Review: Utilizing Machine Learning Techniques for Timely Diagnosis of Parkinson's Disease

Mohd Azhan Umar kamil[1], Muneeba Rahman[2], Ahsan Waseem[3], Mohd Dayyan Ali[4], Mohd Talha Khursheed[5]

[1,2]Student, Department of Computer Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh
[3]Student, Department of Electrical Engineering, Zakir Husain College of Engineering and Technology, Aligarh Muslim University, Aligarh
[4]Student, Department of Computer Science, Aligarh Muslim University, Aligarh
[5]Student, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh

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Abstract - *The second-most dangerous neurological condition, Parkinson's disease (PD), has a history of lowering people's quality of life (QOL). Parkinson's disease is a neurological condition that worsens over time, caused by the degeneration of dopaminergic neurons in the substantia nigra. It is characterized by slow movements, tremors, rigidity in the limbs, and changes in gait such as an abnormal forward-leaning posture, a shuffling gait, a tendency to take small rapid steps, difficulty initiating movement, and a higher risk of losing balance and falling. However, the initial symptoms of Parkinson's disease may be subtle and easily missed, leading to a delayed diagnosis after significant neuronal damage has already occurred.*

Early PD discovery allows for prompt treatment intervention, which lowers morbidity. However, The elderly population, which has a higher prevalence of Parkinson's disease, often experiences progressive slowness due to other health conditions, it can be difficult to correctly identify PD, especially in the early stages. Recent improvements in imaging, biomarker analysis, and other diagnostic tools have made it easier to detect PD early. Magnetic resonance imaging (MRI) has been used to detect changes in the substantia nigra and other brain regions, while biomarker analysis of cerebrospinal fluid and blood has revealed changes in the levels of specific proteins associated with PD. Additionally, several behavioral and cognitive tests have been created to examine the early signs of Parkinson's disease (PD). Optical coherence tomography (OCT) is a type of medical imaging method that creates detailed images of the retina without the need for invasive procedures. By using light waves, OCT can produce high-quality and precise images of the retina. The use of Optical coherence tomography (OCT) has made it possible to measure the thickness of the retinal nerve fiber layer (RNFL), which is proving to be a useful tool in the early detection of Parkinson's disease. OCT is a promising method for early diagnosis because research has indicated that individuals with Parkinson's disease exhibit significantly lower RNFL thickness compared to healthy individuals.

We examined various research articles published until 2022 to gain a comprehensive understanding of the data formats and artificial intelligence (AI) techniques utilized in Parkinson's disease research and diagnosis. The aim was to address the challenge of distinguishing subjective diseases from healthy individuals who exhibit similar medical features by employing machine learning (ML) methods. Through our analysis of 30 academic papers, we discovered that the use of ML methods and novel biomarkers has great potential in improving the diagnostic process for PD, thereby enhancing clinical decision-making.

Key Words: PD, Parkinson's Disease, Neuro-degenerative, Dopamine, Machine Learning, Deep Learning, Neuroimaging, Gait datasets, Voice-based datasets.

1. INTRODUCTION

The human brain is the body's main processing center, even a relatively modest injury to one area of the body can have far-reaching effects on the rest of the body. PD [1] is one of its hidden effects. Parkinson's disease is a type of incurable neurological disorder that worsens over time [2]. Around the world, approximately 9.4 million individuals were still affected by this illness in the year 2020 [3]. People over the age of 60 are most likely to get this disease.

Only 4% of people under the age of 50 get it [4]. There are both motor and non-motor signs of this disease [5].

Movement slowness, The major motor symptoms of Parkinson's disease include tremors, difficulty walking, unstable stance, rapid eye movement problems, and shivering. [6,7]. Low blood pressure, sweating, weariness, constipation, urinary issues, and weight loss are among non-motor symptoms [8]. According to research, speech and voice acoustic problems are present in 90% of individuals with Parkinson's disease [9]. These issues may include microphonia, dysarthria, monochromatic speech, and dysphonia [10]. Therefore, the loss of one's voice is often the first symptom of this illness [11]. While there is no cure for the disease as of yet [12], during the initial stages, there are several medications available that can help alleviate its symptoms. The voice frequency analysis is quick and painless. As a result, changes in voice frequency can serve as a potential method for monitoring the progression of Parkinson's disease [13]. To track the advancement of this challenging disease, several speech tests have been carried out. Machine learning (ML) techniques are commonly employed in the healthcare industry for this purpose. Different kinds of data, like voice recordings and handwritten patterns, are being used by ML algorithms for PD detection. The proper qualities that aren't typically utilized to define Parkinson's disease (PD) may be discovered with the aid of ML approaches, and these additional symptoms may be employed to identify PD in its pre-clinical phases. There are typically three stages in making a diagnosis for this illness: the steps of (1) data preparation, (2) feature extraction, and (3) classification techniques [14,15,16].

