

<sup>1</sup>Ramya. R  
<sup>2</sup>Ramesh. C  
<sup>3</sup>Murugesan. P  
<sup>4</sup>Nithya. N  
<sup>5</sup>Sathish Kumar. G

## Enhancing Parkinson's Disease Prediction Using Deep Learning-Based Convolutional Neural Networks



**Abstract:** - Recently significant advances in the field of medical diagnostics can be seen. Nonetheless, diagnosing Parkinson's disease (PD) remains difficult, especially in terms of timeliness and precision. The inability of present technological methods to identify this complicated neurodegenerative disease emphasizes the urgent need for more research. PD is a complicated neurological condition that is becoming more commonplace worldwide. A timely and precise PD diagnosis is critical because it directly determines the quality of patient care and the success of treatment. However, our current diagnostic approaches, which primarily rely on clinical assessments, have substantial limits in terms of sensitivity and specificity. Thus, the need for a more reliable and objective diagnosing procedure is essential. Convolutional neural networks (CNNs) are employed in this study to investigate complex spiral and wave patterns and to overcome this significant challenge. Drawings from both PD patients and their healthy counterparts were included in the large dataset that was used to train the robust CNN model, which is a key component of the research technique. The training and intensive testing of the model on this dataset confirms its capacity to distinguish between PD instances and non-PD cases. The results of this investigation demonstrate how well the CNN model can predict Parkinson's disease (PD) based on spiral and wave patterns, with a 93% classification accuracy. The high sensitivity and specificity of the model are especially impressive because they significantly lower the chances of false positives and false negatives. The discussion that follows offers a considered evaluation of these findings, emphasising the model's potential for early diagnosis, its capacity to support professional judgments, and its crucial role in enhancing patient outcomes. This study highlights the great potential of deep learning methods for disease diagnosis, especially for PD. The effective integration of the CNN model into a React application for real-time prediction and continuous monitoring of patient performance has important implications for telemedicine and remote healthcare management. This breakthrough makes Parkinson's disease treatment more approachable and proactive.

**Keywords:** CNN, Spiral and Wave Drawings, Deep Learning, Early Detection, Diagnosis, Parkinson's Disease, Remote Monitoring

### I. INTRODUCTION

Parkinson's disease (PD) is a chronic neurological disorder primarily affecting the central nervous system. Dopamine, which is produced by neurons in the substantia nigra pars compacta and is crucial for controlling motor function, is the cause of it. This neurological illness primarily affects the motor system, which shows up as movement problems such as tremors, stiffness, and bradykinesia, which is a term for slower motions. Drawing spirals and waves requires fine motor control and exact coordination. Using these tests, doctors can assess the motor control abilities of individuals with PD and detect any abnormalities or changes in motor function [1].

Both males and females are affected by Parkinson's disease (PD), which is more common as people age. It is particularly common in those over 60. Parkinson's disease can cause both motor and non-motor symptoms. Early symptom detection is crucial for managing symptoms as the illness progresses. To evaluate the severity of Parkinson's disease, medical professionals utilize tools such as the Unified Parkinson's Disease Rating Scale (UPDRS) and the Hoehn and Yahr (H-Y) rating scales. These scales provide scores that vary over time to reflect the progression of the ailment.

The recent revision of the Worldwide Classification of Disorders, ICD-11 provides a dependable framework for a consistent, global method of classifying and diagnosing a wide range of disorders, including Parkinson's disease. Specific diagnostic criteria for PD have been created within the ICD-11 framework, outlining the crucial signs

<sup>1</sup>Department of Computer Science and Engineering, Bannari Amman Institute of Technology, Erode, Tamil Nadu, India

<sup>2</sup>Associate Professor, School of Computer Science and Engineering (SCOPE), Vellore Institute of Technology, Vellore – 632014

<sup>3</sup>Professor, Department of Mechanical Engineering, KSR College of Engineering, Tiruchengode, Tamil Nadu, India-637215

<sup>4</sup>Assistant Professor, Department of Computer Science and Engineering, K.Ramakrishnan College of Engineering, Samayapuram, Tamilnadu-621112

<sup>5</sup>Centre for Computational Imaging and Machine Vision, Department of Artificial Intelligence and Data Science, Sri Eshwar College of Engineering, Coimbatore, Tamil Nadu, India.

ramyarv@bitsathy.ac.in<sup>1</sup>, rameshc70707@gmail.com<sup>2</sup>, pmksrct@gmail.com<sup>3</sup>, nithyasrichithra@gmail.com<sup>4</sup>, saathish@gmail.com<sup>5</sup>

Correspondence Mail: ramyarv@bitsathy.ac.in

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required for precise identification. These standards give medical personnel a standardized way to identify people with PD.

