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Performance Analysis of Deep Learning and Machine Learning Techniques on Detection of Parkinson's Disease

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***Abstract*— Parkinson's disease (PD) is a sophisticated anxiety malady that impairs movement. Symptoms emerge gradually, initiating with a slight tremor in only one hand occasionally. In the early degrees of PD, your face can also additionally display very little expression. Your fingers won't swing while you walk. Your speech can also additionally grow to be gentle or slurred. PD signs and symptoms get worse as your circumstance progresses over time. The goal of this paper is to test the efficiency of deep learning and machine learning approaches in order to identify the most accurate strategy for sensing Parkinson's disease at an early stage. In order to measure the average performance most accurately, this research work has compared an ensemble method, 2 deep learning methods and 6 machine learning methods by utilizing a large dataset with 5876*22 fields collected from UCI machine learning repository which consists of details of both subjects of PD and healthy individuals. Performance analysis of each method is done by considering the metrics like Precision, Recall, F1-Score, Support, Confusion Matrix, Specificity and Sensitivity and are plotted in graph showing training loss and accuracy. The highest accuracy of 97.43% is achieved for KNN with k=5 (K-Nearest Neighbors) algorithm which is a supervised machine learning approach.**

Keywords*— *Parkinson's Disease, Performance, Detecting, Accuracy, Deep Learning, Machine Learning, Ensemble learning.

I. INTRODUCTION

Parkinson's disease (PD) was first described by Dr. Parkinson's as "trembling paralysis". Parkinson's disease may be a brain disease that can cause tremor, firmness, and staggering, balance, and coordination. Parkinson's disease symptoms normally appear gradually and deteriorate over time. People may find it difficult to walk and talk as the disease develops. You'll also have sleep issues, depression, unmindful fullness, and weariness, as well as psychological and behavioral changes. Parkinson's disease can strike anyone, regardless of gender. They are 50% more likely to suffer from this disease than women. The main risk factor for Parkinson's disease is aging. Although most people get Parkinson's disease after the age of 60, there are still 5-10% of people who get Parkinson's disease before the age of 60. 50. Called "early onset" disease.

Early detection of Parkinson' unwellness is important for speed the disease' course. Several data-driven methods are developed over the years to boost the identification of Parkinson' disease. Machine learning, with its data-driven methodologies, had brought an amendment within the templet within the manner essential info in metallic element biomarkers is retrieved and analyzed, since it's latterly emerged as a possible topic of analysis in each academe and trade for the identification of PD. Additionally, machine learning technologies provide vital information that aids in the classification and diagnosis of Parkinson's disease, allowing for faster decision-making. so as to resolve the PD detection challenge, several machine learning algorithms are utilized in the literature.

A deep studying version is created to differentiate regular humans from humans with Parkinson's disease. The number one motivation of this paper is to offer a comparative evaluation and shed mild at the efficacy of superior prediction algorithms whilst implemented to large PD facts sets. The results showed that when compared to deep learning models developed machine learning model has a better detection performance in distinguishing normal persons from Parkinson's disease patients.

The second motivation of this paper is to compare the advanced methods like data-driven prediction

approaches in early-stage detection of PD. In this paper, we compared an ensemble method, 2 deep learning and 6 Machine learning data-driven methods to evaluate the best accurate method that detects the PD at an early stage by using the large dataset. The dataset used here contains 5876*22 records of healthy individuals and subjects of PD. The dataset we collected is from UCI machine learning repository. The methods utilized in this work are XGBoost, SVM (Support Vector Machine), Decision Tree, Logistic Regression, KNN (K-Nearest Neighbors), Random Forest, Naive Bayes, CNN (Convolutional Neural Network), RNN (Recurrent Neural Network). Performance analysis of each method is done by evaluating the metrics like Precision, Recall, F1-Score, Support, Confusion Matrix, Specificity and Sensitivity.