The purpose of this study was to provide neurologists with insights that might aid in the diagnosis and treatment of Parkinson's disease by looking into untested methods and offering unexplored alternatives. This paper's contribution is as follows:

- We provide background information on Parkinson's disease, outlining its primary traits and the main motor and non-motor symptoms.
- Using speech, handwriting, and gait metrics, we categorized ML models and examined their diagnostic efficacy for Parkinson's disease.
- The paper concludes by highlighting the difficulties and outlining suggestions for further work.

We explain what you need to know about Parkinson's disease, including its main signs and symptoms, both motorized and non-motorized. We put ML models into groups and looked at how well they could diagnose Parkinson's disease by analyzing speech patterns, handwriting, and walking factors. In this study, we also talked about a different ML-based framework for diagnosing Parkinson's disease. The goal is to improve Parkinson's disease data. The article's challenges and suggestions for future research are discussed in the paper's conclusion.

2. METHODOLOGY OF THE STUDY

2.1 Data Acquisition

We collected scientometric data from various databases including Web of Science, IEEE, Scopus, and ScienceDirect to diagnose subjective diseases. Our analysis used up-to-date data from various research papers containing the latest research and findings related to Parkinson's disease up until 2022. This data was collected from multiple sources and included abstracts, concepts, and other relevant information. The search process was systematic and thorough, ensuring a comprehensive overview of the disease. Furthermore, artificial intelligence was utilized for disease diagnosis. The indexing process for this database is quick and comprehensive, allowing for the easy retrieval of recent research papers. This resource provided us with access to numerous databases from various fields, enabling us to offer extensive coverage in our analysis.

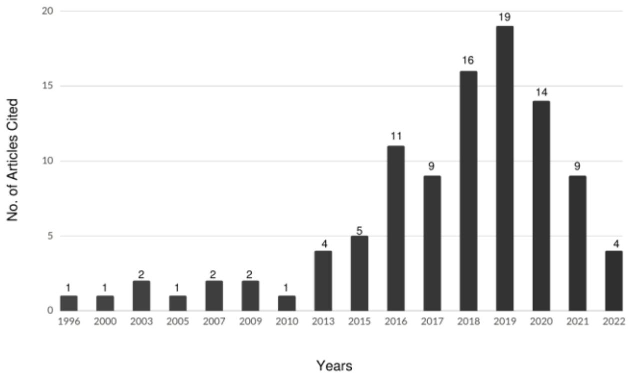

Fig -1: The number of articles cited between the years 1996 and 2022.

2.2 Journals

By looking at 103 articles released between 1996 and 2022, a systematic analysis of the ML approach to diagnosing PD was done. Figure 1 shows the major journal that writes about how different ML techniques can be used to diagnose Parkinson's disease. The studies reviewed in this analysis demonstrate that feature selection techniques and machine learning (ML) algorithms can be utilized to extract valuable insights regarding both motor and non-motor symptoms of Parkinson's disease. This allows medical professionals to make informed decisions by utilizing data from the available datasets. In collaboration with the National Centre for Voice and Speech in Denver, Colorado, MA Little and colleagues established a database by obtaining speech signals in 2017. To classify PD, the authors employed a kernel-support vector machine. Little's PD voice datasets have been the subject of a variety of investigations up to this point, with varying degrees of accuracy obtained by employing various categorization techniques. The works were filtered by looking at the abstracts, and full-length publications were retrieved if there was any doubt about the relevance of the findings.

