. EXISTING SYSTEM

The existing system for detecting neurological disorders primarily relies on traditional clinical assessments and diagnostic procedures conducted by medical professionals. These methods include neurological examinations, imaging techniques such as MRI and CT scans, and cognitive or motor function tests. Disorders like Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis are typically diagnosed based on observable symptoms and specialized medical evaluations.

In some modern healthcare systems, speech analysis has been introduced as a supportive diagnostic tool. However, these implementations are often limited and not fully automated. They require manual intervention for recording, preprocessing, and analyzing speech samples. The analysis is usually performed using basic signal processing techniques, and the results depend heavily on expert interpretation rather than intelligent systems.



Additionally, many existing systems use small and controlled datasets, which restrict their ability to generalize across diverse populations. The lack of standardized speech databases and variations in language, accent, and speaking style further complicate the detection process. Most systems also focus on a single disorder, making them less flexible and less effective in identifying multiple neurological conditions simultaneously.

Another limitation of current approaches is their dependency on expensive equipment and clinical environments. Patients are often required to visit hospitals or specialized centers for diagnosis, which can be time-consuming and inconvenient, especially for individuals in remote areas. Moreover, continuous monitoring of disease progression is not easily achievable with these traditional systems.

IV. PROPOSED SYSTEM

The proposed system aims to develop an intelligent, automated framework for the early detection of neurological disorders through advanced speech signal analysis. Unlike traditional diagnostic approaches, this system leverages machine learning and deep learning techniques to analyze speech patterns in a non-invasive, cost-effective, and efficient manner. It is designed to identify early symptoms of

disorders such as Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis by detecting subtle abnormalities in speech signals.

The system begins with the collection of speech data through microphones or mobile devices, making it accessible and user-friendly. The acquired speech signals undergo preprocessing steps such as noise reduction, silence removal, and normalization to ensure high-quality input for analysis. After preprocessing, the system extracts important acoustic and prosodic features, including Mel-Frequency Cepstral Coefficients (MFCC), pitch, jitter, shimmer, energy, and formant frequencies.

These extracted features are then fed into machine learning models such as Support Vector Machines (SVM), Random Forest, and Gradient Boosting, as well as deep learning models like Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN). The models are trained on large and diverse speech datasets to learn patterns associated with different neurological conditions. The system then classifies the input speech into categories such as healthy or indicative of a specific disorder.

To enhance performance, the proposed system may incorporate hybrid approaches that combine both acoustic and linguistic analysis. Natural Language Processing (NLP)



techniques can be used to analyze speech content for detecting cognitive impairments, particularly in Alzheimer’s Disease. The integration of multimodal data further improves diagnostic accuracy.

V. METHODOLOGY

The proposed methodology for detecting neurological disorders using speech signal analysis follows a systematic pipeline that integrates signal processing and machine learning techniques. Initially, speech data is collected from individuals using microphones or digital recording devices under controlled or real-world conditions. The collected audio signals are then subjected to preprocessing steps such as noise removal, silence trimming, normalization, and filtering to enhance signal quality and remove unwanted distortions. This ensures that the subsequent analysis is based on clean and reliable data.

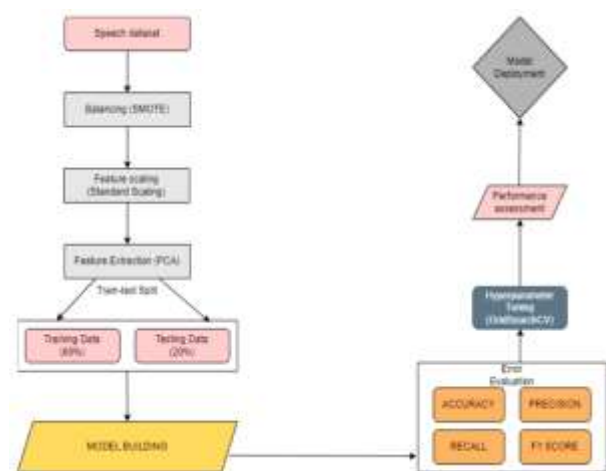
After preprocessing, the system performs feature extraction to capture important characteristics of speech. Key acoustic features such as Mel-Frequency Cepstral Coefficients (MFCC), pitch, jitter, shimmer, energy, and formant frequencies are extracted, as these parameters reflect variations in vocal fold vibration, articulation, and speech

stability. These features are then organized into feature vectors, which serve as input for the classification models.

