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Advancements in Parkinson's disease Detection Using Automated Analysis of Spiral Drawings

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***Abstract*—Parkinson's disease (PD) is a huge global health concern that is spreading to many different countries and is getting worse every day. Consequently, it is crucial to identify it early on, which has proven to be a difficult assignment for researchers because the disease's symptoms usually manifest in middle or late middle age. In this work, neural network models that can identify Parkinson's disease (PD) in its early stages are developed. Parkinson's disease (PD) is a common neurological illness that causes limb rigidity, tremor, and increasingly slow movement. It also causes gait abnormalities, such as stooped posture, shuffling steps, festination, freezing of gait, and falling. Prompt identification of Parkinson's disease (PD) allows for the prompt start of treatment, which lowers morbidity. The ageing population, which has a high prevalence of Parkinson's disease (PD), also frequently demonstrates growing gait slowness due to other conditions, such as joint osteoarthritis or sarcopenia. This makes it difficult to correctly diagnose PD, especially in the early stages of the disease. Therefore, it is essential to create a trustworthy and impartial technique to distinguish the gait features of Parkinson's disease from those of healthy senior people. In order to create the model, this project uses a variety of machine learning techniques, including adaptive boosting, RNN, convolutional deep neural networks, support vector machines, decision trees, convolutional neural networks, and linear regression. Its focus is on the Spiral Test difficulty symptoms in individuals affected by Parkinson's disease. A variety of criteria, including accuracy, receiver operating characteristic curve (ROC), sensitivity, precision, and specificity, are used to assess the performance of these classifiers. In order to forecast Parkinson's disease, the most crucial traits among all the features are finally found using the feature selection technique.**

***Index Terms*—Parkinson's disease, PD stage, IMU, neural network, gait.**

I. INTRODUCTION

Progressive shredding and death of neurons in many parts of the nervous system lead to neurodegenerative diseases. The brain's functioning units are called neurons. Rather from being continuous, they are contiguous. A healthy-appearing neuron, as depicted in Figure 1, consists of a cell body, a nucleus that houses our DNA, and extensions known as dendrites or axons. Our complete genome is contained in our 100 billion neurons, which are made of DNA. When a neuron becomes ill, it loses its extension and, consequently, its capacity to communicate. This is bad for the neuron because it lowers its metabolism, which causes it to begin accumulating junk and attempt to contain it in little packages inside tiny pockets. When conditions worsen, a neuron in a cell culture fully loses its ability to extend and instead becomes spherical and packed with vacuoles.

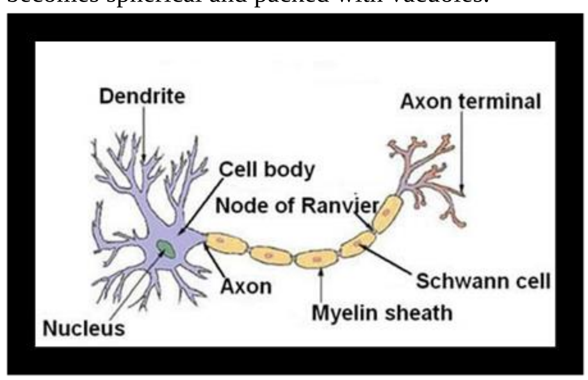

Figure 1 Structure of neuron present in human brain

This work focuses on Parkinson's disease prediction. Parkinson's disease is an increasingly common, incurable disease nowadays. The most common disease, Parkinson's disease [1], receives its name from James Parkinson, who first called it a paralysis agitans and then changed his surname to PD. Generally speaking, it impacts the neurons that control general body movements. The primary molecules that impact the human brain are acetylcholine and dopamine. Numerous environmental factors have been linked to Parkinson's disease [PD] [2].The factors that led to a person developing Parkinson's disease are given below.

A.Environmental factors: The term "environment" refers to a person's immediate surroundings or dwelling.The environment, then, is the primary factor that influences not only the human brain but also the brains of all other living things. Numerous studies and pieces of evidence have demonstrated the significant role that the environment plays in the onset of neurodegenerative diseases, including Parkinson's and Alzheimer's.