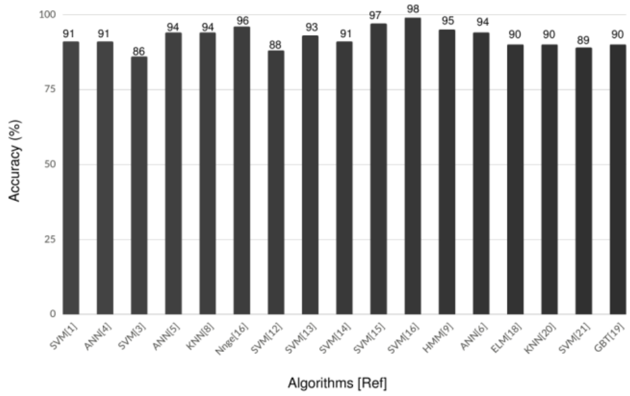

Fig -2: A comparative analysis of ML algorithms employed in the detection of Parkinson's disease, with a specific emphasis on accuracy rates. (I) based on speech characteristics between 2015 and 2020.

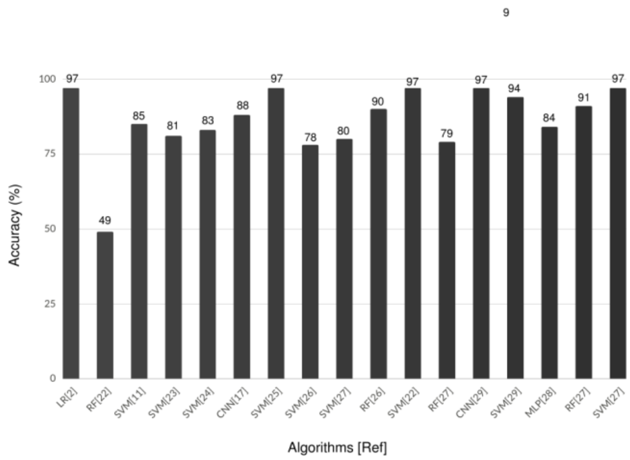

Fig -3: A comparative analysis of ML algorithms employed in the detection of Parkinson's disease, with a specific emphasis on accuracy rates. (II) based on characteristics of handwritten spiral patterns during the period of 2015 to 2020.

In order to ensure that relevant research was considered, the final analysis focused solely on publications that dealt with the use of machine-learning approaches for diagnosing Parkinson's disease.

3. Parkinson's Disease: Background

Parkinson's disease (PD) is a developmental disorder that affects the sensory systems and is characterized by tremors, stiffness, slowed mobility, slurred speech, and flat facial expressions [17-19]. PD symptoms typically develop gradually over time, and there is currently no cure for the disease, although medication and surgery can help manage symptoms [17]. In some cases, doctors may recommend regional brain control as a medical intervention to alleviate symptoms further [20].

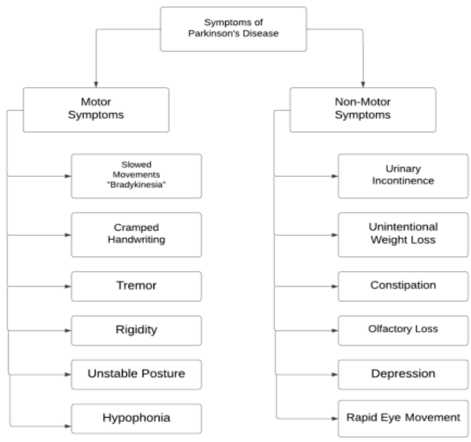

Fig -4: Symptoms of Parkinson's disease.

Studies estimate that seven million people over 60 years old in India are living with PD, which is an illness with unclear diagnostic criteria [21]. Parkinson's disease affects more than a million people in the United States, surpassing the total number of individuals affected by Lou Gehrig's disease and multiple sclerosis [17]. It is predicted that this number will increase to 1.2 million by 2030. The symptoms, treatment responses, and negative effects experienced by Parkinson's disease patients can vary significantly, and while researchers suspect a combination of genetic and environmental factors contribute to the illness, they cannot be certain [22]. Only 10%-15% of correlation between a family history of Parkinson's disease and its occurrence in individuals, and some families have a history of passing down mutations or other changes to certain genes [22].

