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USING MACHINE LEARNING TO DETECT PARKINSON'S DISEASE
ПАРКИНСОН АУРУЫН АНЫҚТАУ ҮШІН МАШИНАЛЫҚ ОҚУДЫ ПАЙДАЛАНУ
ИСПОЛЬЗОВАНИЕ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ОБНАРУЖЕНИЯ БОЛЕЗНИ ПАРКИНСОНА

Abstract. *Parkinson's disease is a progressive neurological disorder that affects millions of people worldwide. Early and accurate detection of this disease is crucial in managing its progression and improving patient outcomes. In this study, machine learning algorithms were applied to a dataset containing 195 instances and 24 features representing both healthy individuals and those diagnosed with Parkinson's disease. The analysis showed that the dataset was unbalanced. Approximately 75% of the records corresponded to individuals diagnosed with Parkinson's disease.*

Five algorithms were implemented to evaluate the effectiveness of machine learning models in detecting Parkinson's disease: Logistic Regression, Support Vector Machine (SVM) with Linear Kernel, Decision Tree, Random Forest, and K-Nearest Neighbor (KNN). The results showed that the Random Forest and KNN models achieved superior performance compared to other methods. In particular, the KNN model showed the highest accuracy (95%), precision (94%), recall (100%), and F1 score (97%). The Random Forest model also achieved high performance with accuracy (92%) and other metrics close to KNN, indicating its reliability for this classification task.

On the other hand, Logistic Regression and SVM showed mediocre results, with precision, recall, and F1-scores below 95%. This study contributes to the growing field of medical diagnostics by demonstrating the potential of machine learning methods to detect Parkinson's disease.

Keywords: *Machine learning. Parkinson's disease, k-nearest Neighbor.*

Аңдатпа. *Паркинсон ауруы – бүкіл әлем бойынша миллиондаған адамға әсер ететін үдемелі неврологиялық бұзылыс. Бұл ауруды ерте және дәл анықтау оның дамуын басқаруда және пациенттердің өмір сүру сапасын жақсартуда маңызды рөл атқарады. Осы зерттеуде машиналық оқыту алгоритмдері Паркинсон ауруына шалдыққан және сау адамдарды қамтитын 195 жазба мен 24 сипаттамадан тұратын деректер жиынтығына қолданылды. Талдау нәтижесінде деректер жиынтығы теңгерімсіз екені анықталды: жазбалардың шамамен 75%-ы Паркинсон диагнозы қойылған адамдарға тиесілі болды.*

Паркинсон ауруын анықтауда машиналық оқыту модельдерінің тиімділігін бағалау үшін бес алгоритм қолданылды: Логистикалық регрессия, сызықтық ядросы бар қолдау векторлық машинасы (SVM), шешім ағашы, кездейсоқ орман (Random Forest) және ең жақын көрші (KNN). Зерттеу нәтижелері көрсеткендей, Random Forest және KNN модельдері басқа әдістермен салыстырғанда жоғары өнімділікке қол жеткізді. Әсіресе, KNN моделі ең жоғары дәлдікке (95%), дәлдік (94%), толықтық (100%) және F1 көрсеткішіне (97%) ие болды. Random Forest моделі де жоғары нәтижелер көрсетті, оның дәлдігі (92%) және басқа метрикалары KNN-ге жақын болды, бұл оны осы классификация міндеті үшін сенімді әдіс етті.

Ал Логистикалық регрессия және SVM алгоритмдері төмен нәтиже көрсетті, олардың дәлдік, толықтық және F1 көрсеткіштері 95%-дан төмен болды. Бұл зерттеу медициналық диагностика саласына үлес қосып, машиналық оқыту әдістерінің Паркинсон ауруын анықтаудағы әлеуетін көрсетеді.