II. RELATED WORK

There are many researches going on Parkinson's disease regarding the diagnosis at early stages and also symptoms identification through various techniques which can be useful for the initiation of therapeutic inventions at an early stage and also the strategies to manage them.

In [1], The Probabilistic Neural Network (PNN) is used in a study to distinguish persons with Parkinson's Disease from healthy ones. They primarily used three types of PNN models: incremental search (IS), Monte Carlo search (MCS), and hybrid search (hybrid search) (HS) and these models provided accuracies from 79% to 81% for diagnosis of the disease for the people who are not diagnosed before. Even if the data is quite variable, the results achieved using PNN demonstrate the robustness of this technology. In[2], They also introduced Pitch Period Entropy (PPE), a new estimate for dysphonia which is used for detecting the variations in the frequency of voice. In their research they collected Phonations from few people among them most of the candidates with PD. The kernel support vector machine achieved a 91.4 percent performance. They predict that future Internet capacity will be sufficient to eliminate the necessity for voice compression, and their conclusions are based on broadband, uncompressed audio transfers. In [3], They used an interactive information metric with a permutation test to determine the pertinences. Mutual information, on the other hand, only works with two components at a time, therefore it overlooks the variables' combined impact on the PD-score. In [4], They used SAS base software for applying classification methods in the diagnosis of PD. Their results proved that Neural Network classification model produces best outcomes. They also compared their results to the outcomes that are yielded by kernel SVM's. This records highest classification score than the previous researches.

In [5], Biomedical voice of human is used as Parkinson's dataset. The 2 varieties of ANNs utilized for classification are Multilayer Perceptrons (MLP) and Radial Basis operate (RBF) Networks. The choice methodology for feature choice from the dataset is that the adaptational Neuro-Fuzzy Classifier (ANFC) with linguistic hedges. Different and unique feature selection and classification strategies are provided, which had provided more accurate solution for diagnosing concealed PD at an early age. In [6], The aim of this observe is to apply fuzzy c-means (FCM) clustering-primarily based totally characteristic weighting to come across Parkinson's sickness (PD) (FCMFW). They found that combining the proposed weighting approach dubbed FCMFW with the k-NN classifier produced the best results in the PD classification experiment. In [7], They proposed a function choice method primarily based totally on fuzzy entropy measurements on this study, which turned into examined along a similarity classifier. Experiments have proven that once a function choice approach primarily based totally on fuzzy entropy measures is used with a similarity classifier, the outcomes are satisfactory. In [8], They attempted to capture the valuable features of automatic identification, learning, and adaptation by drawing inspiration from natural immune systems. Training bio inspired CLONCLAS is the base algorithm that the developed algorithms have. The trials conducted in this study yielded a number of characteristics from artificial immune systems. There is also scope to combine immune system algorithms with other methodologies such as neural networks or genetic algorithms. In [9], The six specific varieties of function choice techniques which are as compared of their studies to get the preferred effects are minimum-redundancy, maximum-relevancy (MRMR), Bhattacharyya, records gain, relief, t-test, and SVM (aid vector machine) techniques primarily based totally on recursive function elimination (SVM-RFE). Experiments conducted shown that 95.13% classification accuracy is obtained from SVM-RFE.

In [10], The MDS-UPDRS (Mobility Disorder Society-Unified Parkinson's Disease Rating Scale) is a useful tool for assessing the most important aspects of Parkinson's disease. The predictive fashions of SVM, Adaboost primarily based totally ensemble, Random forests, and probabilistic generative version that accomplished properly with the AdaBoost-primarily based totally ensemble had the nice accuracy of 97. Finally, they located that once MDS-UPDRS is paired with classifiers, powerful equipment for predicting PD