A complete understanding of the molecular foundation of Parkinson's disease is still lacking, but researchers have identified six genes involved in the inheritance of the disease: Parkin, VPS35, DJ-1, LRRK2, alpha-synuclein, and PINK1 [23]. While the first mutation related to PD was discovered over 20 years ago, recent advances in technologies like next-generation sequencing and genome-wide association studies have led to significant progress in PD genetics studies [23].

4. Machine Learning Techniques to Diagnose Parkinson's Disease

According to the study, machine learning (ML) methods like support vector machines (SVM), artificial neural networks (ANN), naive Bayes, logistic regression, classification and regression trees (CART), decision trees, etc. have shown promising results in predicting the severity of Parkinson's disease (PD) based on clinical metrics with reasonable accuracy. ANN is frequently used for classification and regression issues when there is a strong correlation between features. Access to both training and test datasets is necessary for ML algorithms to function effectively. While algorithms that can synthesize data are the primary focus of ML, any method that can learn from past data to improve performance is included in the field.

By providing symptoms to the algorithm as an attribute, ML can assist in diagnosing PD. Tremors, speech analysis, and handwriting analysis are all used to determine the severity of PD. Various methods have been attempted over the years to diagnose PD reliably.

Resul Das [1] used the same dataset as Little et al. and compared four different methods to diagnose PD: neural networks, data mining neural networks, logistic regression, and decision trees. The Multi-layer feed-forward neural network with the Levenberg–Marquardt algorithm performed the best out of the four methods, with a 92.9% success rate.

Freddie and Rasit [2] employed nine parallel feed-forward neural network techniques on the same voice dataset to predict PD, resulting in an 8.4% increase in the likelihood of PD compared to using a single network. Hui-Ling Chen et al. [3] used a fuzzy k-nearest neighbor approach with Principal Component Analysis on a similar voice dataset to forecast PD and identify the feature subset from the entire feature space. Their technique outperformed previously attempted methods.

Omer et al. [4] examined the accuracy of LS-SVM, SVM, MLPNN, and GRNN when applied to remote monitoring of PD progression. It was seen that LS-SVM maps vocal traits to UPDRS data better than the other methods.

It has been observed that a majority of individuals with PD often face challenges in terms of mobility and speech. In order to accurately measure the severity of motor dysfunction, You-Yin and colleagues have developed a gait regression model that utilizes a collection of gait images. This approach presents a novel and promising technique for assessing the extent of motor dysfunction in individuals with PD.

5. Modification to the ML Framework

There are many possible outcomes since there are so many input factors. For Parkinson's disease (PD) diagnosis, ML algorithms excel when an acoustic voice feature is used as the input variable. The primary motivation for using ML on acoustic voice datasets was for early diagnosis of PD symptoms [25]. Training models can be quite helpful in early PD screening in some circumstances where a gold standard is available. A specific combination of ML techniques, including principal component analysis, was used to reduce the dimensionality of the input datasets. Speech database features can be analyzed with classifiers such as decision trees and k-means clustering techniques to reliably label voice data as either normal or PD.

Since the acoustic speech data was deemed to be in violation of the data in components, it was decided that the most effective course of action would be to use ML techniques like HMM to learn the acoustic speech data and then perform the detection. Utilizing a deep-learning convolutional neural network (CNN) classifier, which has been trained using transfer learning techniques and data augmentation methods, is one approach for predicting the probability of Parkinson's disease (PD). However, detecting PD in the early stages through handwriting data can pose a significant classification challenge. By using the ImageNet and MNIST databases as input sources separately, the classification accuracy was considerably improved.

5.1 Voice Datasets as Input

In a study documented in [26], a range of machine learning classifiers, including SGD, logistic regression, XGB, KNN, random forest, and decision trees, were employed to diagnose Parkinson's disease. The authors utilized feature extraction techniques to improve the accuracy of the trained models by obtaining characteristics from the input data. They reduced the data's dimensionality by removing irrelevant records and combining variables into features that best represented the dataset.

The authors utilized data mining techniques to differentiate individuals with Parkinson's disease (PD) from those without the condition by examining specific speech-related features, with the goal of achieving a high level of accuracy in prediction. They selected PD diagnosis as the target variable and updated the input dataset column accordingly. Lastly, the ML algorithms were evaluated and compared based on their performance, with the random forest classifier achieving the highest accuracy of 97.10%, while SGD and logistic regression had the lowest accuracy of 91.66%.