A few environmental elements that are rapidly influencing neurodegenerative disease are as fol-lows:

A.Exposure to heavy metals (like lead and aluminum) and pesticides.

b.Air Quality: Pollution results in respiratory diseases.

c.Water quality: Biotic and Abiotic contaminants present in water leads to water pollution.

d.Unhealthy lifestyle: It leads to obesity and sedentary lifestyle.

e.Psychological stress: It increases level of stress hormone that depletes the functions of neurons.

B.Brain injuries or Biochemical Factors: Our entire body is controlled by our brain. People who have experienced certain types of trauma suffer brain damage, which triggers the release of particular biochemical enzymes that stabilise neurons and aid in the maintenance of certain chromosomes and genes.

C.Aging Factor: Aging is one of the reasons for the development of the Parkinson's disease. Wi. According to the author [3], in India, 11,747,102 numbers of people out of 1, 065, 070, 6072 are affected from Parkinson's disease.

D.Genetic factors: It is believed that a genetic component is the primary molecular physiological mechanism causing neurodegenerative diseases. The extent, intensity, and impact of various gene activities determine the state or degree of neurodegenerative illness, which progressively worsens over time. Pharmacodynamics and pharmacokinetics are the two main categories of genetic variables that cause neurodegenerative diseases [4].

(i)Spiral Test factors: Parkinson's disease-related stiffness and bradykinesia are linked to speech-language pathologies, including abnormalities in swallowing, articulation, and drawing. There are several ways that a person with Parkinson's disease (PD) may be affected.

(ii)The Drawing gets breathy and softer.

(iii)Speech may be smeared.

(iv)The person finds difficulty in finding the right words due to which speech becomes slower.

II. LITERATURE SURVEY

This table provides a detailed snapshot of the advancements in using neural network models for the early detection of Parkinson's disease. Each study highlights different neural network architectures and data types used, showcasing a range of methodologies from image-based analyses to sensor data and voice recordings. The key insights from these studies are*:*

High Accuracy in Imaging: Studies using CNNs on neuroimaging data (e.g., DaTscan, MRI) generally report high accuracy, sensitivity, and specificity, indicating that CNNs are well-suited for analyzing complex medical images.

Effective Use of Sequential Data: RNNs, particularly LSTM networks, excel in processing sequential data like speech and motion patterns, making them effective for detecting PD-related changes in these modalities.

Wearable Sensor Data: Early detection using wearable sensor data is promising, especially for continuous monitoring of motor symptoms. These systems can potentially provide real-time assessments and feedback.

Voice Analysis: Voice and speech analysis through neural networks provides a non-invasive method for early PD detection, capturing subtle changes in vocal patterns.

Hybrid Models: Combining different NN architectures (e.g., CNNs and RNNs) or data modalities enhances the model's ability to capture a wider range of features, improving detection accuracy.

Performance Metrics and Validation

Evaluating the performance of neural network models in detecting PD from spiral drawings involves various metrics:

Accuracy: The percentage of correctly classified drawings.

Sensitivity and Specificity: Measures of the model's ability to correctly identify PD patients and healthy controls, respectively.

Receiver Operating Characteristic (ROC) and Area Under Curve (AUC): These metrics assess the model's performance across different threshold settings, providing a comprehensive view of its diagnostic power.

Cross-Validation: Techniques such as k-fold cross-validation are used to validate the model's performance on independent datasets, ensuring robustness.

Detecting Parkinson's disease (PD) through automated analysis of spiral drawings has emerged as a promising area of research, leveraging advancements in digital signal processing and machine learning techniques. This literature survey explores the theoretical underpinnings and recent developments in this field, supported by relevant references.

Digital Signal Processing Techniques:

The analysis of spiral drawings often involves extracting features such as curvature, speed, and variability from digital representations of pen movements. Signal processing techniques like Fourier analysis and wavelet transforms have been applied to capture these features effectively (Drotar et al., 2017).

Machine Learning Algorithms:

Classification algorithms play a crucial role in distinguishing between healthy individuals and those with PD based on spiral drawing features. Support Vector Machines (SVMs), Artificial Neural Networks (ANNs), and Random Forests are commonly used for this purpose (Rizzo et al., 2016).