Негізгі сөздер: *Машиналық оқыту. Паркинсон ауруы, k-ең жақын көрші.*

Аннотация. *Болезнь Паркинсона - прогрессирующее неврологическое заболевание, которым страдают миллионы людей во всем мире. Раннее и точное выявление этого заболевания имеет решающее значение для контроля его прогрессирования и улучшения результатов лечения пациентов. В этом исследовании алгоритмы машинного обучения были применены к набору данных, содержащему 195 экземпляров и 24 признака, представляющих как здоровых людей, так и людей с диагнозом болезни Паркинсона. Анализ показал, что набор данных несбалансирован. Около 75% записей соответствуют людям с диагнозом болезнь Паркинсона.*

Для оценки эффективности моделей машинного обучения при выявлении болезни Паркинсона было представлено пять алгоритмов: логистическая регрессия, машина опорных векторов (SVM) с линейным ядром,

дерево решений, случайный лес и K-ближайший сосед (KNN). Результаты показали, что модели Random Forest и KNN достигли более высокой производительности по сравнению с другими методами. В частности, модель KNN показала самую высокую точность (95%), прецизионность (94%), полноту (100%) и оценку F1 (97%). Модель случайного леса также показала высокую производительность с точностью (92%) и другими показателями, близкими к KNN, что указывает на ее надежность для этой задачи классификации.

С другой стороны, логистическая регрессия и SVM показали средние результаты с точностью, полнотой и показателями F1 ниже 95%. Это исследование вносит вклад в развивающуюся область медицинской диагностики, демонстрируя потенциал использования методов машинного обучения для выявления болезни Паркинсона.

Ключевые слова: *Машинное обучение, Болезнь Паркинсона, k-ближайший сосед.*

Introduction

Parkinson's disease has a major impact on society and is a type of neurodegenerative disease affecting millions of people worldwide. It is characterized by motor symptoms such as tremors, rigidity, and bradykinesia, as well as non-motor symptoms including cognitive impairment, depression, and sleep disturbances. Early detection of Parkinson's disease is crucial for improving patient outcomes and quality of life. Traditionally, diagnosis relies on clinical evaluations and the assessment of symptoms by healthcare professionals. However, these methods often lack the accuracy and sensitivity required for early-stage detection.

With advancements in technology, machine learning (ML) has emerged as a promising tool for the early detection and diagnosis of Parkinson's disease. Machine learning models can analyze vast amounts of data, including genetic information, imaging data, and electronic health records, to identify patterns indicative of the disease. These models have shown potential in improving diagnostic accuracy, providing objective insights, and reducing the dependency on subjective clinical assessments.

The integration of machine learning into medical diagnostics has opened new avenues for research and clinical applications. By training models on large datasets, ML algorithms can detect subtle changes associated with Parkinson’s disease, even in its earliest stages. This capability enables timely interventions, personalized treatment strategies, and more effective management of the disease.

Several studies have utilized different machine learning techniques to improve Parkinson's disease diagnosis. These techniques range from supervised learning methods such as Support Vector Machines (SVM) and Random Forest to unsupervised methods like clustering algorithms and neural networks. The choice of algorithm depends on the type of data being analyzed and the desired accuracy level.

Despite these advancements, challenges remain in implementing machine learning solutions in clinical practice. Issues such as data quality, interpretability of results, and ethical considerations need to be addressed to ensure reliable and trustworthy predictions. Additionally, the integration of machine learning models into healthcare systems must be seamless, ensuring that clinicians and patients benefit from these technologies without compromising privacy or accuracy.

In this article, we explore the use of machine learning for Parkinson’s disease detection. We examine various ML techniques, discuss their potential benefits, and address challenges associated with their application in healthcare settings. Through this comprehensive analysis, we aim to highlight the role of machine learning in transforming Parkinson’s disease diagnosis and management.

Machine learning techniques have been used to detect Parkinson's disease using voice signal characteristics. The machine learning techniques K-nearest neighbor (KNN) and Feed-Forward neural network (FNN) achieve high accuracy of 99.11% for FNN and 95.89% for KSVM models [1]. Another study used MRI and SPECT DaTScan datasets. This study presents four deep learning models enhanced with gray wolf optimization for early detection of Parkinson's disease. It demonstrates the effectiveness of machine learning in diagnosing Parkinson's disease. The study results achieve accuracy close to or higher than 99% [2].

