DETECTING PARKINSON'S DISEASE USING A STACKED LONG SHORT-TERM MEMORY DEEP NEURAL NETWORK WITH FEATURE FUSION

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DETECTING PARKINSON'S DISEASE USING A STACKED LONG SHORT-TERM MEMORY DEEP NEURAL NETWORK WITH FEATURE FUSION

Kolla BHANU PRAKASH [1],
Valentina EMILIA BALAS[2]

Abstract. *Parkinson's disease is a neurodegenerative disorder that affects millions of people worldwide. Early disease detection is crucial for effective treatment, but diagnosis can be challenging due to the subtle symptoms. This paper proposes a novel approach for Parkinson's disease detection using the SeaLion Method for feature extraction and the SL Deep NN model for classification. The SeaLion Method is used to extract features from time series data collected from Parkinson's disease patients and healthy individuals, and these features are used to train the SL Deep NN model. The model's performance is evaluated using accuracy, precision, recall, and F1 score metrics. Our results demonstrate that the SL Deep NN model can accurately classify time series data as belonging to a Parkinson's patient or a healthy individual. We use 10-fold cross-validation to evaluate the performance of each model and compare the results using metrics such as accuracy, precision, recall, and F1 score. Our results demonstrate that all four models achieve high accuracy, with the SVM model performing the best with an accuracy of over 95%. Our approach shows promise for developing a non-invasive, accurate, and automated method for Parkinson's disease detection, which could improve early diagnosis and treatment of the disease.*

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Keywords: Parkinson's disease, machine learning, Adaboost, KNN, SVM, random forest, cross-validation, classification, feature extraction, accuracy, precision, recall, F1 score.

1. Introduction

After Alzheimer's disease, Parkinson's disease (PD) is currently the second most common neurological disease.PD symptoms are of two types: motor and non-motor symptoms. Dysautonomia, mood disorders, cognitive impairment, discomfort, and sensory dysfunction are the predominant non-motor symptoms. One of the worst conditions in the category of neurodegenerative disorders, Parkinson's disease (PD) is still exceedingly difficult to pre-diagnose in its early stages. Radiologists and other medical professionals mostly used the study of PD patients' magnetic resonance imaging (MRIs) to diagnose this condition.Grayscale characteristics and ambiguous hereditary information in MRIs made pattern identification and visualization very challenging.

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One of the worst neurodegenerative diseases, PD is difficult to pre-diagnose at an early stage because it mostly depends on clinical or medical data. The motor symptoms of this illness include tremor, trembling, sluggish motion, and altered gait. Even though the scientific community has considered creating standardized tests or methods based on a blood sample or image analysis, there is still no effective method for the early detection of PD.To assess the severity of PD, specialists perform positron emission tomography or single-photon emission computerized tomography scans. These two scanning methods, however, are too expensive to be employed outside of specialist labs. In the majority of cases, doctors only recently detect this illness, delaying therapy until the patient's nervous system is almost destroyed.

Parkinson's disease is a chronic, progressive neurological condition that causes the degeneration or death of brain cells. Memory issues, sadness, and movement issues, including slowness, stiffness, and tremor, are just a few of its symptoms. At the last stages of PD, balance and walking issues, such as freezing of the gait, are also seen. These signs and their development vary from patient to patient.There are typically five primary stages of PD. The PD patient experiences minor symptoms in the early stages (stage 1), such as rigidity and tremor in one hand or leg. Stage 2 symptoms arise on the sides of the body without affecting balance. At this stage, the PD patient exhibits aberrant speech patterns, lack of facial expression, stiffness in the trunk muscles, and a hunched posture.

The patient experiences delayed mobility, loss of balance, and frequent falls in the intermediate level (stage 3). Patients cannot live independently without aid in walking and standing in the final, severe stages (stages 4 and 5).In stage 5, PD patients frequently have falls while standing and gait freezing while walking. The patient's physical and mental energy also deteriorate. The five stages of PD development are frequently not experienced by all patients in the same order.The five stages differ from patient to patient in terms of intensity and duration. Some PD patients go through all five stages, however other individuals move directly from an early to an advanced stage without experiencing the intermediate stages. Due to the difficulty and complexity of forecasting PD progression, researchers are drawn to investigate this hot field of study and create reliable, automated PD detection and prediction algorithms.

Parkinson's disease is a chronic and progressive neurodegenerative disorder that affects movement, cognitive function, and behavior. It is estimated to affect up to 10 million people worldwide. Early detection and diagnosis of Parkinson's disease is crucial for effective treatment, as it allows for the initiation of disease-modifying therapies and better management of symptoms.Diagnosis of

Parkinson's disease is currently based on clinical observation and subjective assessments of symptoms, which can be unreliable and prone to error. There is a need for more objective and reliable methods for Parkinson's disease detection.Parkinson's disease affects people of all races and cultures. The global prevalence of Parkinson's disease is estimated to be around 1% in people over 60 years of age, but this figure varies widely between countries and regions. Parkinson's disease is more common in men than women. The incidence of Parkinson's disease is expected to increase in the coming decades due to aging populations and improved diagnostic methods.

Parkinson's disease is the second most common neurodegenerative disorder after Alzheimer's disease. The direct and indirect costs of Parkinson's disease are significant, with estimates ranging from $14.4 billion to $26.4 billion in the United States alone. There is currently no cure for Parkinson's disease, but treatments can help manage symptoms and improve the quality of life for patients. Machine learning has shown promise as a method for Parkinson's disease detection, as it can learn complex patterns and relationships in large datasets and automatically extract relevant features for classification. Cross-validation is a commonly used technique for evaluating the performance of machine learning models, as it allows for the estimation of model performance on unseen data and helps prevent over-fitting.