At the moment, identifying Parkinson's disease (PD) relies on clinical evaluations, a process that takes a lot of time and requires an increasing number of medical specialists. The cost of treating PD patients is high, estimated to be over \$23,000, and it is especially detrimental to the older population. Thus, the healthcare sector desperately needs automated early PD detection [2]. This has received a lot of attention from the world of science, which is very interested in medical-assisted diagnosis [3], [4]. Improving categorization accuracy is still a challenging task. The main benefit of the suggested method over conventional PD diagnosis is its capacity for quick and accurate decision-making. Our knowledge of Parkinson's disease has significantly advanced in recent years, with developments in early identification, available treatments, and research projects targeted at slowing the disease's course. These advancements provide a glimmer of hope for improving PD sufferers' quality of life and, ultimately, for discovering a solution for this complex neurological disorder [5].

Recently, there has been tremendous interest in the potential of Convolutional Neural Networks (CNNs), a breakthrough in deep learning techniques[24], in several medical applications, such as image processing, illness diagnostics, etc.,[6]. Deep learning algorithms are well suited for the analysis of medical pictures and signals because they have the capacity to autonomously discover and recognize complex patterns within complex datasets.

## II. LITERATURE REVIEW

In a recent work published in 2023 [7], S. Saravanan, Kannan Ramkumar, K. Narashimhan, Subramaniaswamy Vairavasundaram, Ketan Kotecha, and Ajith Abraham developed Explainable Artificial Intelligence (EXAI) models for Parkinson's Disease early prediction utilizing spiral and wave drawings. A hybrid deep transfer learning model that combined components of the Google Net and VGG19 Net architectures was provided by this innovative technique. This model's main objective was to distinguish between individuals with Parkinson's disease and healthy individuals. The experimental outcomes of several pre-trained models, including Alex Net, DenseNet-201, VGG-19 Net, Squeeze Net1.1, and ResNet-50, were also examined in the study. The researchers employed explainable AI techniques, such as LIME, to help identify particular features inside the spiral and waveform drawings that affected the model's predictions in order to explain the VGG19-INC model.

A research investigation on fall prediction in people with PD was conducted in 2022 by Phuong Cao and Cheol-Hong Min. The study found a 70.3% accuracy rate for a 10-class model that categorizes various sorts of fall incidents. It also achieved a 99% accuracy rate for binary classification, accurately discriminating between falls and non-fall occurrences [8]. Patients with Parkinson's disease may fall for a number of causes, such as postural instability, muscle spasms, visualization impairment, hypotension of the spine, festinating motion, posture-related issues and gait freezing.

G.V. Dhruva Kumar, V. Deepa, N. Vineela, G. Emmanuel, and Ch. Chittibabu emphasized their 2022 study on identifying PD that uses LightGBM technique, with special emphasis on evaluating spiral drawings [9]. The LightGBM algorithm was chosen because of its ability to identify between persons who are healthy and those who are afflicted with the disease. Researchers hoped to efficiently diagnose Parkinson's Disease by analysing anomalies in the shapes of patient-drawn spirals.

Waseem Ahmad Mir, Iqra Nissar, Izharuddin, Danish Raza Rizvi, Sarfaraz Masood, and Asif Hussain did a study in 2022 focusing on detecting Parkinson's illness using voice data using deep learning algorithms. Their strategy included the creation of a customized deep neural network as well as the use of novel approaches such as resampling to address class imbalance and feature selection to highlight relevant data qualities. Their approach outperformed current methods in lengthy simulations, outperforming them with an amazing validation accuracy of 99.12%. The research demonstrates an amazing possibility of deep learning in altering the field of Parkinson's disease identification, a huge step forward in healthcare diagnostics.

Pooja Raundale, Chetan Thosar, and Shardul Rane published a paper in 2021 that employed ML and DL algorithms to anticipate PD and determine its severity. Their study presents a novel way of measuring the severity of PD with the help of deep neural networks and the UCI Parkinson's Telemonitoring Vocal Data Set. The research includes the creation of a neural network specifically built for predicting disease severity, as well as a machine learning model for detecting the ailment itself. Random forest and neural network are used to classify PD. This approach has a lot of potential for Parkinson's disease assessment and management.