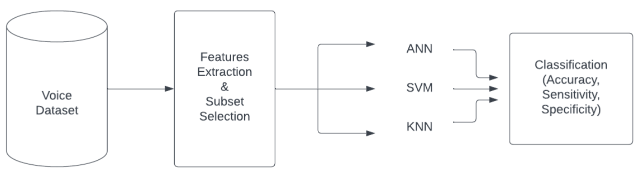

Fig -5: Methods employed for classifying Parkinson's disease (PD).

5.2 Handwritten Patterns as Input

A Structural Co-occurrence Matrix (SCM) based method for PD diagnosis was described in [27]. Features were extracted from the Hand PD datasets using assessments of spiral and meander handwriting [28]. The study details a system that uses both a standardized test plan and a student's handwriting to evaluate performance. A segmentation process is utilized to create two distinct images from the original image, which are then processed using digital image processing techniques to produce grayscale images. Once the grayscale images have been segmented and transformed, feature extraction can be performed. These grayscale images serve as input images for the SCM.

To analyze the relationship between data in a two-dimensional space, the researchers employed feature extraction with the SCM. The study used data from 92 individuals, including 74 PD patients and 18 healthy controls, as described in [27]. The researchers used various classifiers, including SVM, naive Bayes, and OPF, in their analysis of the dataset. Maximum accuracy (85.54%) was achieved when combining the handwritten trace with the spiral format handwriting using SVM.

5.3 Gait datasets as Input

In [29], the authors suggested the use of machine learning (ML) algorithms to examine gait patterns as a way of diagnosing PD. Although each person walks differently, the authors argue that there is a significant difference in gait patterns between HC and PD individuals. The study gathered data from various sources, including individuals themselves and the Laboratory for Gait and Neurodynamics in the Neurology Outpatient Clinic at Massachusetts General Hospital in Boston, Massachusetts, USA, and the University of Michigan.

The authors utilized several machine learning algorithms to diagnose Parkinson's disease based on gait symptoms, such as SVM, PSO, KNN, RF, HMM, LR, ANN, NB, and LDA.

The study involved a total of 424 participants, and various algorithms were applied to diagnose PD based on gait symptoms. The hidden Markov model algorithm achieved an accuracy rate of 85.51%. The deep convolutional neural network algorithm was able to achieve 91.9% accuracy using a small sample size of only 20 individuals. The experimental setup involved the use of MATLAB R2013b and Python. The SVM algorithm was applied to classify 166 individuals and achieved a 100% accuracy rate in distinguishing between PD patients and healthy individuals. Among all 80 cases, where 40 participants were PD patients and 40 were healthy controls, the random forest algorithm exhibited the highest accuracy rate of 79.6%.

5.4 Neuroimages as Input

Preliminary research suggests that people with PD also suffer from a reduction in neurons in the brain's dopamine area. To visually detect and quantitatively measure the loss of neurons in various brain lobes, neuroimaging techniques such as MRI, SPECT, fMRI, and PET have been used throughout the past two decades. Because of its excellent spatial resolution and lack of invasiveness, MRI is the method of choice. Different machine learning methodologies and methods have been shown to be useful in the literature for diagnosing PD patients based on neuroimaging data.

Tao et al. [7] used fMRI and a network model based on graph theory to show how the functional connectivity of motor networks is altered during the resting state in PD. Functional connectivity in the left cerebellum, left primary motor cortex, and left parietal cortex was found to be increased in PD patients compared to normal subjects at rest, while connectivity in the left dorsal lateral prefrontal cortex and left putamen was found to be significantly decreased.

Defeng et al. [8] implanted deep brain electrodes to predict PD tremors in a real-time case study. In a similar vein, Christian Salvotre et al. [9] analyzed a database containing MRI scans from 28 healthy individuals, 28 people with PD, and 28 people with Progressive Supranuclear Palsy. Principal component analysis (PCA) was used for feature extraction, and a support vector machine (SVM) was used for classification, as part of a supervised machine learning technique. The authors have attempted to address the issue of a skewed dataset by including an equal number of patients from each group (PD, HC, and PSP). Classifiers for PD detection have proliferated in recent years, with criteria including accuracy, sensitivity, and specificity used to evaluate their effectiveness. Accuracy is a measure of the overall performance of a procedure or the proportion of positive and negative cases that are correctly detected.