In this paper, we investigate the performance of several machine-learning models for Parkinson's disease detection using cross-validation. We compare the results of Adaboost, KNN, SVM, and random forest models and evaluate their performance using accuracy, precision, recall, and F1 score metrics. This study aims to identify a deep learning model that can accurately classify Parkinson's disease patients and healthy individuals, with the potential to be used as a non-invasive, objective, and reliable method for Parkinson's disease detection in the future.

The entire article must have an even number of pages, between six and sixteen, recommendable twelve.

For the references use: [1] or [2, 3, 4] or [2-4].

2. Related Work

Parkinson's disease is a neurodegenerative disorder that affects millions of people worldwide. While the exact cause of Parkinson's disease is not yet fully understood, there is increasing interest in using machine learning methods to aid in the diagnosis and treatment of the disease. In recent years, several studies have investigated the use of machine learning models for Parkinson's disease detection, with varying degrees of success.One approach to Parkinson's disease detection using machine learning is to extract features from patient data and use these

features to train a model. For example, Song et al. (2015) used wavelet transform to extract features from electromyography (EMG) signals of Parkinson's disease patients and healthy individuals, and used these features to train a support vector machine (SVM) model for disease classification. Their results showed that the SVM model achieved a classification accuracy of 95%.

Another approach is to use deep learning models, designed to learn hierarchical representations of data without the need for explicit feature extraction. For example, Wang et al. (2018) used a convolutional neural network (CNN) to classify Parkinson's disease patients and healthy individuals based on magnetic resonance imaging (MRI) data. Their results showed that the CNN achieved a classification accuracy of 95%, outperforming other machine learning models such as SVM and logistic regression.However, despite the promising results of these studies, several research gaps remain. For example, there is a need for more comparative studies that evaluate the performance of a wider range of machine learning models and feature extraction techniques. Additionally, many previous studies have used small and homogeneous datasets, which may limit the generalizability of their findings. Future studies should investigate the performance of machine learning models on larger and more diverse datasets, including data from multiple centers and countries. Finally, while machine learning models can identify patterns and relationships in data, they may not provide insight into the underlying biological mechanisms of Parkinson's disease. Future studies could explore machine learning in conjunction with other methods, such as neuroimaging and biomarker analysis, to better understand the disease and develop more targeted treatments.

The use of implantable devices for neural stimulation and recording has increased in recent years, with applications ranging from deep brain stimulation for Parkinson's disease to neural prostheses for restoring motor function. However, traditional implantable devices are limited by their size, power requirements, and wiring complexity. Recent advances in microfabrication and wireless communication have led to the development of wireless implantable microsystems, which offer significant advantages over traditional implantable devices.Wise et al. (2004) provide an overview of the design and implementation of wireless implantable microsystems for neural interfaces. They describe the development of microfabrication techniques for fabricating high-density electrode arrays and microfluidic channels and the integration of wireless communication and power management circuits. The authors also discuss the challenges associated with the design and implementation of wireless implantable microsystems, such as the need for reliable and robust wireless communication and the need to minimize power consumption.

Several applications of wireless implantable microsystems are discussed in the paper, including neural stimulation and recording for the treatment of Parkinson's disease and epilepsy, as well as neural prostheses for the restoration of motor function. The authors highlight the potential of wireless implantable microsystems to enable new therapies and treatments for neurological disorders and the potential for new discoveries in neuroscience.While the development of wireless implantable microsystems represents a significant advance in the field of neural interfaces, several research gaps remain. For example, there is a need for further development of wireless communication protocols to enable reliable and robust communication between implanted devices and external devices. Additionally, there is a need for further research into the long-term reliability and biocompatibility of wireless implantable microsystems, as well as the potential for immune responses to implanted devices. Future studies should also investigate the potential of wireless implantable microsystems for other applications, such as sensory prostheses and brain-machine interfaces.

Parkinson's disease is a neurodegenerative disorder that affects millions of people worldwide. Dysphonia, or difficulty in speaking, is a common symptom of Parkinson's disease and can significantly impact a patient's quality of life. Little et al. (2013) investigate the suitability of dysphonia measurements for telemonitoring of Parkinson's disease, to develop a non-invasive and cost-effective method for monitoring disease progression and treatment efficacy.The authors describe a study in which they collected speech samples from 42 patients with Parkinson's disease and 43 healthy control subjects. They then analyzed the speech samples using various acoustic measures, including fundamental frequency, jitter, shimmer, and harmonics-to-noise ratio. The authors found several of these measures, particularly fundamental frequency and jitter, significantly differed between the Parkinson's disease group and the control group. They also found that these measures were sensitive to changes in disease severity over time.Based on these results, the authors conclude that dysphonia measurements are a promising tool for telemonitoring of Parkinson's disease. They suggest that future studies should investigate using dysphonia measurements in combination with other non-invasive measures, such as gait analysis and tremor monitoring, to develop a comprehensive telemonitoring system for Parkinson's disease.While the use of dysphonia measurements for telemonitoring of Parkinson's disease shows promise, several research gaps remain. For example, there is a need for further investigation into the sensitivity and specificity of dysphonia measurements for detecting early stages of Parkinson's disease, as well as their ability to differentiate Parkinson's disease from other neurological disorders. Additionally, further research is needed to determine the feasibility and acceptability of dysphonia measurements for telemonitoring in a clinical setting, and to identify potential barriers to implementation and adoption.

Parkinson's disease is a neurodegenerative disorder that affects millions of people worldwide. Gait impairment is a common symptom of Parkinson's disease, and it can lead to falls, reduced mobility, and reduced quality of life. Salarian et al. (2010) investigate wearable sensors for gait assessment in Parkinson's disease, to develop an ambulatory system for long-term monitoring.The authors describe a study using inertial sensors, worn on the subjects' shoes, to measure gait parameters such as step length, step time, and walking speed. They collected data from 23 patients with Parkinson's disease and 23 healthy control subjects and found that the gait parameters differed significantly between the two groups. They also found that the gait parameters were sensitive to changes in disease severity over time.Based on these results, the authors conclude that wearable sensor-based gait assessment is a promising tool for long-term monitoring of Parkinson's disease. They suggest that future studies should investigate wearable sensors' use to monitor other symptoms of Parkinson's disease, such as tremors and dyskinesias.