staging may be produced, which could resource therapists with inside the diagnostic process. In [11], Early identification of Parkinson's malady (PD) is regarded critical since it allows for the early implementation of treatment therapies and management methods. The Patient Questionnaire (PQ) phase of the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) is used. They determined that with the aid of using the usage of system mastering strategies to hyperlink the objects of a questionnaire, prediction fashions have the capacity to useful resource clinicians with inside the prognosis process. In [12], The primary aim of this look at is to examine and evaluate sentiment evaluation of sufferers with Parkinson's ailment the use of deep getting to know and phrase embedding fashions. Convolutional Neural Networks (CNNs), Long Short-Term Memory Networks (LSTMs), and Recurrent Neural Networks (RNNs) are utilized to put into effect the type approach. This work's researchers additionally aimed to enhance a hybrid version that integrates textual and vocal facts recording facts if you want to useful resource with inside the early detection of Parkinson's ailment. In [13], The researchers compared the recommended deep learning model with few machine learning and collaborative learning methods that use a tiny amount of data. Including 183 healthy people and 401 early-stage Parkinson's disease patients, the developed model showed the best detection efficiency, with standard accuracy rate of 96.45%. The research conducted in this study shows that the developed deep learning model is superior to 12 machine learning models used to distinguish between abled-bodies and Parkinson's disease patients.

III. Dataset and Proposed Methods

The system framework is given in the figure: 1. Two main stages are involved in detection of PD: a) Training and b) Testing. The dataset which consists of raw data is pre-processed and split into training dataset and testing dataset. Classification is done for both the datasets and results are obtained.

A. Dataset Details

UCI Machine Learning Repository (https://archive.ics.uci.edu/ml/index.php) provided the dataset used in this study. This dataset is comprised of 23 and 31 patients with a biological voice measuring range for Parkinson's disease (PD). A specific audio measurement is provided by each column of the table, and each row corresponds to one of the 195 audio recordings (the "Name" column). Data mainly aim at distinguishing between healthy individuals with PD on the basis of a "status" column with healthy individuals at 0 and PD at 1. The data is in ASCII CSV format. There are approximately 6 records per patient.

- MDVP: Average vocal fundamental frequency of Fo (Hz)
- MDVP: Fhi (Hz) Highest recorded vocal fundamental frequency
- MDVP: Flo (Hz) Lowest recorded Vocal Fundamental Frequency
- MDVP: Jitter (%), MDVP: Jitter (Abs), MDVP: RAP, MDVP: PPQ, Jitter: DDP Measured values of multiple fluctuations in the fundamental frequency
- MDVP: Shimmer, MDVP: Shimmer (dB), Shimmer: APQ3, Shimmer: APQ5, MDVP: APQ, Shimmer: DDA Measure some changes in amplitude
- NHR, HNR Two measurements of voice pitch component noise ratio
- State Subject health state (1) Parkinson’s disease, (0) Two non-linear dynamic complex measurements of Healthy
- RPDE, D2
- DFA signal Fractal scaling index
- spread1, spread2, PPE Three non-linear measurements of fundamental frequency variation

B. Proposed Methods

The proposed methods used to construct this paper are 6 Machine Learnings methods, 2 Deep Learning methods and an Ensemble Learning method. Performance Analysis of all these methods are done to detect the best method that accurately detects PD.

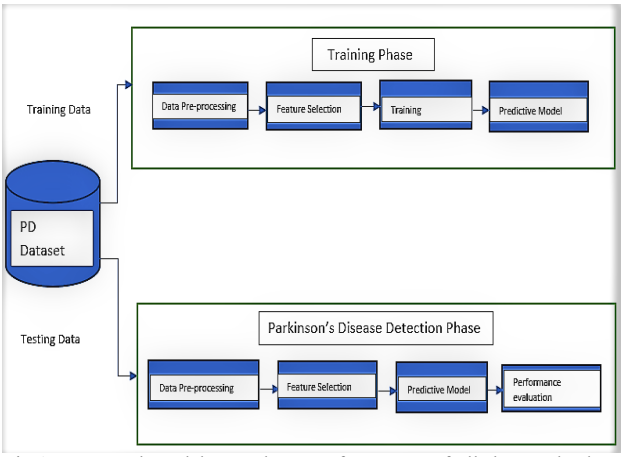

Fig 1: Proposed Model to evaluate performance of all the methods used in detecting PD.