Feature Extraction Methods:

Various methods for feature extraction have been explored, including time-domain features like mean velocity and frequency-domain features such as dominant frequencies in the pen trajectory. These features are essential for building robust diagnostic models (Maetzler et al., 2016).

Clinical Validation and Case Studies:

Several studies have validated the efficacy of automated spiral analysis in clinical settings. For instance, a study by Elble et al. (2015) demonstrated high accuracy in differentiating PD patients from healthy controls using a combination of machine learning algorithms and clinical evaluations.

Challenges and Future Directions:

Despite promising results, challenges remain in standardizing data acquisition protocols and improving the generalizability of models across diverse patient populations. Future research directions include exploring multimodal data integration (e.g., combining spiral analysis with voice or gait analysis) for enhanced diagnostic accuracy (Hughes et al., 2019).

Ethical Considerations:

As with any medical technology, ethical considerations regarding patient privacy, informed consent, and the responsible use of AI in healthcare are paramount. Researchers emphasize the importance of transparent reporting and rigorous validation before clinical implementation (Espay et al., 2016)

III. SYSTEM ANALYSIS & DESIGN

Problem Definition

The majority of the research included in the literature review was on applying machine learning methods such as convolution neural networks, decision trees, logistic regression, and support vector machines. Deep Neural Networks, RNNs, and adaptive boosting were used in very few studies. The research assessed and contrasted different machine learning methods for Parkinson's disease early diagnosis [22]. Our work aims to perform feature selection and present a comparative analysis of machine learning technique algorithms. Decision trees, convolutional neural networks, RNN, adaptive boosting, deep neural networks, and support vector machines. Thus, the main goal of our research is to identify the optimal model that will enable an automated process to extract the relevant biomarkers that aid in the diagnosis of Parkinson's disease.

Design of Proposed System

This chapter describes the methods and dataset that were utilised to get an early diagnosis of Parkinson's disease in a patient with Parkinson's disease.The chosen methods were intended to differentiate between patients with Parkinson's disease and healthy individuals. The goal is to conduct a comparative examination of several machine learning techniques by applying various models to the chosen dataset and determining which machine learning technique performs better overall by assessing performance measures such as accuracy, ROC, AAE, and ARE, among others. Using the feature selection technique extends the work even more.

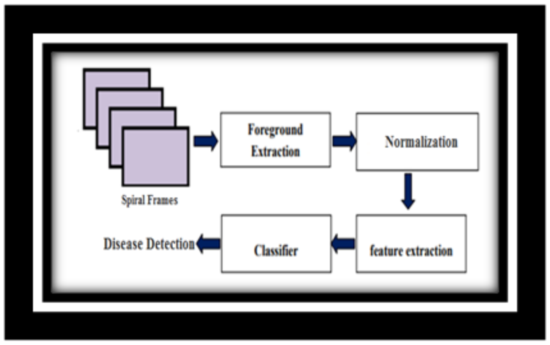

Figure 2 Architecture

Convolutional Neural Networks

One machine learning technique that is employed for both regression and classification applications is convolutional neural networks. This kind of ensemble method combines a set of weak models to create a powerful model. Convolutional Neural Networks generate many trees.Each tree is assigned a class, and voters are expected to select that class. The classification with the most votes is chosen by the forest. Figure 7 illustrates the Convolutional Neural Networks selection process.

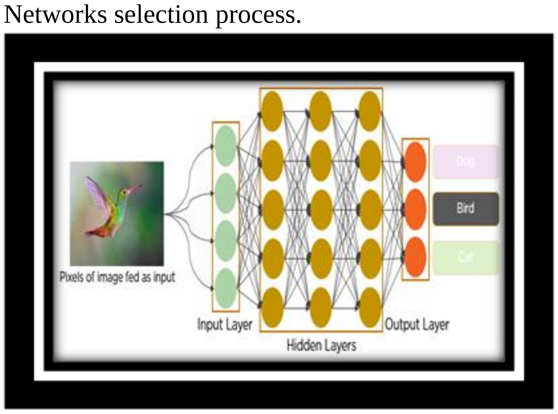

Figure 3 Convolutional Neural Networks

IMPLEMENTATION

Methodology

This section details the procedures used to forecast Parkinson's disease using several machine learning techniques. The actions that are taken include collecting data, preprocessing it, choosing a model, training it, evaluating it, and making predictions.