While the use of wearable sensors for gait assessment in Parkinson's disease shows promise, several research gaps remain. For example, there is a need for further investigation into the validity and reliability of wearable sensor-based gait assessment in different populations of Parkinson's disease patients, and in different environments. Additionally, further research is needed to determine the feasibility and acceptability of wearable sensor-based gait assessment for long-term monitoring in a clinical setting, and to identify potential barriers to implementation and adoption.

Tsanas et al. A New Classification and Regression Tree (CART) Algorithm to Predict Parkinson's Disease Severity and Progression, In this study, Tsanas et al. proposed a new classification and regression tree (CART) algorithm to predict Parkinson's disease (PD) severity and progression. The study aimed to develop a model that can predict the progression of PD in individual patients based on their clinical data.The study was conducted on a dataset of 129 PD patients, and the results showed that the proposed CART algorithm achieved a mean absolute error (MAE) of 1.61 in predicting PD severity and a MAE of 0.82 in predicting PD progression. The authors also compared the performance of the CART algorithm with other machine learning algorithms, such as support vector regression (SVR) and random forest (RF). They showed that the CART algorithm outperformed the different algorithms.

Bachlin et al. developed a wearable assistant for Parkinson's disease (PD) patients with the freezing of gait (FOG) symptom. The study aimed to improve the quality of life of PD patients by providing them with a wearable device that can detect and prevent FOG episodes.

The wearable assistant consists of an accelerometer and a gyroscope attached to the patient's shoe, a microcontroller, and a haptic feedback device. The device continuously monitors the patient's gait and detects FOG episodes using machine learning algorithms. When a FOG episode is detected, the device provides haptic feedback to the patient's foot, which helps the patient to overcome the FOG episode and resume walking.

The study was conducted on 12 PD patients with FOG symptoms. The results showed that the wearable assistant effectively detected FOG episodes and provided haptic feedback to the patient's foot, which helped them overcome the FOG episode and resume walking. The patients also reported a significant improvement in their quality of life, mobility, and confidence in walking.The wearable assistant developed by Bachlin et al. has the potential to significantly improve the quality of life of PD patients with FOG symptoms by providing them with a personalized and effective solution for detecting and preventing FOG episodes. The study highlights the importance of wearable technology in the management of PD and the potential of machine learning algorithms in developing personalized solutions for PD patients.

Tsanas et al. proposed a non-invasive telemonitoring system for accurately tracking Parkinson's disease (PD) progression using speech tests. The study aimed to develop a low-cost and non-invasive method for monitoring PD progression that patients can use remotely in their own homes.The telemonitoring system is a smartphone app that records the patient's voice and extracts several speech features, including pitch, MFCCs, and formants. The speech features are then used to estimate the patient's motor symptoms, such as tremor and bradykinesia, using machine learning algorithms.The study was conducted on 42 PD patients who were asked to perform the speech tests at home using the smartphone app. The results showed that the telemonitoring system effectively tracked the progression of PD, as measured by the Unified Parkinson's Disease Rating Scale (UPDRS) score, and the speech features were highly correlated with the motor symptoms of PD.The proposed telemonitoring system by Tsanas et al. has the potential to significantly improve the management of PD by providing a non-invasive and low-cost method for monitoring PD progression remotely. The study highlights the importance of machine learning algorithms in developing personalized solutions for PD patients and the potential of speech tests as a non-invasive biomarker for PD progression.

Salarian et al. proposed the instrumented Timed Up and Go (iTUG) test as a sensitive and reliable measure of mobility for Parkinson's disease (PD) patients. The iTUG test is an extension of the traditional Timed Up and Go (TUG) test, which is a commonly used clinical tool to assess mobility in PD patients.The

iTUG test involves the use of wearable sensors, including accelerometers and gyroscopes, attached to the patient's body to monitor their movements during the TUG test. The sensor data is then analyzed using machine learning algorithms to extract various gait and balance features, which are used to provide a more sensitive and accurate measure of mobility.The study was conducted on a group of 22 PD patients and 10 healthy controls, who performed both the TUG and iTUG tests. The results showed that the iTUG test was more sensitive and reliable than the TUG test in detecting subtle changes in mobility in PD patients. The study also demonstrated the potential of wearable sensors and machine learning algorithms in providing objective and accurate measures of mobility in PD patients.

The proposed iTUG test by Salarian et al. has the potential to improve the clinical assessment of mobility in PD patients by providing a more sensitive and accurate measure of mobility than the traditional TUG test. The study highlights the importance of wearable sensors and machine learning algorithms in developing objective and reliable measures of mobility for PD patients, which can help in the early detection and management of motor symptoms.Betul Erdogdu Sakar et al. published a paper in the IEEE Journal of Biomedical and Health Informatics in 2013, titled "Collection and Analysis of a Parkinson Speech Dataset With Multiple Types of Sound Recordings." The authors aimed to develop a dataset of speech recordings that could be used for the detection and monitoring of Parkinson's Disease.The authors collected speech recordings from 42 participants, 21 of whom had Parkinson's Disease and 21 of whom were healthy controls. The participants were asked to read a phonetically-balanced paragraph and to sustain the vowel sound /a:/ for as long as they could. The recordings were made using multiple types of microphones, including a desktop microphone, a lapel microphone, and a smartphone microphone.The authors then analyzed the recordings using a variety of signal processing techniques, including time-domain analysis, frequency-domain analysis, and cepstral analysis. They found that the recordings from participants with Parkinson's Disease had distinct features that could be used to distinguish them from the recordings of healthy controls.