Detection of Parkinson's disease using machine learning was achieved using LSTM neural network. The study processed gait deceleration data and achieved 96.3% accuracy. The model used wavelet features extracted from a publicly available dataset to improve recognition performance[3].

A deep learning architecture combining CNN, GRU, and GNN for early detection of Parkinson's disease was proposed in a study using gait cycle data from wearable sensors. As a result, high accuracy was achieved while overcoming the limitations of traditional machine learning approaches [4]. Other studies have also used clinical characteristics, voice features, and motor tests. Machine learning models for early detection of Parkinson's disease were developed. The study achieved 100% accuracy in classifying patients and 92% accuracy in distinguishing them from healthy controls [5].

A machine learning-based prediction system for early detection of Parkinson's disease was proposed in a study using support vector machine (SVM) and L1-Norm features, which was able to achieve high classification performance confirmed by K-fold cross-validation. It improves early diagnosis and integration into healthcare systems [6]. Studies using electroencephalogram signals and Mel spectrogram images combined with convolutional neural networks have been developed. By implementing an automated approach to Parkinson's disease detection, it significantly improves accuracy and provides early diagnosis and personalized treatment strategies [7].

A study using transfer learning with ResNet50 and SVM classifiers, using time-frequency images extracted from patient voice recordings, achieved 95.07% accuracy in training and 92.13% accuracy in testing [8]. It demonstrated 68% accuracy in classifying Parkinson's disease from UK Biobank fundus images [9]. It presents a hybrid LSTM-GRU model with voice recordings. It addresses the imbalance of the dataset through oversampling methods. It is observed that it significantly improves detection performance compared to traditional machine learning methods, achieving 100% accuracy with balanced data [10]. It also demonstrates the potential for non-invasive diagnosis with 88.46% accuracy using Support Vector Machine (SVM) algorithms based on voice recordings [11]. Parkinson's disease detection using machine learning involves analyzing speech signals using algorithms such as K-nearest neighbor, Random Forest, and Bayesian neural networks. Based on the parameters of the processed speech data, the recognition accuracy was 94.7%, 88.16%, and 74.74%, respectively [12].

Materials and methods

This study used the “Parkinson’s Disease” dataset and machine learning methods such as logistic regression, machine learning vector, decision trees, random forest, and nearest neighbor.

About the dataset

This dataset consists of a variety of biomedical voice measurements from 31 individuals, including 23 individuals diagnosed with Parkinson's disease (PD). Each column represents a specific voice metric, and each row corresponds to one of 195 voice recordings from these individuals (identified in the "name" column). The primary goal of the dataset is to distinguish between healthy individuals and those with PD, with the "state" column representing 0 for healthy and 1 for PD.

The data is available in ASCII CSV format. Each row in the CSV file represents one voice recording instance, consisting of approximately six recordings per patient. The first column contains the patient's first and last name.

Matrix column entries (attributes):

name-ASCII subject name and entry number

MDVP:Fo (Hz) - average vocal fundamental frequency

MDVP:Fhi (Hz) - maximum vocal fundamental frequency

MDVP:Flo (Hz) - minimum vocal fundamental frequency

MDVP:Frequency (%), MDVP:Frequency (Abs), MDVP:REP, MDVP:PPQ, Frequency: DDP-variable measures of variation in fundamental frequency

MDVP:Gloss, MDVP:Gloss(dB),Gloss:APQ3,Gloss:APQ5, MDVP:APQ,Gloss:DDA-variable measures of variation in amplitude

NHR, HNR-measures of the ratio of noise to tonal components in the voice

status-subject's health status (1 for Parkinson's disease, 0 for healthy)

RPDE, D2-nonlinear Two measures of dynamic complexity

DFA Fractal scaling index of the signal

spread1, spread2, PPE - three non-linear measures of the radical change in frequency

Machine learning methods

In the above sections, machine learning methods play a major role in the detection of Parkinson's disease. Several types of machine learning methods were used in this study.