1. Pre-Processing of Data:

Data preprocessing is a process in which raw data are produced and adapted to a learning model. It's the first crucial step to build a model for learning machines. We

do not always find the data clean and formatted when building an applied project and any data operation requires the data to be cleaned and placed on a prepared form.

2. Feature Selection:

Feature choice is the technique of lowering the wide variety of enter variables whilst growing a predictive model. It is applicable to lessen the wide variety of enter variables to each lessen the computational fee of modeling and, in a few cases, to enhance the overall performance of the model. These techniques may be rapid and effective, even though the selection of statistical measures relies upon at the records form of each the enter and output variables.

3. Training a Model:

A training model is a collection of data for the training of an ML algorithm. It comprises of samples of the output data and the related data set which affects the output. The training model is used to use the input data to link the processed output with the output sample through the algorithm. Here, we denote the training data by {(X1, y1), . . . ,(Xn, yn)}.

4. Predictive Models:

a. Ensemble Learning: Ensemble learning is a general meta-approach to machine learning that combines predictions from different models to improve predictive performance. Bagging, stacking, and boosting are the three primary classes of ensemble learning algorithms.

- *XGBoost* stands for Extreme Gradient Boosting method. It is a synthetic machine learning technique that uses a gradient boosting framework and is based on decision trees. In forecasting circumstances involving unstructured data, Artificial Neural Networks outperform all other algorithms or frameworks .

b. Machine Learning: Machine learning is described as the study of computer programmes that learn through inference and patterns without being explicitly programmed using algorithms and statistical models. There are two main methods of machine learning approach.

i. *Supervised Learning*: Supervised learning is one of the most fundamental types of machine learning. Despite the fact that properly labelled data is required for this method to perform, supervised learning has proven to be extremely effective.

- *SVM*: The Support Vector Machine is one of the most widely used supervised learning approaches for classification and regression problems (SVM). The SVM algorithm's purpose is to find the optimum decision line or boundary that divides the n-dimensional space into classes so that additional data points can be readily placed in the correct category in the future. The hyperplane is a term used to describe the optimal decision boundary.
- *Decision Tree:* The decision tree is a supervised learning technique that may be used to solve both classification and regression issues, however it is best for classification. It's a tree-based structured classifier, with internal nodes representing data set attributes, branches representing decision rules, and decision rules expressing decision rules.
- *Logistic Regression:* Logistic regression is a prominent machine learning algorithm that uses a number of independent factors to predict a categorical dependent variable. It is part of the supervised learning technique. The result must be a discrete or categorical value, such as yes or no, 0 or 1, true or false, and so on.
- *KNN:* K Nearest Neighbor is a supervised learning method that is one of the most basic machine learning techniques. The KNN algorithm assumes that the new case / data and the existing cases are comparable and places the new case in the category that is closest to the existing categories.
- *Random Forest:* Random Forest is a popular machine learning algorithm that is part of the supervised learning technique. It is frequently used in machine learning for both classification and regression problems. It is based on the notion of ensemble learning, which is a method of combining numerous classifiers to solve a complex problem and improve the model's performance.
- *Naive Bayes:* The Naive Bayes algorithm is a supervised learning algorithm for addressing classification issues which is based on the Bayes theorem.

ii. *Unsupervised Learning:* Unsupervised Learning has the advantage of being able to work with untagged data, which means it doesn't take human labor to make a dataset machine readable, allowing a program to work with much larger datasets.

c. *Deep Learning*: Deep learning is a sort of machine learning and artificial intelligence (AI) that mimics how people learn. Deep learning is a key component of data science, which also encompasses statistics and forecasting. Deep learning can be regarded of as a means to automate predictive analytics in its most basic form.