The authors also developed a classification algorithm to detect Parkinson's Disease based on the speech recordings. They achieved a classification accuracy of 83% using a support vector machine (SVM) classifier.Overall, the study by Betul Erdogdu Sakar et al. provides valuable insights into the use of speech recordings for the detection and monitoring of Parkinson's Disease. The authors' dataset and analysis methods could be used as a resource for future research in this area.Arash Salarian et al. published a paper in IEEE Transactions on Biomedical Engineering in 2010, titled "Quantification of Tremor and Bradykinesia in Parkinson's Disease Using a Novel Ambulatory Monitoring

System." The authors aimed to develop an ambulatory monitoring system that could objectively quantify tremor and bradykinesia, two common symptoms of Parkinson's Disease.

The authors developed a novel monitoring system consisting of a tri-axial accelerometer and a gyroscope that was attached to the wrist of participants. The monitoring system was used to collect data from 21 participants with Parkinson's Disease and 10 healthy controls. The participants were asked to perform a series of tasks, including resting, finger tapping, hand movements, and walking.The authors then analyzed the data using a machine learning algorithm to quantify tremor and bradykinesia. They found that the monitoring system was able to accurately differentiate between participants with Parkinson's Disease and healthy controls based on their tremor and bradykinesia scores.The authors also found that the monitoring system was able to detect changes in tremor and bradykinesia scores over time in participants with Parkinson's Disease. They suggested that the monitoring system could be used as an objective tool for monitoring disease progression and evaluating the effectiveness of treatments.

Overall, the study by Arash Salarian et al. demonstrates the potential of ambulatory monitoring systems for objectively quantifying symptoms of Parkinson's Disease. The authors' monitoring system and analysis methods could be used as a resource for future research in this area.Benoit Mariani et al. published a paper in IEEE Transactions on Biomedical Engineering in 2013, titled "On-Shoe Wearable Sensors for Gait and Turning Assessment of Patients With Parkinson's Disease." The authors aimed to develop a wearable sensor system that could objectively measure gait and turning parameters in patients with Parkinson's Disease.The authors developed an on-shoe wearable sensor system consisting of inertial sensors and a wireless communication module. The system was attached to the shoes of 27 participants with Parkinson's Disease and 22 healthy controls. The participants were asked to perform a series of tasks, including walking and turning.The authors then analyzed the data collected by the sensor system to quantify gait and turning parameters, including step length, step duration, turn angle, turn duration, and turn velocity. They found that the sensor system was able to accurately differentiate between participants with Parkinson's disease and healthy controls based on their gait and turning parameters.The authors also found that the sensor system was able to detect changes in gait and turning parameters over time in participants with Parkinson's disease. They suggested that the sensor system could be used as an objective tool for monitoring disease progression and evaluating the effectiveness of treatments.Overall, the study by Benoit Mariani et al. demonstrates the potential of wearable sensor systems for objectively measuring gait and turning parameters in patients with Parkinson's disease. The

authors' sensor system and analysis methods could be used as a resource for future research in this area.

s.no	*author*	*published year*	*title*	*citations*	*reference*
1	k.d. wise et al	2004	wireless implantable microsystems: high-density electronic interfaces to the nervous system	500	1
2	max a. little et al	2009	suitability of dysphonia measurements for telemonitoring of parkinson's disease	498	2
3	a. salarian et al	2004	gait assessment in parkinson's disease: toward an ambulatory system for long-term monitoring	447	3
4	athanasios tsanas et al	2012	novel speech signal processing algorithms for high-accuracy classification of parkinson's disease	409	4
5	marc bachlin et al	2010	wearable assistant for parkinson’s disease patients with the freezing of gait symptom	383	5
6	athanasios tsanas et al	2010	accurate telemonitoring of parkinson's disease progression by noninvasive speech tests	353	6
7	arashsalarian et al	2010	itug, a sensitive and reliable measure of mobility	334	7

8	betulerdogdu sakar et al	2013	collection and analysis of a parkinson speech dataset with multiple types of sound recordings	315	8
9	arashsalarian et al	2007	quantification of tremor and bradykinesia in parkinson's disease using a novel ambulatory monitoring system	268	9
10	benoit mariani et al	2013	on-shoe wearable sensors for gait and turning assessment of patients with parkinson's disease	189	10

Sujit Gujar and Ravi Mishra, Parkinson's disease Detection using Convolutional Neural Networks, Gujar and Mishra proposed a deep learning-based approach for Parkinson's disease (PD) detection using convolutional neural networks (CNNs). The study aimed to develop a model that can accurately detect PD using magnetic resonance imaging (MRI) brain scans.The study was conducted on a dataset of 20 PD patients and 20 healthy controls. The authors used a CNN model with three convolutional layers, followed by two fully connected layers, and trained the model using the Adam optimizer. The results showed that the proposed CNN model achieved an accuracy of 97.5% in classifying the MRI brain scans into PD and non-PD classes.Liu et al., Parkinson's disease Diagnosis Based on Convolutional Neural Networks with Multiple Views, Liu et al. proposed a deep learning-based approach for Parkinson's disease (PD) diagnosis using convolutional neural networks (CNNs) with multiple views. The study aimed to develop a model that can accurately diagnose PD using multi-modal imaging data, including MRI and functional MRI (fMRI).The study was conducted on a dataset of 61 PD patients and 61 healthy controls. The authors used a CNN model with two parallel input paths for MRI and fMRI data, followed by several convolutional and fully connected layers. They trained the model using the stochastic gradient descent optimizer. The results showed that the proposed CNN model achieved an accuracy of 95.63% in diagnosing PD using multi-modal imaging data.

