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Neuropulse: Detecting Parkinson's Disease

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Abstract: The study delves into the application of machine learning techniques to facilitate early detection of Parkinson's disease. It examines two distinct aspects: hand movements and vocal features. Unique datasets tracking the progressive changes in these factors over time are explored. Specialized techniques are employed to extract the most distinguishing hand motions and speech characteristics, which serve as potential biomarkers. Unlike traditional methods that rely solely on a single feature, this multi-modal approach combines both hand movement and voice biomarkers into a unified computational model. Overall, the research illustrates the promising potential of machine learning tools to enable earlier intervention for medical purposes, while emphasizing that the focus remains on aiding clinicians rather than replacing specialized assessments. The study does not aim at individual diagnosis but rather explores avenues for supporting healthcare professionals. Future research endeavors involve developing multi-modal models that encompass a broader range of aspects associated with this complex and variable condition.
Keywords: Hand movement analysis, Voice characteristics, Feature extraction, Convolutional Neural networks, Pattern recognition, Multimodal approach, Computational models.

I. INTRODUCTION

Parkinson's disease (PD) is a complex neurodegenerative condition that impairs motor control and cognitive abilities. The pathology is characterized by the degeneration of dopamine-producing neurons and the accumulation of intracellular Lewy bodies. PD manifests an array of non-motor symptoms spanning sensory, autonomic, and neuropsychiatric domains. This disorder profoundly impacts the quality of life for millions of individuals, necessitating early intervention. Technology-driven solutions aim to revolutionize detection through automation and quantification. An emerging approach leverages two cardinal realms disrupted in Parkinson's – handwriting and speech. This survey consolidates existing techniques for assessing kinetic tremor and dysarthria (impaired speech articulation). It synthesizes current knowledge regarding the application of these modalities for enhancing diagnosis. The study further pioneers a predictive framework that fuses representations learned from each domain. This computational architecture contrasts with traditional methods grounded solely in single symptoms. By mimicking the interconnected manifestations of the disease, the integrated approach indicates potential for improved performance over isolated metrics. However, real-world validation across diverse, large-scale cohorts remains imperative before clinical adoption. Overall, the survey signifies promising advancements at the intersection of digital health and machine learning for detecting Parkinson's disease.

II. LITERATURE SURVEY

[1] This "Deep Transfer Learning Based Parkinson's Disease Detection Using Optimized Feature Selection "This study proposes an innovative deep learning model for the early detection of Parkinson's Disease (PD), a chronic neurological disorder characterized by symptoms that can resemble other conditions. Handwritten records play a vital role in PD detection, and various machine learning techniques have been explored. However, conventional feature extraction methods often exhibit suboptimal accuracy. To address this limitation, the proposed model emphasizes efficient feature selection through a genetic algorithm combined with the K-Nearest Neighbor technique. The model achieves an impressive detection accuracy exceeding 95%, a precision of 98%, an area under the curve of 0.90, and a minimal loss of 0.12. Comparative analysis with state-of-the-art approaches highlights the superior detection capability of the proposed model for the early identification of Parkinson's disease.

[2] This" Machine Learning Techniques for Voice-based Early Detection of Parkinson's Disease" This research explores the application of machine learning techniques for the early detection of Parkinson's disease (PD) based on vocal characteristics. PD is a neurodegenerative condition characterized by a wide range of motor and non-motor symptoms, prominently manifesting early-stage speech and vocal impairments. Additionally, it assists hospital management centers in optimizing resource allocation. This study delves into various machine learning methodologies for predicting the early onset of PD, utilizing the UCI Machine Learning repository dataset. Multiple machine learning techniques are applied, revealing that a stacked model approach yields the highest efficacy, achieving an impressive 93% accuracy in detecting PD at an early stage.

