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Deep Learning-based Prediction Models for Parkinson's Disease: A Literature Review

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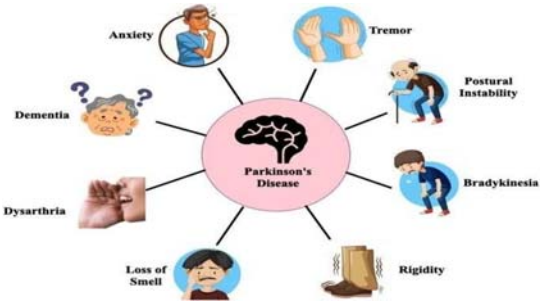
***Abstract*— Parkinson's disease Slowly progressive degeneration of nervous system i.e destruction of brain cells which produce dopamine. It significantly impacts the quality of life for those who have it. Timely and accurate diagnosis is crucial to ensure management and intervention. In years learning techniques have become increasingly popular, for analyzing complex data offering promising possibilities for improving PD diagnosis and tracking its progression. This study focuses on exploring how deep learning techniques can be applied to aspects of Parkinson's Disease such as detection, assessing symptom severity and predicting disease progression. Various Algorithms are used in this project for detecting the illness using both features Hand Drawing and Speech. Additionally, a customized model is developed to determine whether an individual has Parkinson's Disease by utilizing Hand written Images. The process of utilizing learning models for PD diagnosis includes gathering data from sources, preprocessing it, extracting relevant features, training models, conducting testing and evaluating their performance. Transfer learning and domain adaptation techniques are employed to enhance the models effectiveness.**

***Index Terms*— Parkinson's disease, Deep Learning, Hand Drawing, Speech**



I. INTRODUCTION

Parkinson's disease (PD) is a progressive neurodegenerative disease that affects million. This debilitating condition has neurological symptoms shown in Figure 1. tremor, bradykinesia (slowness), rigidity, and postural

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instability, aswell as non-neurological symptoms such as speech andcognition an quick detection of illness is critical for timely intervention, due to the disease Choice of treatment is most effective when started early, traditionally, the diagnosis of PD has increasingly relied on clinical examination by neurologists, which can be subjective and lead to laterdiagnosis. Objective and quantitative biomarkers that can contribute to the early diagnosis and management of the disease are important for clinical and research purposes. Advances in technology and data analytics have opened new possibilities for the development of new methods to aid in the early detection of disease. The research lays a robust groundwork for future explorations aimed at constructing ensemble algorithm for detecting the illness using voice features and hand-drawn images. Each author thoroughly reviewed 10 outof 30 papers. The paper's remainder is organized as follows: Section II provides a thorough review of the existing System, providing an overview of relevant studies. Section III outlines the overarching observations derived from the literature survey. In Section IV, the limitations identified in the literature survey are discussed. The paper concludes witha summary and acknowledgment in the final sections.