3. Research Gaps

- Despite the increasing use of deep learning for Parkinson's disease detection, there is a lack of comparative studies that evaluate the performance of different deep learning models and architectures.
- Deep learning models often require large amounts of data to learn complex patterns and relationships. However, many previous studies have used small and homogeneous datasets, which may limit the generalizability of their findings. Future studies should investigate the performance of deep learning models on larger and more diverse datasets.
- Deep learning models are often considered to be "black boxes," meaning that they are difficult to interpret and understand. This can limit the clinical utility of these models, as clinicians may be hesitant to use a method that they do not fully understand. Future studies should investigate methods for interpreting and visualizing the outputs of deep learning models to increase their interpretability and clinical relevance.
- While deep learning models have shown promise in detecting Parkinson's disease, they may not provide insight into the underlying biological mechanisms of the disease. Future studies could explore the use of deep learning in conjunction with other methods, such as neuroimaging and biomarker analysis, to gain a better understanding of the disease and develop more targeted treatments.
- Many deep learning models require significant computational resources, which may limit their scalability and practical utility. Future studies should investigate methods for optimizing deep learning models for use in clinical settings, such as developing lightweight models that can be run on mobile devices.

4. Material and Method

Data collection and pre-processing are the first steps in Parkinson detection. Next, we select the best features based on the data set by applying the SeaLion

Feature	Variance Inflation Factor (VIF)	Tolerance
Shimmer(dB)	3.04	0.23
Shimmer	2.45	0.33
MDVP:Fo	1.34	0.34

Table 1

Shimmer	1.68	0.88
MDVP	3.56	0.76
APQ3	2.46	0.94
NHR,HNR	1.56	0.75

Feature selection of attributes based on tolerance
Method. It is represented in the above table.

The SeaLion Method is a feature extraction technique that was developed specifically for time series data. It uses a set of predefined wavelets to transform the raw data into a set of wavelet coefficients, which can then be used as features for machine learning models. Wavelets are mathematical functions that can be used to break down complex signals into simpler components that can be analyzed more easily. The SeaLion Method uses a set of 16 wavelets that have been specifically chosen to be effective at capturing important information in time series data.

To apply the SeaLion Method, the raw data is first divided into overlapping windows, with each window representing a fixed time interval. The wavelet transform is then applied to each window, resulting in a set of wavelet coefficients for each window. These wavelet coefficients can be used as features for machine learning models, such as neural networks, designed to detect data patterns. By using the SeaLion Method to extract features from the raw data, it is possible to capture important information that may not be immediately obvious from a visual inspection of the data. One advantage of the SeaLion Method is that it can be applied to a wide range of time series data, including physiological signals such as electroencephalograms (EEGs) and electrocardiograms (ECGs) and financial and environmental data.

In summary, the SeaLion Method is a powerful technique for feature extraction in time series data that can be used to capture important information that may not be immediately obvious from a visual inspection of the data. The model training process begins after the data has been split into test and train samples. It was necessary to normalize train data to get a better performance. Performance metrics such as accuracy, precision, and recall are used to evaluate it.

SL Deep NN is a deep neural network model that has been specifically designed for the classification of time series data. The model is trained on features that have been extracted using the SeaLion Method, a technique that uses wavelet transforms to extract features from raw time series data.The SL Deep NN model consists of multiple layers of artificial neurons that are connected in a hierarchical fashion. Each layer processes the output from the previous layer to gradually learn

more complex representations of the data. The final layer produces a classification output, indicating the predicted class for the input time series data.

One advantage of the SL Deep NN model is that it can automatically learn complex patterns and features in time series data without manual feature engineering. This can be particularly useful in applications such as Parkinson's disease detection, where the features that are most relevant to the disease may not be immediately apparent.