Logistic regression

In statistics, a logistic model (or logit model) is used to predict the probability of an event by modeling the probability of the event as a linear combination of one or more independent variables. In regression analysis, logistic regression (or logit regression) estimates the coefficients of a logistic model using linear or nonlinear combinations of these independent variables. In binary logistic regression, there is one binary dependent variable represented by an indicator variable with values of "0" and "1". The independent variables can be binary (with two classes coded as indicator variables) or continuous (with specific measured values). The probability associated with a "1" can range from 0 (of course "0") to 1 (of course "1"), which explains the labeling. The logistic function is used to convert log odds into probabilities, giving the model its name. The unit of measure for the log odds scale is called the logit, which comes from the term logistic unit, and is therefore sometimes referred to as such.

Support vector machine

In machine learning, support vector machines (SVMs, also known as support vector networks) are supervised maximum likelihood models with associated learning algorithms used for classification and regression analysis. SVMs, developed at AT&T Bell Laboratories, are Vapnick (1982, 1995) and The most widely studied models are based on the statistical learning frameworks proposed by Chervonenkis (1974), in particular VC theory.

In addition to linear classification, SVMs can perform nonlinear classification using the kernel trick. This involves representing data using a set of pairwise similarity comparisons between the original data points, which are transformed into coordinates in a high-dimensional feature space using a kernel function. Thus, SVMs efficiently map inputs to high-dimensional spaces where linear classification is possible. As maximum margin models, SVMs are robust to noisy data such as misclassified examples.

Decision trees

A decision tree is a decision support tool that uses a recursive partitioning structure to model decisions and their possible outcomes. This tree-like model takes into account possible consequences, including the outcomes of random events, resource costs, and utility. It serves as a visual representation of an algorithm consisting only of conditional control statements.

Decision trees are widely used in operations research and decision analysis to determine the best strategy to achieve a desired goal. They are also a popular technique in machine learning for classification and regression tasks, providing insight into how to make decisions based on different input features.

Random Forest

Random forests or random decision forests are ensemble learning methods used for classification, regression, and other tasks. They work by building multiple decision trees during training. For classification tasks, the final output is the class that individual trees most often choose, while for regression tasks, it is the average of their predictions. This method addresses the tendency for decision trees to overfit the training data using ensemble methods.

The first random forest algorithm was introduced in 1995 by Tin Kam Ho using the random subspace method. This method implements the classification strategy originally proposed by Eugene Kleinberg, "stochastic discrimination".

A more advanced version of the algorithm was later developed by Leo Breiman and Adele Cutler, who trademarked "Random Forests" in 2006 (the trademark is currently owned by Minitab, Inc. as of 2019). This extension combines Breimann's "covering" technique with a random selection of features-a concept first introduced by Ho and later independently extended by Amit and Geman-to create a set of decision trees with reduced variance.

k-Nearest Neighbor

In statistics, the k-nearest neighbor algorithm (k-NN) is a nonparametric supervised learning method first introduced by Evelyn Fix and Joseph Hodges in 1951 and later extended by Thomas Cover. It is commonly used for classification, where it serves as a k-NN classifier. In this context, the algorithm assigns class membership to an object based on the majority vote of its k nearest neighbors. An object is classified into the class that is most common among its neighbors. When k=1, the object is assigned to the class of its nearest neighbor.

The k-NN algorithm can also be applied to regression tasks, known as k-NN regression or nearest neighbor smoothing. Here, the output is a numerical feature, which is calculated as the average of the k nearest neighbors. Similarly, when k=1, the output is the value of the nearest neighbor, often referred to as nearest neighbor interpolation.