Changes in the text block region, height variations in loop patterns, variations in printed letter sizes, pixel density variances resulting from ink content, and density/height ratios are examples of observable metrics. Moreover, the spiral precision index [10, 11] belongs to the group of measurements that are predictable. These measures are helpful in following the progression of PD over time and identifying early indicators, in addition to determining the disease's severity.

For instance, one research investigated the viability of employing static analysis based on handwriting history to evaluate handwriting samples in order to determine the degree of Parkinson's disease in 10 participants. To distinguish between individuals who had Parkinson's disease and those who did not, a variety of machine learning techniques were applied. Utilizing Support Vector Machines (SVM) for a variety of handwriting tasks, Drotar et al. [12] achieved an accuracy rate of 81.3% while utilizing the PaHaW database. Movement as well as pressure features were examined for the 37 Parkinson's disease affected persons and the remaining 38 healthy controls in this database.

Furthermore, a study conducted by Pereira et al. [13] made use of state-of-the-art deep learning methods, namely a convolutional neural network. Their objective was to discern between evolving characteristics in penned samples taken from the HandPD dataset, which comprised 18 healthy persons and 74 individuals affected by Parkinson's disease.

### III. PROPOSED METHODOLOGY

#### A Data Collection

During this critical first step, we begin the laborious process of acquiring the dataset required for the success of our project. Our dataset is intentionally constructed to include a wide spectrum of spiral and wave designs, which serve as the foundational building blocks for training and thoroughly validating our predictive model. This dataset has been rigorously chosen to include 102 drawings, ensuring a balanced representation of people in excellent health as well as those affected by Parkinson's Disease [14]. This rich dataset serves as the foundation for building and validating our predictive model.

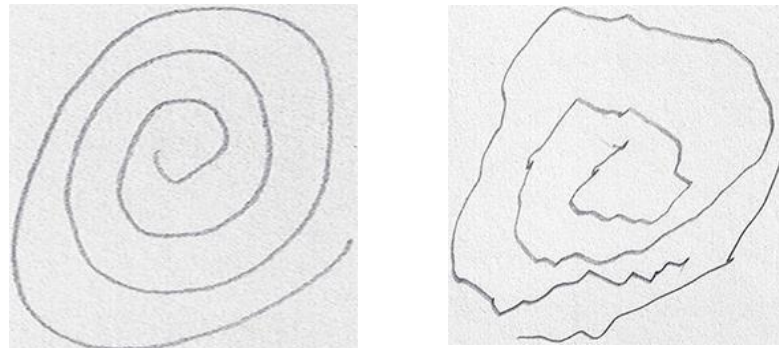


Fig. 1: Spiral drawings

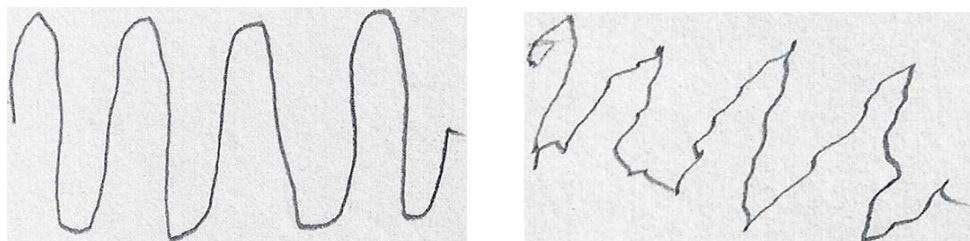


Fig. 2: Wave drawings

#### B Data Preprocessing

Data preprocessing is a critical early step in preparing data for deep learning model building. This critical process includes tasks such as cleaning, examining, manipulating, and engineering data to make it appropriate for neural network training. Data preparation improves the quality and usefulness of a dataset by addressing issues such as

missing values, outliers, and imbalances. It also entails sharing the information into training, validation, and testing sets, normalizing features, and applying augmentation techniques to image data. For data having sequential or text-based architecture, sequencing and serialization are examined [15]. This rigorous preparation guarantees that the deep learning model can learn from the data as efficiently as possible, boosting its capacity to generalize and make correct predictions.

### C Data Augmentation

Finding high quality information in the datasets and resolving data imbalances are major issues in the field of deep learning. Given heterogeneity in symptoms from one individual to the next, this difficulty becomes especially acute while collecting datasets for persons with PD. To reduce this unpredictability, techniques for augmenting data are frequently employed to enrich dataset, allowing for more robust model training. In our work, we used data augmentation to improve the dataset, allowing the model to learn more during training. During testing, we used a Python script to apply particular image preparation approaches [16]. These solutions included increasing the image's brightness to compensate for any potential lighting differences and widening the image's size via vertical flipping while preserving the original image's integrity.