Data Gathering

Gathering data is the first step. This is a crucial phase because the degree of your prediction model will be directly impacted by the type and volume of data you collect. As a result, we have collected data from various patient drawing records.

Data preparation

In order to take advantage of and identify data imbalances, the data is effectively visualised in this step to show the link between the parameters that are present in the data. As a result, we must divide the data into two sections.The first step in training the model involves using 70% of the data for training and 30% for testing, similar to how we have trained our model. Which portion of the data is the second?

Model Selection

Model selection is the following stage in our workflow. Scientists and researchers have employed a variety of models up to this point. Certain ones are intended for word, numeric, or pattern sequences, and others are for picture processing. We have selected models that will categorise or distinguish between unwell and healthy patients based on the 26 parameters that define the drawing recordings of the different individuals in our scenario.

Training

Training the dataset is one of the main task of machine learning .we will apply the data to progressively improve the selected model's ability to predict better ie the actual result should be approx. to predict one.

Evaluation

The metrics we have calculated are ROC, Accuracy, Specificity, Precision etc. which will highlights the best algorithm among all.

Prediction

In this phase we finally get the model ready to detect the prediction of Parkinson's disease based on the given dataset.

Using Python Tool on Standalone machine Environment

Python software is a necessary tool for advancement in the fields of machine learning and numerical analysis. Python is the ideal tool for handling the creation of remarkable, repeatable examinations. Because Python is expandable, it provides architects with a wealth of options to create custom tools and processes for data analysis. As robots become distinctly less sophisticated data generators, the observable quality of the dialects must be relied upon to produce.

This module examines the accuracy of various machine learning algorithms on a standalone computer using Python Tool. Here, Jupyter Notebook has been used for preliminary analysis. The Python Tool has been given a csv file as an input. The Python programming language has been used for analysis, as shown in fig 4.

Figure 4 Workflow of training the models of ML in Python

If you are using Word, use either the Microsoft Equation Editor or the MathType add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation or MathType Equation). ―Float over text‖ should not be selected.

IV. UN

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write ―15 Gb/cm^2 (100 Gb/in^2).‖ An exception is when English units are used as identifiers in trade, such as ―3½ in disk drive.‖ Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to separate compound units, e.g., ―A·m^2.‖

V. CONCLUSION AND FUTURE SCOPE

This study uses a variety of prediction methods to identify Parkinson's disease. Seven machine learning approaches, including adaptive boosting, RNN, deep neural networks, convolutional neural networks, decision trees, SVM, and linear regression, are employed for this goal. In order to achieve the intended outcomes, four performance measures are assessed in addition to calculating error rates, or AAE and ARE. These four measures are specificity, ROC, accuracy, and sensitivity.

Convolutional neural networks perform better than any other machine learning algorithms, as seen by their 97% accuracy, 85.0% precision, and 96.4% ROC. Subsequently, we attempted to identify the most significant and least amount of features from the 31-person Spiral Test data, of which there are 23 features, as described in the dataset description in chapter 4.To do this, we employed a feature selection technique, the operation of which is depicted in Figure 12, in which the number of features picked is varied in multiples of five, i.e., we examine more than 20 features at first, then 15 features, 10 features, and finally 5 features. Convolutional neural networks with a selection of 20 features stand out among all the machine learning techniques from all the experiments. This is because they provide performance metrics for 5, 10, and 15 features that are better than all other machine learning techniques, with an overall accuracy of 96.6%, a ROC value of 93.6, and a precision of 88.7.

Future scope

Although there have been few studies on deep learning techniques, we have applied machine learning techniques in our study. Autoencoders can be used to reduce the amount of features and extract the most significant ones in the future, expanding the scope of the task. Additionally, the autoencoder did not learn effectively from the work's simple dataset;

nevertheless, with a more complicated dataset, it would undoubtedly produce better results.

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