In both classification and regression, it is often advantageous to assign weights to neighbors based on their distance from the target object, giving greater weight to the nearest neighbors. A common weighting scheme assigns a weight of $1/d$, where d is the distance to the neighbor, which ensures that the nearest neighbors contribute more to the result.

Results

In this section, predictions are made by machine learning algorithms after a preprocessing process on the dataset used in the study to detect Parkinson's disease.

Preprocessing

The dataset considered in the study consists of 24 columns and 195 rows. The calculations for the dataset considered in the study for the disease are summarized in Figure 1 below.

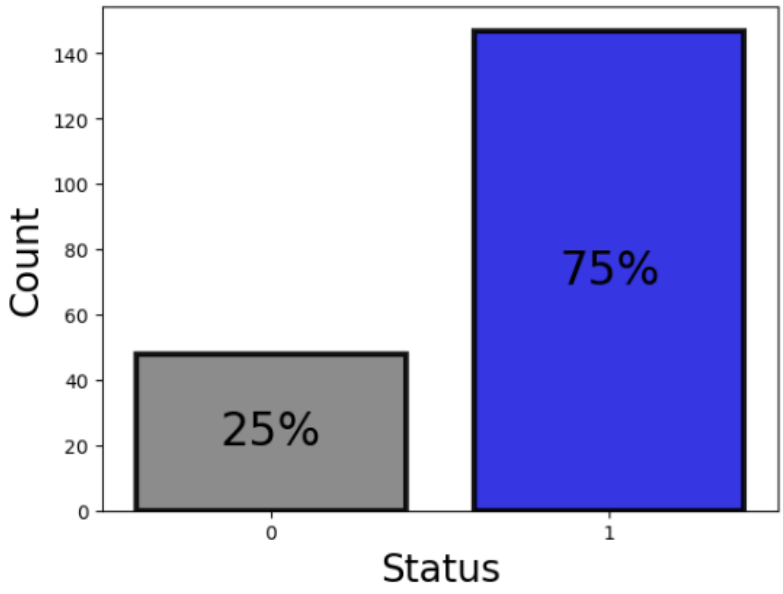

Figure 1. Proportion of Parkinson's disease in the dataset.

As shown in the figure above, the proportion of Parkinson's disease patients in the dataset used in the study is 75 percent. This means that the majority of the data in the dataset is filled with data from patients with Parkinson's disease. Table 1 below shows the dataset used in this study.

Table 1. Dataset used in the study.

name	MDVP:Fo(Hz)	MDVP:Fhi(Hz)	MDVP:Flo(Hz)	MDVP:Jitter(%)	MDVP:PPQ	Jitter:DDP	status
0	phon_R01_S01_1	119.992	157.302	74.997	0.00370	0.00554	1
1	phon_R01_S01_2	122.400	148.650	113.819	0.00465	0.00696	1
2	phon_R01_S01_3	116.682	131.111	111.555	0.00544	0.00781	1
3	phon_R01_S01_4	116.676	137.871	111.366	0.00502	0.00698	1
4	phon_R01_S01_5	116.014	141.781	110.655	0.00655	0.00908	1

The MDVP:Fo(Hz) values given in Table 1 are the mean vocal fundamental frequency values. Figure 2 below shows the prevalence of MDVP:Fo in Parkinson's disease.