- *CNN:* In deep learning, a convolutional neural network (CNN) is a sort of deep neural network that is frequently used to analyze visual pictures. It employs a technique known as folding.

- *RNN:* A recurrent neural network (RNN) is a sort of artificial neural network in which nodes are connected in a directed graph in a temporal order. RNNs, which are built from feedforward neural networks, can use their internal state to process variable length sequences of inputs (memory).

IV. IMPLEMENTATION

We randomly divided the data and utilized 70% as training data and the remainder as test data to analyze the accuracy of the above Parkinson's Discrimination algorithms. Through stratified sampling, the proportion of patients with healthy persons in the training and test data is preserved equal to the original data. We utilize the training data to train machine learning methods, which we then use to predict whether the instances in the test data are Parkinson's patients or not. We have repeated the division over 100's of times. We report measures of performance in the test data using precision, recall, f1-score, support, specificity, sensitivity and confusion matrix and get the overall accuracy for each method.

For each model, firstly we are checking whether the training data consists of any missing values or not. And we are training the model and predicting it. And then we are finding all the performance metrics for it along with the accuracy. Once we are done with all the models, we are comparing all the models with the accuracy achieved. Confusion matrix is also predicted for each method with the predicting variables as 0 and 1, where 1 is considered as true and 0 to be false. The classification report for each method is generated with precision, recall, f1-score, support, micro average, macro average, weighted average, specificity, sensitivity and confusion matrix. Three-fold cross-validation is considered for all the methods except CNN. For better comparison results we have tuned all the methods to achieve the best performance.

V. RESULTS

The evaluation metrics used to evaluate the performance of all the methods in detecting the Parkinson's Disease are:

- Accuracy: AC= (TP+TN)/ (TP+TN+FP+FN)
- Precision: TP/ (TP+FP)
- Recall: TP/ (TP + FN)
- F1-score: 2 * (Precision * Recall) / (Precision + Recall)
- Support: Number of samples of the true answer found in each class of target values.
- Confusion Matrix: The output can be two or more types of classes.
- Specificity: TN / (TN + FP)
- Sensitivity: The proportion of actually positive cases that were predicted to be positive. It is also called as Recall.

Here, TP is the number of true positives, FP is the number of false positives, TN is the number of true negative results, and FN is the number of false negatives.

The dataset is slitted into 70-30 train and test sets respectively and are loaded into each model. Here, we denote the training data by {(X1, y1), . . . ,(Xn, yn)}.Then for each model we first calculate the overall accuracy and the classification report with all the metrics used to evaluate the model as discussed above. In the classification report generated zero represents false and one represents true for Parkinson's Disease subjects. Confusion matrix is Predicted for each method. Three-fold cross validation is used for all the methods implemented. The results are generated and are compared and then, the best method is evaluated based on the overall accuracy of it. The following are the results:

A. Results of Ensemble Learning Method XGBoost:

The results of Ensemble learning method XGBoost are shown in Fig2.

```
------Accuracy------
('XGBoost Accuracy:', 94.87179487179486, '%')


------Classification Report------
              precision    recall  f1-score   support

           0       0.86      0.86      0.86         7
           1       0.97      0.97      0.97        32

   micro avg       0.95      0.95      0.95        39
   macro avg       0.91      0.91      0.91        39
weighted avg       0.95      0.95      0.95        39


Confusion_matrix
[[ 6  1]
 [ 1 31]]
XGB_specificity: 0.857
XGB_sensitivity: 0.857
```

Fig 2: Results of XGBoost ensembling method.

94.87% is the overall accuracy we have achieved for XGBoost algorithm.

B. Results of Machine Learning Methods:

1. *SVM (Support Vector Machine):* The results of SVM are shown in Fig3.