II. Literature Survey

Yousif et al. [1] detected the disease using hand-drawingImages and speech data. pre-trained CNN models were utilized, and Different Classification algorithms are used in the analysis. In terms of speech analysis, functions have been extracted from the speech statistics with the use of sixteen distinct function extraction algorithms, including MFCC and ZCR. Additionally, spectrograms were generated from the speech features and various CNNs were applied to them. When assessing accuracy, the average of both methods was considered. However, a significant limitation of their approach is the use of pretrained models instead of custom algorithms, and machine learning algorithms were used for speech analysis where RNNs may be more appropriate. The accuracy achieved was 99.75% using VGG19 CNN and 99.44% using SVM and KNN. Malathi et al. [2] detected PD using a handwritten dataset. The model used was efficientNet-B3 using a dataset from UCI repository. The accuracy they have achieved is 99.03% at 90 epochs. Aveleira-Mata et al. [3] employed a dataset containing various biomedical voice measurements obtained from 42 individuals. They utilized an autoencoder for data reduction and implemented several models, includ-ing MLP (Multi-Layer Perceptron), MLP after autoencoder, Autoencoder with MLP, and a Double-Task MLP for Supervised Learning Technique. H. Gunduz et al. [4] applied the CNN algorithm to analyze spectrographs. The results showed an impressive average ac- curacy of 98.15%.Notably, this study highlights that regression problems may yield better results than classification tasks in the context of PD detection. Sahu et al. [5] focus on efficiently detecting Parkinson's disease (PD) using a hybrid approach combining Recurrent Autoencoders (RA) and Artificial Neural Networks (ANN) to estimate disease probability. The dataset contains five features, each with 741 values. The detection process includes three steps: Probability Estimation with MSE, ANN Classifier for Probability Computation, and a Hybrid RA-ANN for Accurate Probability Estimation of PD. Features like PPE, DFA, RPDE. Numerous category Algorithms gave distinct accuracy. For a Handdrawing Dataset using Decision Trees and Deep Learning (DTL), the accuracy reaches 99.22%.Kamran et al. [7] Developed a model for detecting the Disease by analyzing patients handwriting patterns using various CNN architectures, including AlexNet, GoogleNet, VGGNet, and ResNet. However, the study has notable limitations. N. P. Narendra et al. [12] focus on voice source information. The dataset comprises 50 PD patients, with an equal distribution of 25 male and 25 female subjects, and features Spanish record- ings. Various machine learning algorithms, including SVM, CNN, and MLP, are employed, and three baseline feature sets are evaluated. Among these sets, articulation features proveto be the most effective in PD detection. The study also underscores the importance of incorporating glottal features using the QCP method with the help of different approaches mentioned in the paper. H. Azadi et al. [13] suggested an approach for detecting the Disease using voice features. The dataset contains 224 voice phonation's collected from 47 individuals, including 23 individuals with the illness. We conduct separate analyses for male, female, and combined populations. It is important to share the restrictions of the approach mentioned in the paper, which include the challengeof voice feature variability and noise, potential gender-specific performance differences, and the relatively small dataset consisting of 47 subjects. A. Shoeibi et al. [16] have used least squares SVM to categorize the dataset obtained. The paper has considered different criteria to rank features. Type-2 Fuzzy Analytical Hierarchy Process (IT2F-AHP) is employedto rank the above criteria (IT2F-AHP) is an extension of the AHP that incorporates Type-2 Fuzzy Logic. In AHP, decision-makers create a hierarchy of criteria, sub- criteria, and alternatives. They then assign numerical values to represent the relative importance or preference for one element over another. Fuzzy logic is a mathematical framework usedto work with ambiguity in data or decisions. Allow values to be expressed as truth levels, often on a scale of 0 to1, rather than just true or false (1 or 0).Type-2 fuzzy logic extends standard fuzzy logic by introducing additional levels of uncertainty, such as fuzzy sets having their own