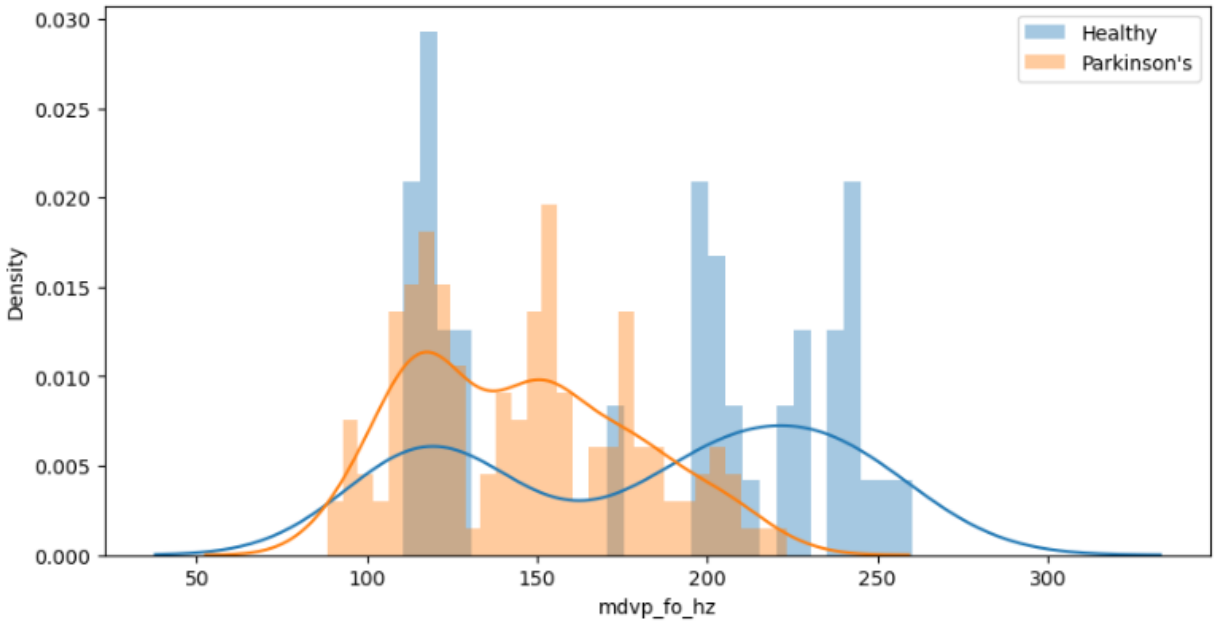

Figure 2. Prevalence of Parkinson's disease according to MDVP:Fo.

From the above diagram, it is observed that Parkinson's disease is more common at low Hz values of the mean vocal fundamental frequency. These results can be seen in the diagram shown in Figure 3 below.

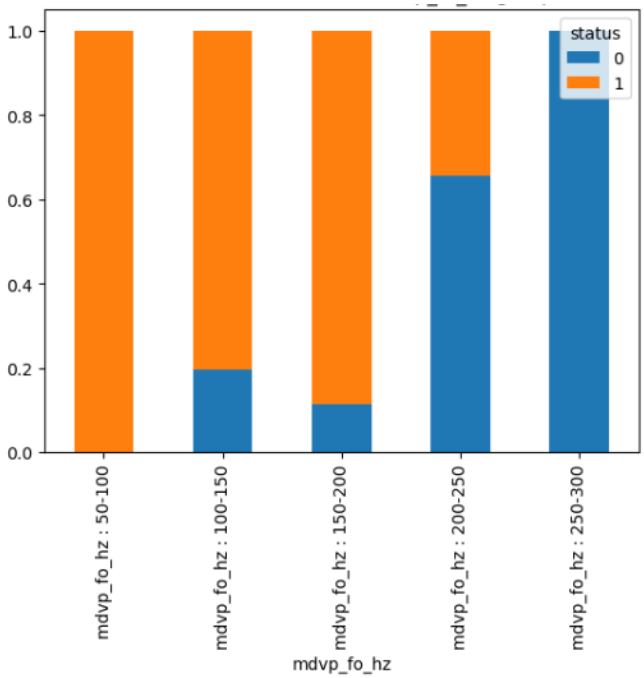

Figure 3. Relative frequencies of MDVP:Fo prevalence in Parkinson's disease.

In order to clarify the study, the relationships between the values of the given variables in the dataset were examined. During this examination, the appearance of the correlation data set is shown in Figure 4 below.