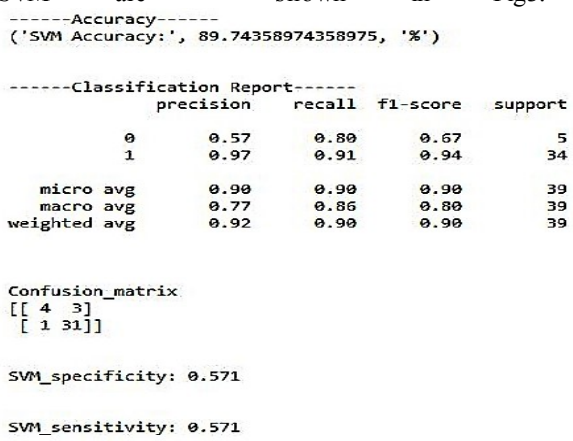

Fig 3: Results of SVM

The accuracy achieved for SVM is 89.74%.

2. *Decision Tree:* The results of Decision Tree Supervised Machine learning method are shown in Fig:4.

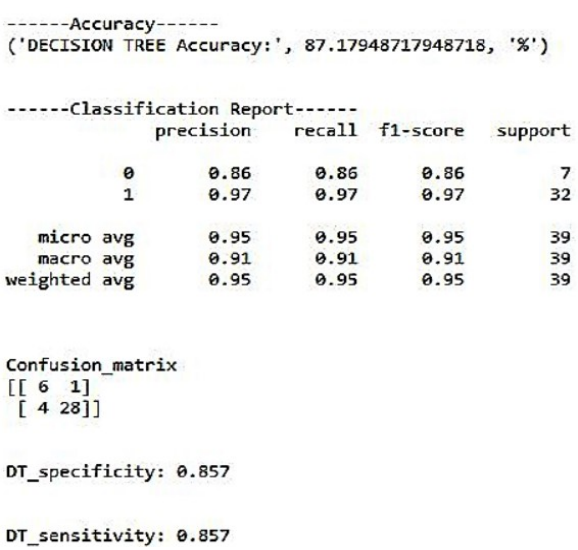

Fig 4: Results of Decision Tree classification method.

The accuracy achieved for Decision Tree is 87.17%.

3. *Logistic Regression:* The results of Logistic Regression, a Supervised Machine learning method are shown in Fig5.

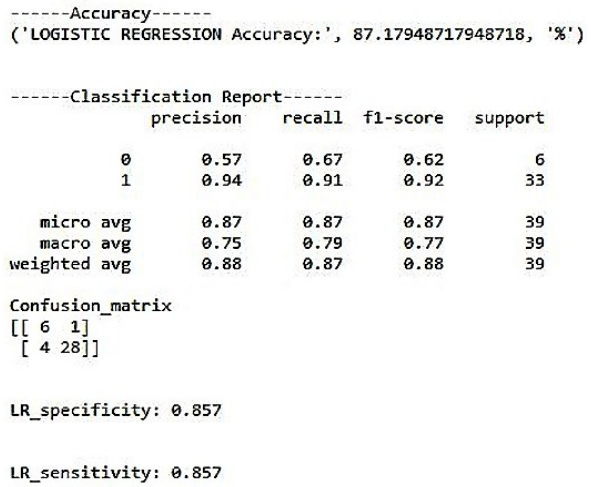

Fig 5: Results of Logistic Regression

The Overall accuracy achieved for Logistic Regression is 87.17%.

4. *KNN:* The results of K Nearest neighbors (KNN), a Supervised Machine learning method with k=5, are shown in Fig 6.