membership functions. This allows for a more flexible representation ofuncertainty. Shivangi et al. [17] have employed DL modelsfor diagnosing the infection in the early stages. Algorithm consists of a VGFR Spectrogram Detector, which uses CNNfor classifying spectrogram images of motion signals and the other is a Voice Impairment Classifier, which uses ANNs of deep dense networks to analyze voice recordings. E. J. Alqahtani et al. [18] have employed the NNGE (Non-Nested Generalized Exemplars) classification algorithm, which comes under the family of nearest-neighbor-like algorithms. NNGE (Instance Generalized Unexpected) is a classification algorithm that generalizes new instances and the nearest neighbors of a class while avoiding generalization and ensuring consistency. The paper also employs the SMOTE algorithm, which stands for "Synthetic Minority Oversampling Method," which is an algorithm used in machine learning and data mining to solve class inequality problems in databases. SMOTE is designedto increase the number of cases in the minority class by creating synthetic examples, thereby helping machine learning models perform better in unbalanced databases. This is done by interpolating between existing minority classes to create an additional synthetic sample that can equalize the class distribution and improve the model's ability to learn from minority classes and ensemble algorithms like AdaBoostM1 have been used alongside NNGE to improve the accuracy of the proposed model. A. Agarwal et al. [19] have used an ELM method which comes under feed-forward neural networks and the dataset has been collected from UCI repository. This employed technique achieves a huge accuracy. N. Fayyazifar et al. [20] focus on early identification of disorder through Speech features. This study employs ensemble techniques, specifically AdaBoost and Bagging, in combination with a Genetic Algorithm for feature selection to achieve accurate PD detection. Genetic Algorithm (GA): The authors employ a genetic algorithm to select an optimal set of features from a high-dimensional feature vector extracted from voice recordings. This reduces the dimensionality of the feature vector from 22to 6 features, making the analysis more efficient. Ensemble Learning: Two ensemble learning techniques are used for classification: AdaBoost and Bagging. Ensemble learning combines multiple models to improve classification accuracy and compared all the models. In this case, it is applied to classify individuals as either having PD or being healthy based on their voice features. Y. Li et al.[21] introduced an innovative hybrid algorithm for feature learning on voice recordingsfor the classification of the disease. Evaluation criteria included in feature selection. S. Biswas et al. [22] have used DL models like CNN and LSTM for the detection of PD form hand- drawings in dataset which consist of 35 healthy people and 31 PD patients. M. Wodzinski et al.[23] have used a DL model based on CNN (pre-trained networks) for the detection of PD using the dataset from PC-GITA [15] dataset which includes the corpus of 50healthy Unhealthy persons. For the SVD database, the minibatch size was 64 and for the Parkinson's database, it was 16. S. A. Kumar et al.[24] have employed the YAMNet model for identifying the disease using voice recordings using theprovided dataset which consists of 130 audio files per 4 seconds. The YAMNet model, which is an existing DL algorithm utilized for feature extraction and classification. J. Gascon et al. [25] have used two distinct deep-learning models to detect PD, One pertains to image detection, while the other is associated with tasks in computer vision. The dataset consists of two kinds of drawings that are spiral and wave from the UCI repository. The image detection algorithmis pretrained and the accuracy is 98%. S. Chakraborty et al.[26] explained the importance of overfitting and How it is effected, Suggested a system for identification of the illnessby utilizing the dataset consisting of 2 different types of drawing and using deep learning neural networks(Existing models/pre-trained) and meta-classifier. CNNs are trained on a dataset of 55 subjects and features extracted. The meta-classifier is either a random forest or a logistic regression model. Ali et al. [27] have used a system that can detect PD from voice signals. The paper achieves this by using lineardiscriminant analysis which uses PCA extracted signals which is used for the optimization of hyperparameters in neural networks which is also used as a predictive model andfor validation and to avoid subject overlap in the dataset. Saeeda Naz et al. [29] have detected PD from handwriting dynamics using neural networks. with deep layers. To enhance model performance and increase the dataset size, data augmentation techniques are applied. The study explores the effectiveness of various pre-trained deep learning models. Multiple Parkinson's disease handwriting datasets are combined for the analysis, including PaHaW, HandPD, NewHandPD, and Parkinson's Drawing. This integrated approach enables a more reliable assessment of the potential of the deep nervous system in the diagnosis of PD. K. Yang et al. [30] have employed a novel neural network with deep layers (PDGNet)to predict the PD of the dataset from the DisGeNet database as shown in Table 1. This model uses adeep neural network model to combine multivariate characteristics.

III. OBSERVATIONS

Classification is employed to detect Parkinson's Disease (PD), while regression gauges its severity and evaluates the disease's degree. It's apparent that a smaller dataset negatively affects performance, underscoring the impact of dataset size and the number of classes on model accuracy. Whenever the Dataset size is small we observed that

we can utilize the different methods to augment the dataset size and improve the model's accuracy through augmentation techniques shownin Table 1 Hand-drawing Images like meander, spiral, and wave prove effective in accurately identifying early-stage ofthe illness. Ensemble learning methods can enhance outcomes by improving individual classifiers and mitigating variance. From Table 1, it is observed that Transfer Learning based Approach results in giving better accuracy.