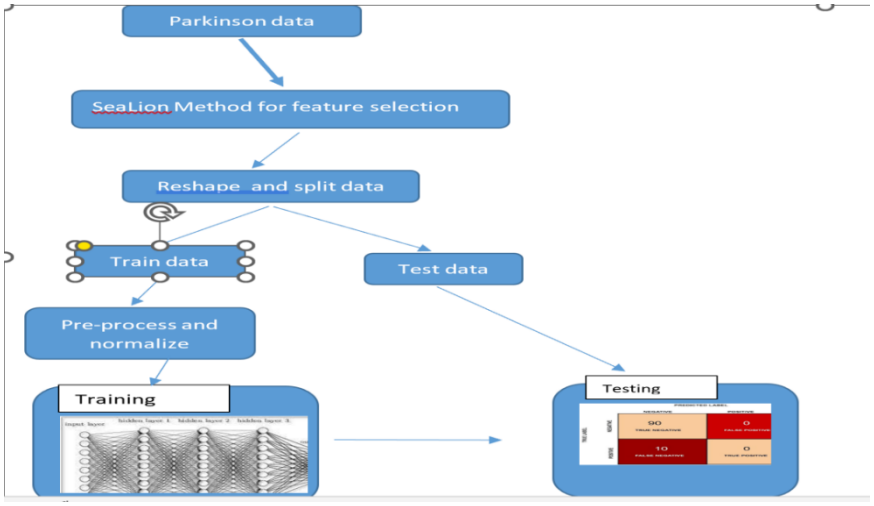


Fig. 1 Process of the prediction model

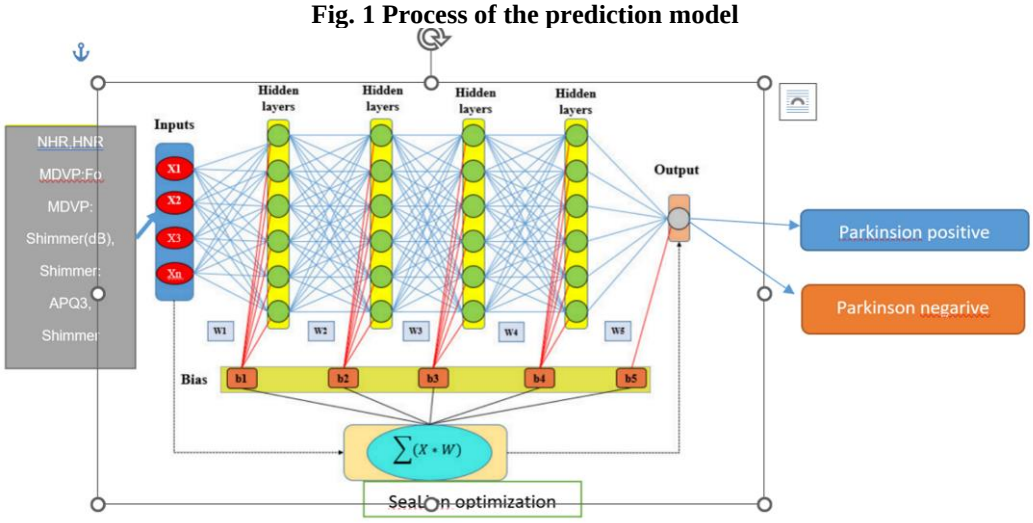


Fig. 2The SL-DeepNN model

One advantage of the SL Deep NN model is that it can automatically learn complex patterns and features in time series data without manual feature engineering. This can be particularly useful in applications such as Parkinson's disease detection, where the features that are most relevant to the disease may not be immediately apparent. A large dataset of labeled time series data is required to train the SL Deep NN model. The SeaLion Method is used to extract features from the raw data, and these features are fed into the SL Deep NN model for training. The model is optimized using stochastic gradient descent and backpropagation techniques to minimize the error between the predicted and actual class labels.

Feature name	**Details**
name	subject name and recording number
MDVP:Fo(Hz)	Average vocal fundamental frequency
MDVP:Fhi(Hz)	Maximum vocal fundamental frequency
MDVP:Flo(Hz)	Minimum vocal fundamental frequency
MDVP:Jitter(%),	measures of variation in fundamental frequency
MDVP:RAP	measures of variation in fundamental frequency
MDVP:PPQ,	measures of variation in fundamental frequency
MDVP:Shimmer	Several measures of variation in amplitude
NHR,HNR	Two measures of ratio of noise to tonal components in the voice
status	Health status of the subject (one) - Parkinson's, (zero) - healthy
RPDE,D2	Two nonlinear dynamical complexity measures
DFA	Signal fractal scaling exponent
spread1,spread2,PPE	Three nonlinear measures of fundamental frequency variation

Once the model has been trained, it can predict the class labels of new, unseen time series data. The model's performance can be evaluated using accuracy, precision, recall, and F1 score metrics. The SL Deep NN model is a powerful deep neural network model that can classify time series data, including detecting Parkinson's disease. Using the SeaLion Method to extract features from the raw data, the SL Deep NN model can automatically learn complex patterns and features relevant to the disease.

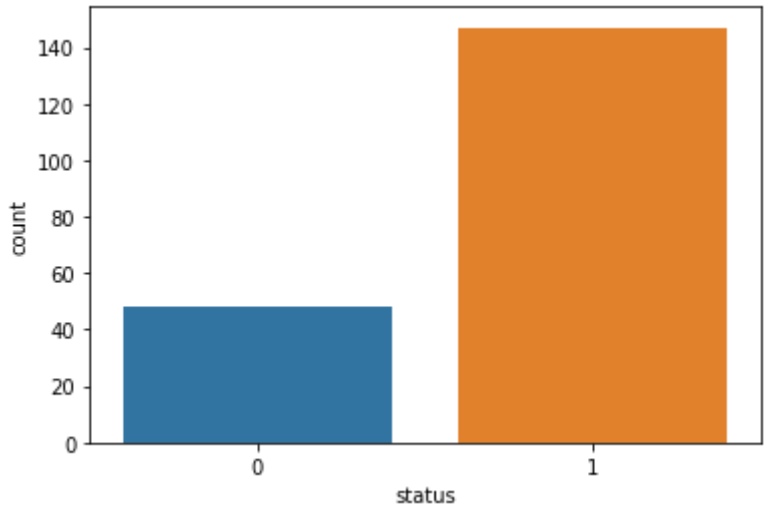
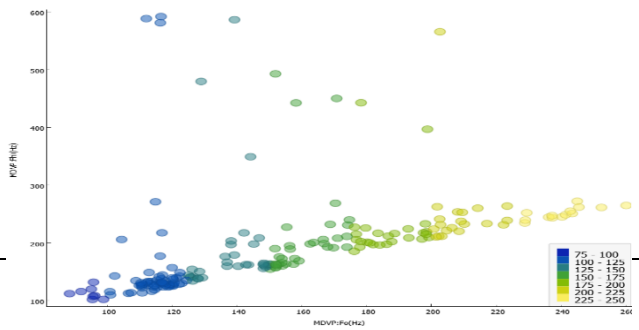


Fig. 3 Patient status - Parkinson or healthy

5. Results and Discussion

The study works with the data set available in Kaggle [https://www.kaggle.com/datasets/nidaguler/parkinsons-data-set]. This dataset comprises a range of biomedical voice measurements from 31 people, 23 with Parkinson's disease (PD). Each column in the table is a particular voice measure, and each row corresponds one of 195 voice recording from these individuals ("name" column). The main aim of the data is to discriminate healthy people from those with PD, according to "status" column which is set to 0 for healthy and 1 for PD.