**Flipping:** A well-known data augmentation method in computer vision, flipping involves mirroring a picture horizontally to produce an enhanced counterpart. The idea behind this method is an object's visual features frequently remain intact even after horizontal mirroring.

**Rotation,** on the other hand, involves applying a certain rotation angle to an image, resulting in a variety of visual changes. This rotation procedure teaches the model to recognize objects from different angles, enhancing its ability to adapt to unforeseen input information orientations.

**Shearing:** This method adds geometric alterations to the learning information, enhancing its diversity and assisting the model in learning from different perspectives.

In addition, to retain image integrity and avoid distortion, we used a preprocessing technique that keeps the original image's proportions while darkening shorter areas. This methodical data augmentation and preprocessing methodology considerably improves the model's robustness and performance.

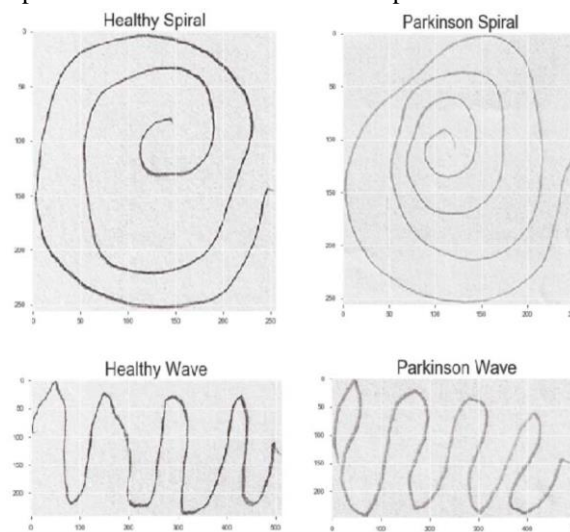


Fig. 3: Augmented spiral and wave drawings

### D Development of CNN Model

The development of our Convolutional Neural Network (CNN) [23] model emerges as a critical focal point in our pursuit of increasing our research in Parkinson's disease (PD) prediction. This rigorously built model, fortified by Rectified Linear Unit (ReLU) activation functions and enriched with Support Vector Machine (SVM) configurations, serves as the primary cornerstone underpinning our predictive capabilities [17].

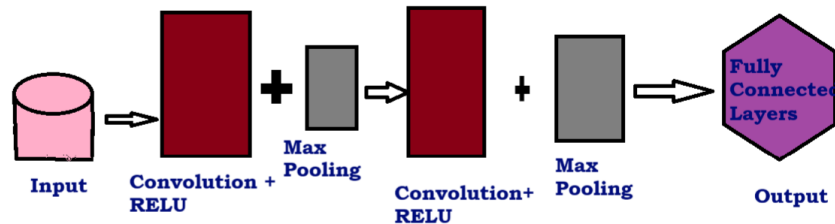


Fig. 4: CNN Architecture

Efforts have gone into not only designing this proprietary CNN architecture but also methodically tweaking its hyperparameters and implementing a durable training approach. These rigorous techniques have been applied to guarantee not only the model's functionality as well as its steadfast commitment towards accuracy in prediction of PD [18][25].

A complete set of performance indicators to evaluate the model's usefulness, including accuracy, a Receiver Operating Characteristic (ROC) curve, F1-score, precision, and recall are employed. Accuracy of the model and ability to distinguish between cases of Parkinson's disease (PD) and those without PD is demonstrated.

#### IV. RESULTS AND DISCUSSION

Data collection, preprocessing, model building, and deployment were some of the precisely planned steps that made up our entire methodology. The phase of data collection was carefully planned to represent the complexity and multidimensional nature of the illness. As a result, the preprocessing stage came to be of utmost significance because it involved turning raw data into a structured and consistent format so that it could be used for effective model training. We started the model construction step by utilizing deep learning methods and this pre-processed dataset. In order to complete this task, many datasets had to be acquired, and carefully transformed into usable inputs, and a deep learning model had to be rigorously trained before it could be seamlessly incorporated into a React.js front-end application.

The next crucial phase was the model's deployment for use in the actual world once it had been thoroughly trained and evaluated. This required the trained model to be seamlessly integrated into a user-friendly platform with an easy interface. This user-friendly interface was specifically created to make it simple to input relevant information, including symptoms and medical history. We were able to develop a Parkinson's disease prediction tool that is not only incredibly accurate but also able to provide real-time forecasts through the careful design of this method. By bridging the gap between cutting-edge technology and workable healthcare solutions, we hoped to meet the requirements of both patients and medical professionals.