Next, the dataset is divided into training and testing sets to build and evaluate predictive models. Machine learning algorithms such as Support Vector Machines (SVM), Random Forest, and Logistic Regression are applied to classify speech samples as either normal or indicative of neurological disorders like Parkinson’s Disease, Alzheimer’s Disease, and Amyotrophic Lateral Sclerosis.

VI. SYSTEM MODEL

System Architecture



VI. RESULTS AND DISCUSSIONS

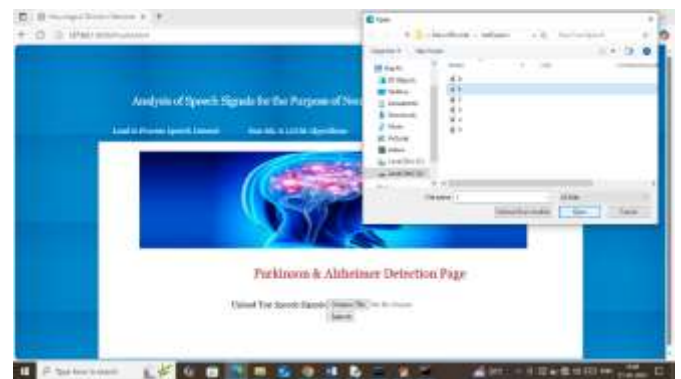
test size and now click on ‘Run ML & LSTM Algorithms’ link to train ML and LSTM algorithms and then will get below page



In above screen in table format can see Random Forest, Decision Tree, SVM and LSTM algorithms performance where LSTM got 96% highest accuracy and can see other metrics like precision, recall and FSCORE. In confusion matrix graph x-axis represents ‘Predicted Labels’ and y-axis represents True labels and then green and yellow boxes in diagonal represents correct prediction count and remaining blue boxes represents incorrect prediction count which are very few. In second graph showing comparison between both algorithms where x-axis represents algorithm names and y-axis represents accuracy and other metrics in different colour bars. Now click on ‘Parkinson & Alzheimer Detection’ link to get below page



In above screen in blue text can see uploaded speech file predicted as ‘Alzheimer’ disease and similarly you can upload and test other speech file and below is another example



In above screen uploading another speech file and below is the output



In above screen selecting and uploading test speech signal file and then system will extract MEL and GABOR features and then input to LSTM algorithm to get below prediction output



Above file predicted as ‘Healthy’ and below is another sample



In above screen uploading another speech file and below is the predicted output



Above uploaded file predicted as “Parkinson”

VIII. CONCLUSION

The analysis of speech signals for the detection of neurological disorders presents a promising and innovative approach in modern healthcare. This project demonstrates how speech, being a natural and non-invasive medium, can be effectively utilized to identify early symptoms of conditions such as Parkinson’s Disease, Alzheimer’s Disease, and Amyotrophic Lateral Sclerosis. By leveraging advanced signal processing techniques and machine learning algorithms, the system is capable of detecting subtle changes in speech that are often difficult to perceive through traditional diagnostic methods.

The proposed system offers several advantages, including cost-effectiveness, accessibility, and the ability to perform early diagnosis. The integration of machine learning and deep learning models enhances the accuracy and efficiency of the detection process, making it a reliable tool for supporting medical professionals. Additionally, the capability for continuous monitoring allows for better tracking of disease progression and timely intervention.

Despite certain challenges such as variability in speech patterns, dataset limitations, and environmental noise, the system provides a strong foundation for future advancements. With further improvements, such as the incorporation of larger datasets, multilingual support, and real-time deployment through mobile and cloud platforms, speech-based neurological disorder detection systems can become an essential component of digital healthcare.

IX. FUTURE WORK: Future work for this

The proposed system for speech-based neurological disorder detection provides a strong foundation; however, several enhancements can be implemented to further improve its performance, scalability, and real-world applicability. Future work can focus on expanding the dataset by including diverse



speech samples from different age groups, languages, and cultural backgrounds. This will help improve the generalization capability of the system and make it more robust in detecting disorders such as Parkinson's Disease, Alzheimer's Disease, and Amyotrophic Lateral Sclerosis across varied populations.

Another important direction is the integration of multilingual and cross-lingual speech analysis. Since speech patterns vary significantly across languages, developing models that can adapt to multiple languages will enhance the usability of the system on a global scale. Additionally, incorporating advanced deep learning architectures such as Transformers and attention-based models can improve feature learning and classification accuracy.

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