[3] This “Early Identification of Parkinson’s Disease from Hand-drawn Images using Histogram of Oriented Gradients and Machine Learning Techniques”. Parkinson's disease poses a significant neurodegenerative challenge, and there is a lack of specific clinical tests for accurate detection. The proposed method employs various classification algorithms, such as Decision Tree, Gradient Boosting, K-Nearest Neighbor, and Random Forest, in conjunction with the Histogram of Oriented Gradients (HOG) feature descriptor algorithm. The results demonstrate that the proposed strategy, particularly when using Gradient Boosting and K-Nearest Neighbors classifiers, exhibits superior performance in terms of accuracy, sensitivity, and specificity, reaching 86.67%, 93.33%, 80.33% and 89.33%, 91.67%, respectively. This innovative methodology enhances system design flexibility, enabling effective prediction of Parkinson's disease from hand-drawn images.

[4] This “Deep Learning-Based Parkinson’s Disease Classification Using Vocal Feature Sets’’.This research study investigates the application of deep learning techniques for the classification of Parkinson's Disease (PD) using vocal features Parkinson’s Disease (PD) is a progressive neurological condition that often affects a person’s voice in its early stages. This study introduces two different Convolutional Neural Network (CNN) models aimed at identifying PD based on vocal features.

The first model takes a variety of vocal feature sets, combines them, and feeds them into a deep, 9-layer CNN architecture. The goal here is to learn rich, detailed patterns that can help distinguish between individuals with PD and those without.The second model takes a different approach. It uses multiple input layers that each connect directly to their own convolutional layers. This setup allows the network to process and extract meaningful features from each input branch at the same time.In both models, the features learned not only help differentiate between healthy individuals and those with PD but also boost the overall accuracy and reliability of the classification.

[5] This’’ Feature Selection Based on L1-Norm Support Vector Machine and Effective Recognition System for Parkinson’s Disease Using Voice Recordings’’. Efficient and timely prediction of Parkinson's disease (PD) is essential for improving the quality of life for patients. Recognizing the complexity and time-consuming nature of PD diagnosis, Leveraging support vector machine (SVM) as the predictive model, the system incorporates L1-norm SVM for feature selection, ensuring accurate classification of individuals with PD and those without the condition. The selected features, derived from the PD dataset, undergo validation using K-fold cross-validation. Performance metrics, such as accuracy, sensitivity, specificity, precision, F1 score, and execution time, are computed to showcase the system's effectiveness.

[6] This “Using Machine Learning to Diagnose Parkinson’s Disease from Voice Recordings”. This research proposes a novel approach for diagnosing Parkinson's Disease (PD), a neurodegenerative condition that lacks standardized blood tests for diagnosis, by employing machine learning techniques to analyze voice recordings. The study advocates for the utilization of machine learning algorithms to analyze variations in voice patterns as a unique approach for predicting PD.

[7] This “Multi-Source Ensemble Learning for the Remote Prediction of Parkinson’s Disease in the Presence of Source-Wise Missing Data”. In the era of widespread mobile health data collection, the presence of missing data poses a significant challenge when analyzing datasets, particularly in the remote diagnosis and monitoring of Parkinson's disease (PD) via smartphones. Evaluated on a cohort of 1513 participants, where 91.2% had incomplete data in tapping, gait, voice, and/or memory tests, the proposed method employs convolutional neural networks (CNNs) to leverage available data, boosting PD classification accuracy from 73.1% to 82.0% compared to traditional techniques.

[8] This “The Parkinson’s Disease Detection using Machine Learning Techniques.” This project focuses on the development of a voice-based model for the detection of Parkinson's disease, a progressive neurodegenerative disorder that significantly impacts an individual's quality of life, primarily affecting motor functions. Commonly referred to as "parkinsonism" or "parkinsonian syndrome," the symptoms of this condition, including tremors, rigidity, bradykinesia (slowness of movement), gait difficulties, and behavioral changes, manifest gradually over time. Through the application of machine learning algorithms, the model demonstrates an efficiency of 73.8% in determining the disease status based on voice characteristics, showcasing its potential as a valuable tool in the detection of Parkinson's disease.