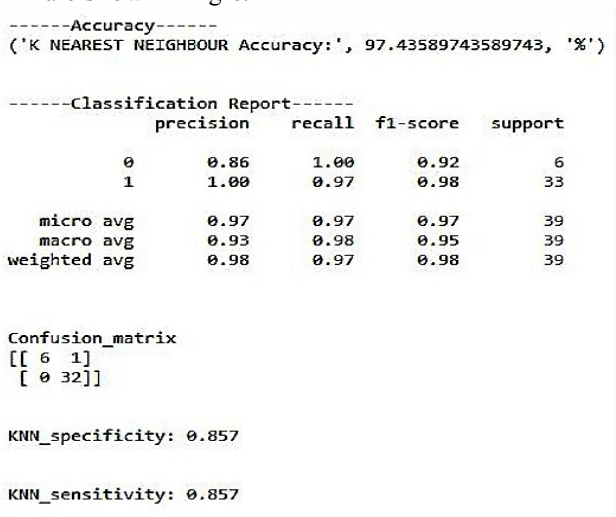

Fig 6: Results of KNN

The Overall accuracy achieved for KNN is 97.43%.

5. *Random Forest:* The results of Random Forest, a Supervised Machine learning method are shown in Fig 7.

```
------Accuracy------
('RANDOM FOREST Accuracy:', 92.3076923076923, '%')

------Classification Report------
              precision    recall  f1-score   support

           0       0.57      1.00      0.73         4
           1       1.00      0.91      0.96        35

   micro avg       0.92      0.92      0.92        39
   macro avg       0.79      0.96      0.84        39
weighted avg       0.96      0.92      0.93        39


Confusion_matrix
[[ 4  3]
 [ 0 32]]

RF_specificity: 0.857

RF_sensitivity: 0.857
```

Fig 7: Results of Random Forest

The Overall accuracy achieved for Random Forest is 92.30%.

6. *Naive Bayes:* The results of Naive Bayes, a Supervised Machine learning method are shown in Fig 8.

```
------Accuracy------
('NAIVE BAYES Accuracy:', 71.7948717948718, '%')

------Classification Report------
              precision    recall  f1-score   support

           0       0.71      0.36      0.48        14
           1       0.72      0.92      0.81        25

   micro avg       0.72      0.72      0.72        39
   macro avg       0.72      0.64      0.64        39
weighted avg       0.72      0.72      0.69        39


Confusion_matrix
[[ 5  2]
 [ 9 23]]

NB_specificity: 0.714

NB_sensitivity: 0.714
```

Fig 8: Results of Naive Bayes

The Overall accuracy achieved for Naive Bayes is 71.79%.

C. Results of Deep Learning Methods:

1. CNN: The results of Convolutional Neural Network (CNN), a Deep learning method are shown in Fig 9.

```
CNN Accuracy: 82.56410360336304 %

Classification_report
              precision    recall  f1-score   support

           0       1.00      0.29      0.44         7
           1       0.86      1.00      0.93        32

   micro avg       0.87      0.87      0.87        39
   macro avg       0.93      0.64      0.69        39
weighted avg       0.89      0.87      0.84        39


Confusion_matrix
[[ 2  5]
 [ 0 32]]

CNN_specificity: 0.7142857142857143

CNN_sensitivity: 0.7142857142857143
```

Fig 9: Results of CNN

The Overall accuracy achieved for CNN is 82.56%.

2. RNN: The results of Recurrent Neural Network (RNN), a Deep learning method are shown in Fig 10.

```
RNN accuracy is: 96.65814030476105 %

Classification_report
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        14
           1       0.64      1.00      0.78        25

   micro avg       0.64      0.64      0.64        39
   macro avg       0.32      0.50      0.39        39
weighted avg       0.41      0.64      0.50        39


Confusion_matrix
[[ 0 14]
 [ 0 25]]

RNN_specificity: 0.714

RNN_sensitivity: 0.714
```

Fig 10: Results of RNN

The Overall accuracy achieved for RNN is 96.65%.