Optical coherence tomography (OCT) has been the subject of several research efforts aimed at its potential application in the diagnosis of Parkinson's disease at an early stage. Objectives of these investigations include contrasting retinal thickness and retinal nerve fiber layer thickness in people with Parkinson's disease and healthy controls using optical coherence tomography (OCT). Researchers in [10] investigated the link between disease severity and RNFL values by comparing OCT findings of retinal thickness and retinal nerve fiber layer thickness in patients with idiopathic Parkinson's disease (IPD) and healthy volunteers.

6. Discussion and Recommendations

Researchers and medical professionals are becoming increasingly interested in using AI in disease diagnosis and treatment. Big data on health is being generated by mobile technologies like smartphones and cheap, widely used sensors. In a free-flowing population and with access to additional clinical datasets, AI may be able to glean insights about disease prevalence and patient status that were previously unavailable. Artificial intelligence can aid in worldwide epidemiology efforts and in monitoring patient symptoms. Despite the excitement of these new uses, it is vital to weigh the benefits and drawbacks of these innovative approaches to analysis. The most exciting uses of AI are yet in the future. By applying AI to relevant datasets in the future, we can better characterize the molecular sub-types of Parkinson's disease, for example. This will facilitate precision medicine by allowing clinicians to match patients with effective molecular therapies. Until AI proves it can progress in precision medicine, its primary value will remain in its ability to facilitate individualized monitoring [30]. We identified the remaining challenges and proposed recommendations for future research that could result in effective ML approaches to tackle these challenges.

We evaluated the selected articles based on their strengths and weaknesses. Using the criteria for critical appraisal, we then identified potential research areas for further investigation. The findings were categorized based on their relevance to similar or related research questions.

In order to make a real-time diagnosis of Parkinson's disease using picture and sensory data, it is important to adopt real-time and customized-based equipment equipped with a sophisticated processing unit. The capacity of ML models to spot outliers in data collected in real-time from IoT-based devices has already been demonstrated. To process data at the network's edge and immediately distribute the results, edge computing might be combined with specialized devices. Researchers have already implemented a variety of ML models capable of making a differential diagnosis of Parkinson's disease. The research team should concentrate on creating a machine-learning model for Parkinson's disease that takes into account all of the symptoms at once. In order to detect the various symptoms of PD, a compact and easily transportable device can be used to measure different features such as speed, duration, range of motion, and coordination. This device should be easy to use, easy to clean, and capable of detecting and analyzing changes in disease progression and treatment response.

The diagnosis of Parkinson's disease using gait metrics is currently the only use for wearable sensors. Other modules should be integrated into the wearable device for Parkinson's disease detection. Wearable sensor technologies for the diagnosis of many ailments should be a primary focus of research. A wrist-worn gadget, for instance, could be created to gather data continuously for an extended duration and detect various symptoms of Parkinson's disease.

7. CONCLUSIONS

Day-to-day life with PD is extremely difficult to manage. Therefore, it is helpful to have a reliable screening strategy in place, especially in cases where medical intervention is not required. Consequently, machine learning (ML) algorithms were evaluated to determine their effectiveness in detecting Parkinson's disease (PD). The primary objective of this literature review was to identify studies utilizing ML-based approaches to diagnose PD through handwriting, speech characteristics, and gait data. The ultimate goal was to select the most suitable method for accurately diagnosing PD. The review showed that a machine learning approach utilizing support vector machines with L1 regularization and K-fold cross-validation achieved a diagnostic accuracy of 99.0\% when analyzing speech characteristics for PD detection., 97.96\% when using handwritten patterns to detect PD, and 100\% when using gait analysis to detect PD. We found that much remains to be done in the future, and this evaluation helped us think through some of the challenges we might face and the opportunities we might be able to take advantage of. The advancements of neural networks and similar learning systems also benefit greatly from this overview, since new insights and rules for the field are provided.

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