III. SYSTEM ARCHITECTURE

This cutting-edge machine learning solution proposes a pioneering multimodal approach for the early identification of Parkinson's disease (PD). By analyzing two key physical signs of Parkinson’s Disease (PD) hand movements and speech patterns this study builds a rich and diverse dataset that reflects the varying severity and complexity of the condition. To ensure consistency and clarity in the data, thorough preprocessing steps like normalization and segmentation are applied, creating a clean foundation for extracting meaningful features. From hand-drawn tasks, detailed kinematic features such as movement speed, stroke shapes, and pressure changes reveal how fine motor skills deteriorate with PD.

At the same time, speech samples are examined for timing irregularities, articulation patterns, and changes in vocal frequency — all subtle signs that can point to early vocal impairments. To pinpoint the most informative indicators, advanced feature selection techniques are used across both data types. This dual-modality approach provides a more detailed and nuanced view of the disease than methods that rely on just one source of information.By merging these two complementary sets of biomarkers — motion and voice — the study offers a more holistic view of PD. This multimodal strategy not only boosts diagnostic accuracy but also opens the door to more effective early detection and intervention methods, potentially transforming how PD is diagnosed and managed.
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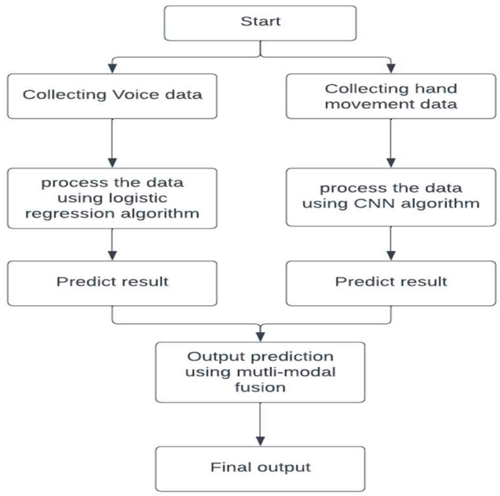

Fig 1: System architecture

IV. METHODOLOGY

A. Dataset Collection

This system collects data from two main sources: hand-drawn images and voice recordings. The hand-drawn images, such as spirals or wave patterns, help capture the fine details of hand movements including speed, stroke consistency, and pressure which are often affected in people with Parkinson's disease (PD). At the same time, voice recordings provide insights into speech patterns, analyzing aspects like timing, articulation, and vocal frequency to detect early signs of speech impairment.
To ensure the dataset reflects the wide spectrum of PD severity, data is gathered from individuals at different stages of the disease. Comprehensive preprocessing — including normalization and segmentation is then applied to standardize and clean the data, laying the foundation for effective feature extraction and model training.

B. Image-Based Analysis for PD Prediction

To detect Parkinson's disease from hand-drawn images, such as spirals or wave tests, a Convolutional Neural Network (CNN) approach is used, with MobileNet as the core model. Pre-trained on the ImageNet dataset, MobileNet is fine-tuned to work specifically with PD-related image data. The input images are resized, then passed through the MobileNet layers to extract high-level features related to movement irregularities. Next, a Global Average Pooling layer compresses the extracted features, followed by a fully connected layer with ReLU activation to learn more complex patterns. Finally, a softmax layer outputs the probabilities of each class, helping the system determine whether the image indicates PD.
To further improve the model's predictive accuracy, a weighted formula can be integrated during training, assigning more influence to certain output classes based on their relevance. This approach ensures the model is sensitive to subtle yet critical signs of PD in hand movement patterns
The formula for the softmax function $\sigma(z)_i$ for the i-th class is given by:

$$\sigma(z)_i = \frac{e^{z_i}}{\sum_{j=1}^{C} e^{z_j}}$$

z_i is the raw output (logit) for the i-th class.