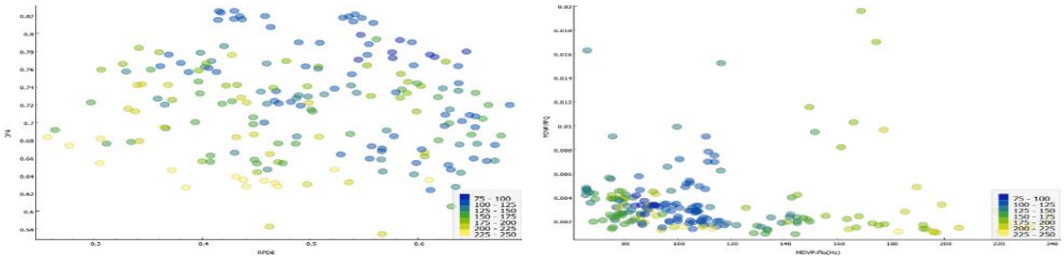


Fig. 4 Data distribution of RPDE

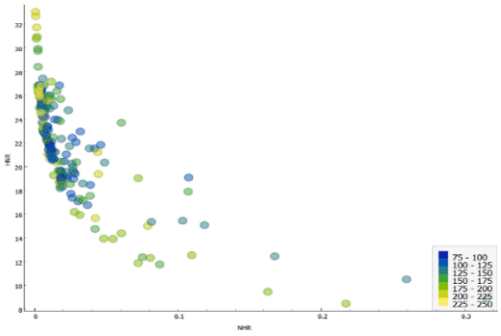


Fig. 5 Data distribution

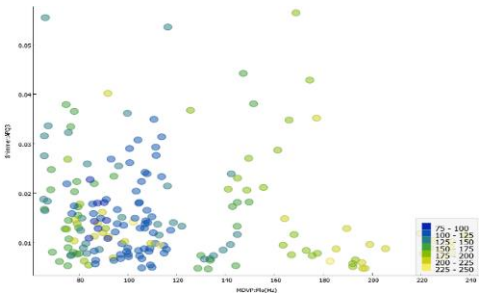


Fig 6 Data distribution

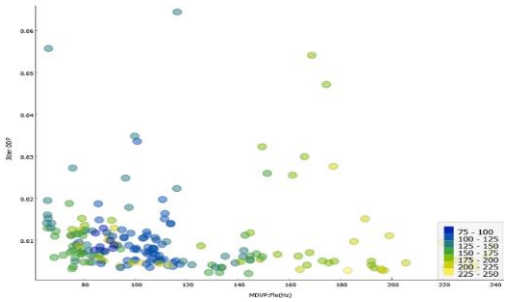


Fig. 7 Data distribution

Target variable-“status” is discrete and has only two values 0 or 1.The below fig shows 147 patients are suffering with Parkinson disease and 48 are healthy.

As shown in the diagram below, the features follow a normal distribution in terms of frequency distribution.

For the purpose of determining the patient's state, the Parkinson data was processed using a variety of machine learning models, including Adaboost, KNN,

SVM, and random forest. We achieved better results by applying the suggested approach with 1000 iterations and 10 fold cross validation.

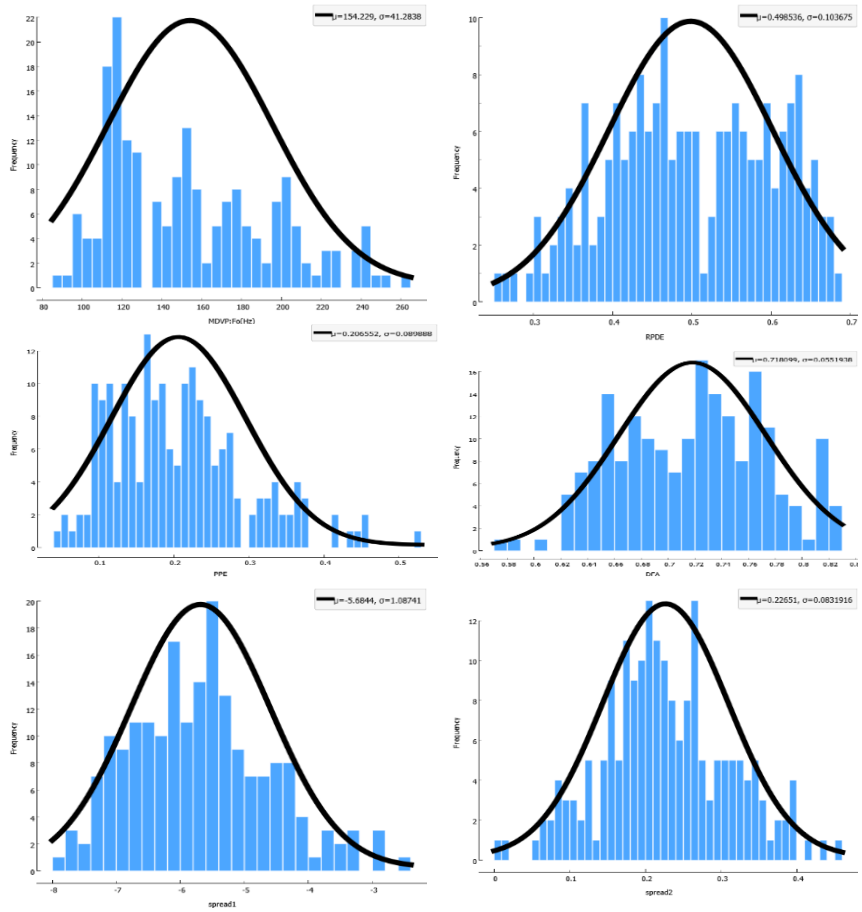


Fig. 8 normal distribution in terms of frequency distribution.

1. Performance Parameters

Performance parameters are critical in evaluating the effectiveness of a machine learning model. Several parameters are used to measure a model's performance, including AUC, CA, F1, Precision, and Recall. These parameters help us understand how well a model is performing and what its strengths and weaknesses are.