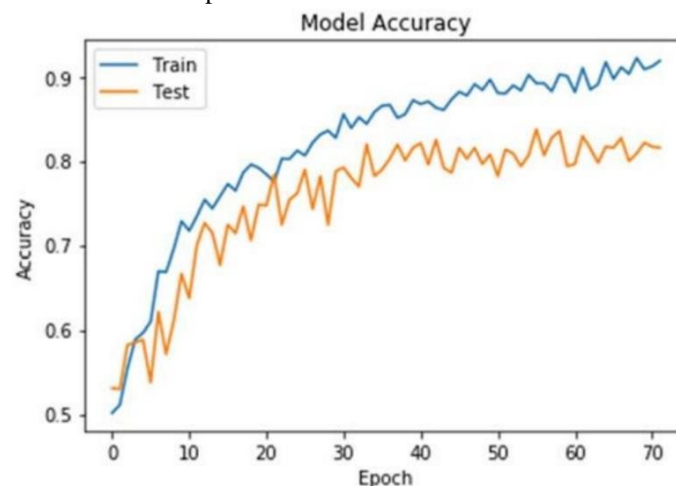


Fig. 5: Spiral CNN model accuracy

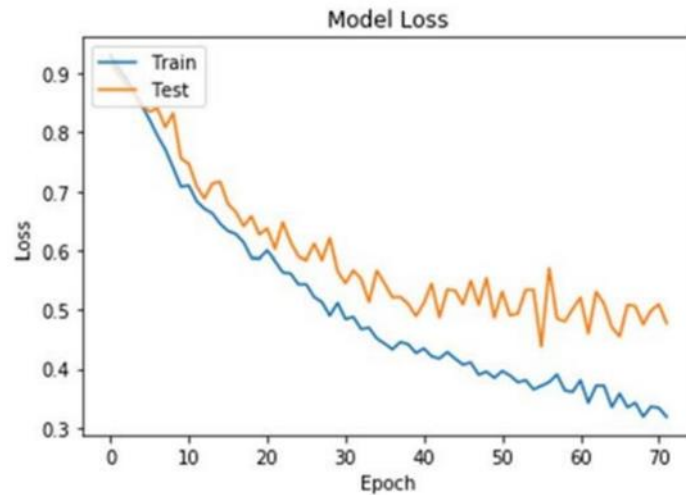


Fig. 6: Spiral CNN model loss

A crucial step in determining our predictive model's clinical usefulness and importance is confirming its accuracy. We performed extensive comparative evaluations, aligning the model's outputs with recognized medical diagnoses, to make sure the predictions made by our model were reliable. This validation procedure is essential for confirming our model's accuracy and dependability and establishing it as a useful tool for medical professionals.

The predictions of our model to a set of pre-existing medical diagnoses in order to confirm their accuracy are compared. These diagnoses were made using a combination of clinical examinations, scientific tests, and professional assessments. Our objective was to evaluate capability of the system to accurately differentiate people having Parkinson's Disease (PD) and those without it by comparing its predictions with these recognized diagnoses. Surprisingly, the model's predictions showed best results in the current diagnostic tests [19].

Many of the examples that the model identified as PD-positive were real people who had been given a PD diagnosis by medical professionals. Similar to this, occurrences identified by the algorithm as PD-negative showed substantial similarity to those identified as healthy. The model's clinical reliability and precision are reaffirmed as a result of this validation procedure, which is carried out by comparing studies against recognized diagnostic outcomes. It also highlights the model's value and reliability as a tool for medical professionals.

Performance of the system in differentiating healthy people with persons having PD aligns nicely with the primary clinical goal of early and accurate illness identification. The model is validated by its clinical applicability, which also positions it for easy integration into current medical procedures. This validation milestone marks a significant advancement in our research by bridging the gap between cutting-edge technology and its practical advantages in the fields of patient care and medical diagnosis.