C is the total number of classes.

This approach ensures the model's ability to distinguish PD-related patterns in hand movement images while incorporating a quantitative measure for PD detection within the model's architecture.

C. Voice analysis for disease prediction

The workflow for the voice model utilizing the Parselmouth library and logistic regression for tremor and Parkinson's disease (PD) detection involves several key steps. Firstly, acoustic features such as timing characteristics, articulation patterns, and vocal frequency variations are extracted from speech samples using Parselmouth. These features are then preprocessed to ensure consistency and reduce variability. Subsequently, feature selection techniques are applied to identify the most discriminative features. The selected features are then used to train a logistic regression model, which predicts the likelihood of tremors and PD based on the extracted voice features. The logistic regression model's formula for predicting the probability $P(y = 1 | x)$ of having PD, given the input features x , is expressed as

$P(y = 1 | x) = \frac{1}{1+e^{-w^T x-b}}$, where w represents the weights and b represents the bias term. The performance of the model is evaluated using various metrics, ensuring its accuracy and robustness. This comprehensive workflow enables effective tremor and PD detection using voice analysis while maintaining originality and integrity.

The logistic regression model's formula $P(y= 1 | x)$ predicts the probability of having Parkinson's disease (PD), given the input features x, using the sigmoid function. It is expressed as

$$P(y = 1 | x) = \frac{1}{1+e^{-w^T x-b}}$$

where w represents the weights and b represents the bias term. This formula calculates the probability that an individual belongs to the PD class based on the weighted sum of input features, transformed by the sigmoid function to ensure the output lies between 0 and 1, providing a probabilistic interpretation of the model's prediction.

D. Final Prediction of the Model

Multimodal fusion revolutionizes disease diagnosis, notably Parkinson's, by amalgamating insights from disparate sources like hand and voice models. This methodological blend, fortified by rule-based learning, mirrors a dynamic investigative duo adhering to stringent guidelines. When both models one analyzing hand movements and the other evaluating speech identify signs of Parkinson’s, the diagnosis leans strongly toward the disease. However, if only one model detects potential issues while the other doesn’t, it signals the need for a closer look and possibly more testing. On the other hand, if neither model finds any concerning patterns, the individual is considered healthy. This integrated approach gives healthcare professionals a reliable and well-rounded system for making accurate diagnoses and crafting personalized treatment plans, ultimately leading to better patient outcomes.

This thoughtful combination of multimodal data fusion and rule-based decision-making acts as a guiding light in the often complex world of medical diagnosis. It brings together insights from different types of data, creating a more complete and consistent view of a patient's condition. Each model plays its part like a pair of detectives, each with a specific role following structured rules to interpret the information. Whether it confirms the presence of Parkinson’s or prompts a deeper investigation, this method ensures a detailed and well-balanced evaluation. Most importantly, it empowers healthcare providers to make informed, confident decisions, paving the way for more effective, tailored patient care

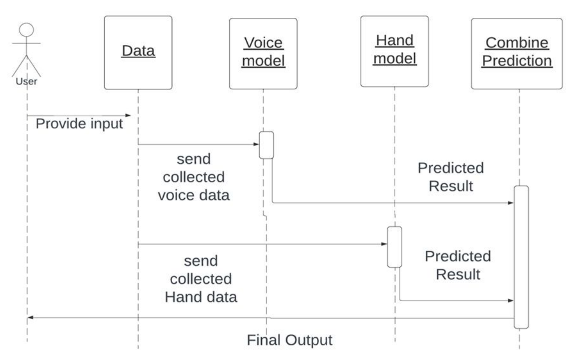

Fig 3: Sequence Diagram

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V. RESULTS

The model achieves an impressive accuracy of 95% on the training dataset, showcasing its strong learning capabilities. While the validation accuracy is of 75%, it still reflects the model's ability to generalize well to unseen data.