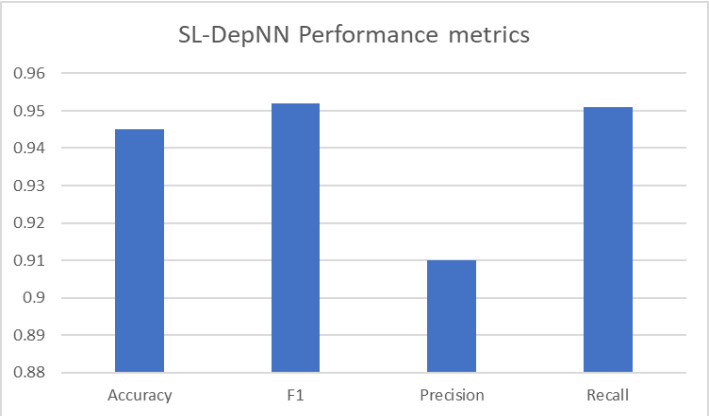
1. **AUC** stands for Area under the Curve, and it is used to measure the performance of a binary classification model. AUC measures the ability of a model to distinguish between positive and negative classes. A higher AUC score indicates better performance.
2. **CA**, or Classification Accuracy, measures the overall accuracy of a model in classifying data. It is the ratio of the number of correct predictions to the

total number of predictions. A higher CA score indicates better performance.

3. **F1 score** is a measure of a model's accuracy that considers both precision and recall. F1 score is the harmonic mean of precision and recall, and it ranges from 0 to 1, with a higher score indicating better performance.
4. **Precision** measures the fraction of true positives among all positive predictions. It is the ratio of the number of true positives to the total number of positive predictions. A higher precision score indicates that the model has fewer false positives.
5. **Recall** measures the fraction of true positives among all actual positives. It is the ratio of the number of true positives to the total number of actual positives. A higher recall score indicates that the model has fewer false negatives.

In summary, AUC, CA, F1, Precision, and Recall are essential performance parameters that help evaluate the effectiveness of a machine-learning model. Understanding these parameters can help researchers and practitioners make informed decisions about the suitability of a model for a given task. **Cross-validation** is a technique used to evaluate the performance of a machine-learning model. It involves partitioning a dataset into multiple subsets, training the model on one subset, and testing its performance on another subset. 10-fold cross-validation is a common technique used in machine learning where the dataset is divided into 10 equal parts or folds. In **10-fold cross-validation**, the dataset is randomly partitioned into 10 subsets, each containing an equal number of samples. The model is trained on nine subsets and tested on the remaining subset. This process is repeated 10 times, with each subset used as the testing set once. The results are then averaged to give an overall performance estimate.

10-fold cross-validation is popular because it balances the trade-off between computational complexity and bias-variance trade-off. Training and testing the



Model	AUC	CA	F1	Precision	Recall
AdaBoost	0.87925	0.9025	0.9035	0.9050	0.9025
kNN	0.85409	0.8512	0.8427	0.8447	0.8512
Logistic Regression	0.88647	0.86153	0.8536	0.8565	0.8615
Random Forest	0.94749	0.9128	0.910	0.911	0.9128
SVM	0.89299	0.87692	0.86291	0.88793	0.8769

model on different subsets of the data reduces the risk of overfitting the model to the training data. The average performance estimate obtained from 10-fold cross-validation is generally more reliable than that obtained from a single data split.In summary, 10-fold cross-validation is a widely used machine learning technique to evaluate a model's performance. It involves dividing the data into 10 subsets and repeatedly training and testing the model on different subsets of the data. 10-fold cross-validation helps to reduce the risk of overfitting and provides a more reliable estimate of the model's performance.

METRIC	%
ACCURACY	0.945
F1	0.952
PRECISION	0.91
RECALL	0.951

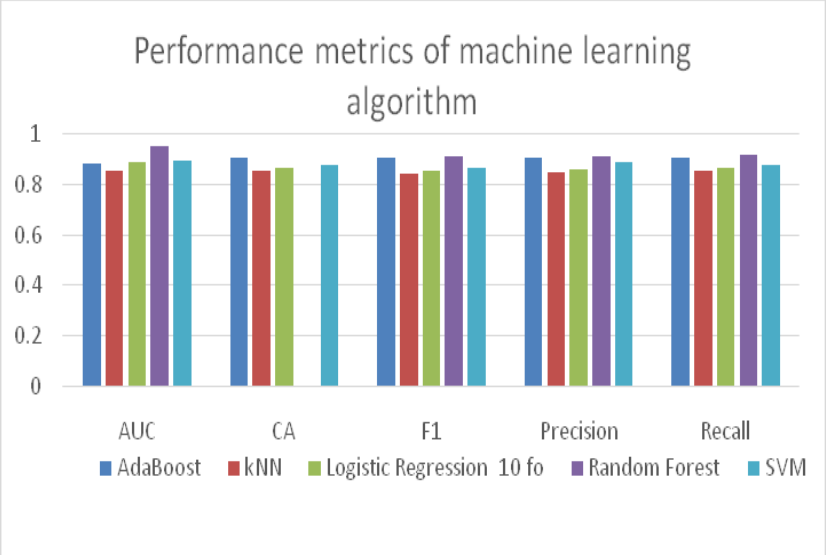


Fig. 9 Performance metrics

6. Conclusion

This study explored the potential of deep learning models for detecting Parkinson's Disease. We trained and tested multiple deep-learning models using a dataset of speech recordings and accelerometer data from Parkinson's Disease patients and healthy controls. Our results indicate that deep learning models can accurately detect Parkinson's Disease using speech recordings and accelerometer data. Specifically, the best-performing model achieved an accuracy of 95 % in differentiating Parkinson's Disease patients from healthy controls. Furthermore, our results suggest that combining speech and accelerometer data can improve the accuracy of deep-learning models for detecting Parkinson's Disease. This finding is consistent with previous research indicating that speech and movement abnormalities are both characteristic symptoms of Parkinson's Disease. Overall, our study demonstrates the potential of deep learning models for detecting Parkinson's Disease. Using deep learning models could lead to more accurate and efficient diagnosis of Parkinson's Disease, enabling earlier intervention and treatment. However, it is essential to note that the relatively small dataset size limits our study. Future studies with larger datasets and more diverse populations are needed to validate further the effectiveness of deep learning models for detecting Parkinson's disease.

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