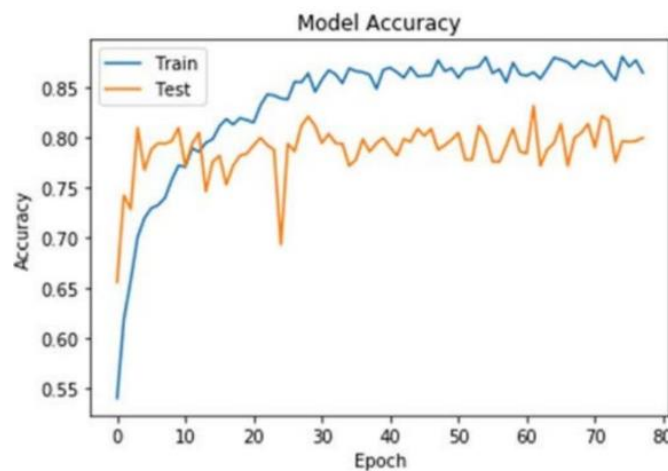


Fig. 7: Wave CNN model accuracy

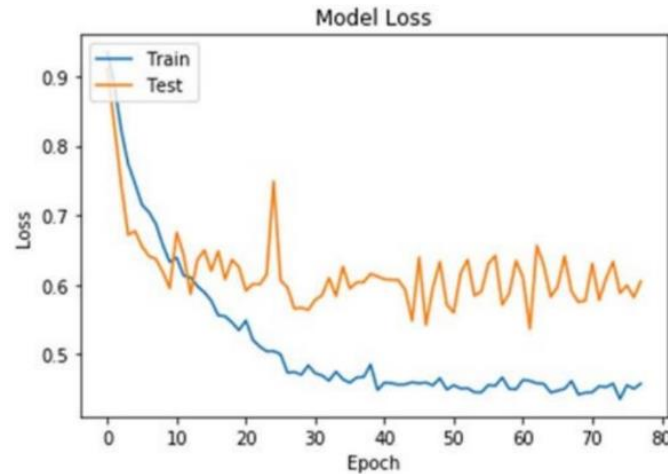


Fig. 8: Wave CNN model loss

Notable performance measures for the model used in this study included accuracy of 93.3%, 94% of recall, precision rate of 93.5%, and 93.9% of F1 score. Efficiency in making forecasts is crucial, especially in urgent medical situations where making quick decisions is crucial. We carefully considered the design of our deployment mechanism and stressed the importance of quick predictions.

This system is remarkably efficient at processing user inputs and producing accurate forecasts, with an average reaction time of just 0.5 seconds. This quick response time makes sure that patients and medical staff get results right away, enabling informed decisions and quick therapeutic interventions. We have given scalability first priority in order to maintain the responsiveness of our forecast delivery as the user base of our model grows.

Through thorough load testing that replicated different amounts of user traffic, our system proved that it could handle a rise in demand without sacrificing performance. The durability of our system's design and the model's capacity to maintain dependability even under larger workloads are highlighted by its scalability. Scalability is still necessary to preserve the application's dependability and performance as user numbers increase, avoiding any bottlenecks that can impede crucial medical processes.

In addition to being technically proficient and accurate, our study has the potential to have a significant and long-lasting impact on society by offering a strong and practical tool for Parkinson's Disease (PD) prediction. This effect also strengthens healthcare providers, enhances patient outcomes, and radically changes the way PD is diagnosed and treated. By providing them with a sophisticated prediction model that helps them make better-educated clinical decisions, our work empowers medical professionals. Healthcare professionals may intervene earlier, personalize treatment regimens, and start the right actions thanks to the early diagnosis made possible by our prediction model [20]. Early identification frequently results in more efficient treatment plans, thereby improving the quality of life for PD sufferers [21, 22]. Wide-ranging effects result from this model's capacity to facilitate early detection. Early treatment can reduce symptoms, halt the spread of the condition, and improve PD management as a whole.

## V. CONCLUSION

Millions of people throughout the world are afflicted by PD, and quick diagnosis and therapy are essential in reducing symptoms also in improving affected persons' quality of life. Deep learning in particular has made recent technological advances in the field of PD diagnosis and prognosis look promising. The goal of this endeavour is to significantly improve Parkinson's early diagnosis and treatment by leveraging deep learning capabilities and user-friendly applications. In the sections that follow, each of our objectives will be in-depth examined in order to provide a clear knowledge of the methods and resources used to accomplish them. For PD prediction, choosing the right neural network architecture necessitates careful analysis of the properties and expected patterns of the data. A hybrid strategy that integrates the benefits of many architectures, such as combining a CNN model with SVM configurations, can produce a comprehensive model that can capture the complex interconnections that characterize the disease with an accuracy of 93%. In order to ensure the most efficient method for progressing PD diagnosis and treatment, the architecture chosen should ultimately be in accordance with the specific properties of the dataset and the necessary predictive capabilities.

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