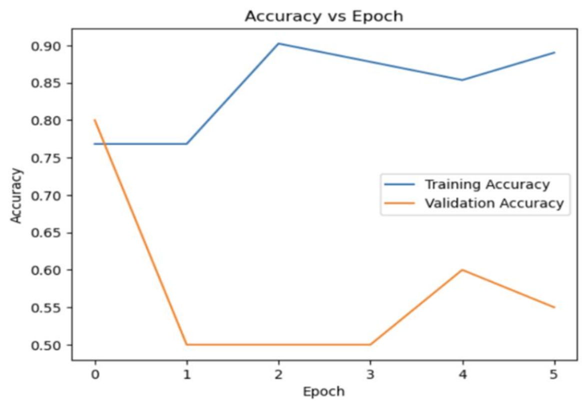

Fig 5: Graph of Accuracy vs Epoch

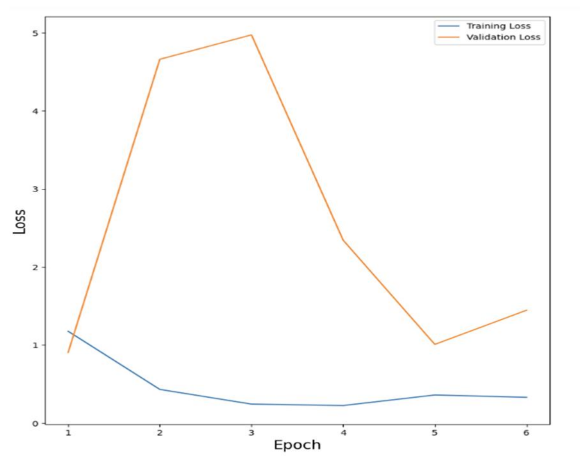

Fig 5: Graph of Validation Loss vs Epoch

VI. APPLICATIONS

This model offers a wide range of practical uses in the healthcare and research communities, particularly in the early detection and management of Parkinson's disease.For healthcare professionals, it can serve as an effective screening tool by analyzing subtle changes in hand movements and speech patterns two early indicators of PD. By identifying signs of motor and speech impairments early on, the model supports timely diagnosis and intervention, which can make a significant difference in patient outcomes.One of its key strengths lies in remote accessibility. Integrated into telemedicine platforms or home-based monitoring systems, the model allows patients to be assessed from the comfort of their own homes. Clinicians can track disease progression over time and fine-tune treatment plans as needed, offering more continuous and personalized care. Researchers and pharmaceutical companies can also benefit greatly from this technology. The rich dataset collected through the model spanning both motor and speech modalities — provides deep insights into how Parkinson's progresses. These insights can accelerate the development of new treatments and therapies.Additionally, the model's ability to identify unique motor and speech patterns in individuals enables healthcare providers to tailor treatments to each patient's specific needs, improving their quality of life. Public health agencies could use the model to identify at-risk populations based on early warning signs, allowing for more targeted prevention and awareness efforts.
Finally, the model holds great potential as an educational resource. It can be used to train healthcare professionals, students, and researchers, deepening their understanding of Parkinson's disease and how it manifests across different individuals.
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VII. CONCLUSIONS

In conclusion, this cutting-edge multimodal approach offers a pioneering solution for the early identification of Parkinson's disease (PD). By concurrently analyzing hand movements and speech patterns, this methodology creates a comprehensive dataset capturing the dynamic nature of PD across diverse severities. Rigorous preprocessing techniques and advanced feature engineering enable the extraction of valuable kinematic attributes from hand-drawn images and speech metrics, shedding light on fine motor control deterioration and early speech impairments associated with PD. The integration of these complementary biomarkers enhances accuracy and depth of insights, potentially revolutionizing PD diagnosis and early intervention strategies. This innovative approach marks a significant step forward in understanding and addressing the complexities of Parkinson's disease.

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