D. Comparison of all the Methods:

Comparison of all the methods is done to identify the best method that accurately detects the PD at an early stage. The results are validated based on the overall accuracy achieved for each method and then comparing them to analyze the highest accuracy achieved method which is proved to be the best method that can accurately diagnose the PD at an early stage. Among all the methods employed the best accuracy was

achieved for the supervised Machine Learning Method KNN (K Nearest Neighbors) with 97.43%. We have considered the value of K as 5. XGBoost an ensembling learning method and RNN a Deep Learning method, both gives the best accuracy next to KNN as 94.87%. And finally, the next best accurate method is Random Forest Supervised Machine Learning method which generated 92.30% accuracy. Out of all the methods implemented Naive Bayes less accurate with 71.79% accuracy. Decision Tree and Logistic Regression which are supervised machine learning methods both had produced 87.17% accuracy. Besides these SVM had achieved 89.74% accuracy and CNN Deep learning method had achieved 84.61% accuracy.

Hence, the best accuracy of 97.43% was achieved for KNN (K Nearest Neighbors) with K=5. The comparison graph for evaluating the performance of all the methods used is given below in the Fig 11.

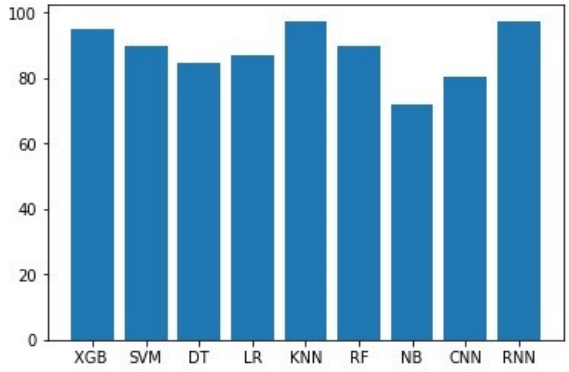

Fig 11: Bar chart representation of Overall Performance achieved for each method.

The subjects of Parkinson's Disease by discriminating with healthy ones are plotted in a graph with 'one' as subjects of PD and 'zero' as healthy ones as Shown in Fig 12.

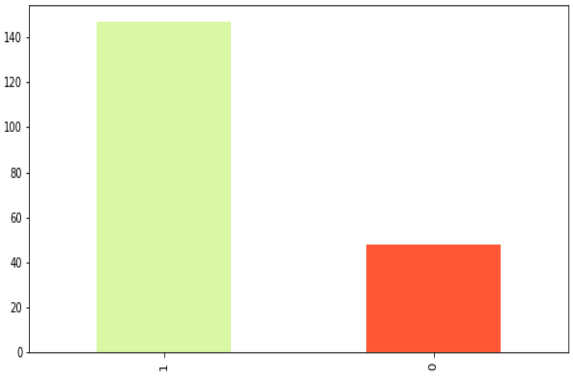

Fig 12: Bar chart representation of PD subjects and healthy individuals.

VI. CONCLUSION

To understand the causes and to proceed with medical advancement for treating Parkinson's Disease (PD), early detection of it is very important. This study proposed a Supervised Machine Learning method KNN (K nearest neighbors) where k=5, is capable of detecting the subjects of PD by discriminating the healthy ones. The Proposed Machine learning method generated good result in detecting the PD accurately with the highest overall accuracy 97.43%. The reason for this highest record is because of the uniqueness of KNN in utilizing the concept of "Maximum Voting" within the range of K and choosing the class with maximum number of votes when the problem to be solved is of type 'classification'. The results had proved that among all the 9 models chosen, a Supervised Machine Learning Model offers the highest detection rate of accuracy in discriminating PD subjects from the healthy individuals. Ensemble learning method XGBoost and Deep learning method RNN offers the next best accuracy 94.87%. Even though the experiments proved that KNN is the best accurate method with k=5, the results may vary with the values of k chosen differently. Hence, the outcome we achieved is the best performance approach for detecting PD in the early stage accurately. Apart from this feature selection and feature importance can also be considered as the major scope of work to be concentrated as considerably less work is contributed in this aspect.

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