TABLE I. OBSERVATIONS AND LIMITATIONS FROM LITERATURE SURVEY

S. No	Reference No	Observations	Limitations
1	[1]	1) There are 8 pre-trained CNN models for hand drawings. 2) The decision was based on the performance of the Handwritten model and Speech model with the maximum accuracy of 99.75% for the first and 99.94% for latter.	1) The datasets used are small and both of them do not belong to the same person. 2) There are more disadvantages of using pre trained model than the advantages
2	[3]	1) Classification used for determining the presence of PD and regression used for the evaluation of disease. 2) 99.15% of average accuracy is obtained in classification tasks and an average MSE is 0.1576.	The dataset is manually recorded and consist of single point of recordings
3	[5]	1) It first includes finding the probability of PD using MSE and computation of probability through ANN classifier 2) The accuracy obtained through ANN classifier is 81.12%	1)Dataset not available publicly. 2) No proper information regarding the features used.
4	[6]	Transfer Learning Approach produces better results 1) For 'a' it is 73.7%, for 'e' it is 75% , for 'i' it is 81.4% , for 'o' it is 72.6 %, for 'u' it is 82.3% on Epoch size 9 2) For word /apto/ accuracy 77.2% for epoch size 7 and weighted learning rate - 60	1) No comparison between other methods for the same problem. 2) The data is not sufficient.
5	[7]	1) Smaller the network the better the accuracy. 2) Data augmentation techniques and multiple combined datasets result in improved performance	The paper doesn't explore the possibility of using other features for PD diagnosis
6	[8]	1) Able to identify subtle changes in symptoms 2) Able to provide insights like specific biomarkers and clinical parameters	1) No integration of multi-modal data sources. 2) Less data for training
7	[9]	1) Achieves high accuracy in identifying the disease 2) The dynamic features extracted are used as biomarkers	1)Overfitting concerns due to less data 2) No integration of additional modalities, such as facial expressions or physiological signals
8	[10]	The model performance is increased due to DCGAN based spectrogram	1) No usage of other advanced deep-learning techniques. 2)The introduction of synthetic bias
9	[11]	1) Linear Discriminant Analysis (LDA) gives an accuracy of 96%	CROWD:autoencoder not integrated with fuzzy models
10	[12]	1) Pipeline approach achieved a accuracy of 67.93% and end-to-end approach achieved a accuracy of 68.56%	1) Does not predict the severity of PD. 2) No Investigation of multiclass classification models
11	[13]	1) 10-fold cross validation achieved 95.14% accuracy 2) Leave one speaker out achieved 93.23% accuracy	1) Voice features are variability and a lot of noise present in them. 2) No gender specific performance difference
12	[14]	1) Dynamic spiral test features are more informative for PD detection 2) It has achieved 88.89% accuracy for Dynamic spiral test features	Does not provide the impact of hyperparameters on accuracy.

13	[15]	1) Image Transformer architectures outperform other deep learning models 2) Achieves accuracy of 92.37%	Didn't give detail explanation about Image Transformer architectures
14	[28]	Ensemble techniques improves the result of individual classifiers and they reduce the variance	Does not provide the interpretation of selected feature
15	[30]	Achieves higher prediction performance compared to other models.	PDG Net may not be able to predict candidate genes accurately if data for genes are missing.

IV. Limitations

- Used Pre-trained CNN
- The datasets of hand-drawn images and voices do not belong to the same person.
- Dataset size is small i.e Overfitting occurs due to less data.
- The analysis neglects the explanation of how various parameters such as learning rate, batch size, and epoch count, influence the overall performance of the model.
- Small size and imbalance of the PD dataset, which may affect the generalization and robustness of the model.

V. Conclusion

The development of an ensemble model for detecting the illness using hand-drawing images and speech data represents a promising advancement in the field of neurodegenerative disease diagnosis. Addresses several critical challenges associated with PD detection, offering potential benefits forboth patients and healthcare providers to achieve betteraccuracy for early diagnosis of the Disease.

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