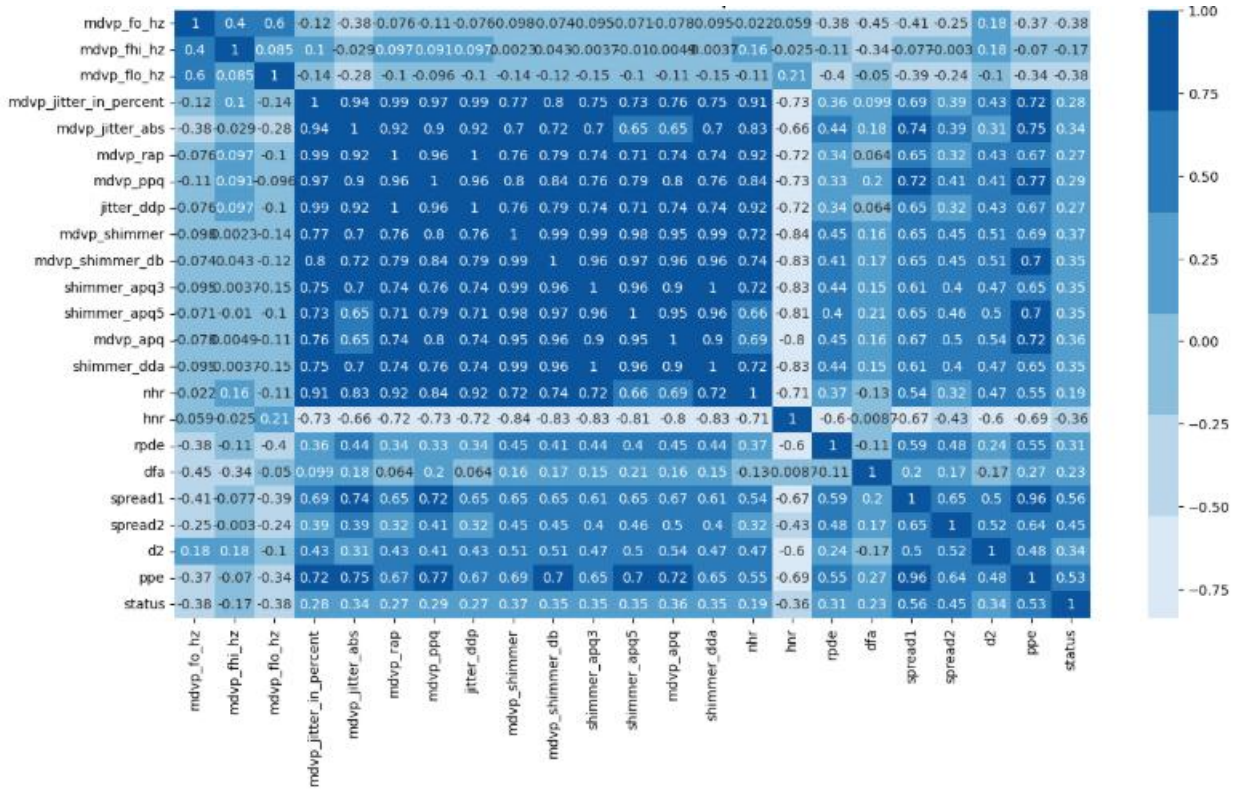

Figure 4. Results of the correlation dataset

After these steps, the data in the dataset is ready for machine learning algorithms to make predictions. Table 1 below presents the results of the machine learning algorithms used in the study.

Table 1. Results of machine learning algorithms in the detection of Parkinson's disease.

	Model	Precision	Recall	F1-Score	Accuracy
1	Logistic Regression	0.888889	1.000000	0.941176	0.897436
2	Support Vector Machine(linear)	0.888889	1.000000	0.941176	0.897436
3	Decision Tree	0.937500	0.937500	0.937500	0.897436
4	Random Forest	0.939394	0.968750	0.953846	0.923077
5	K-Nearest Neighbor	0.941176	1.000000	0.969697	0.948718

The table above shows the results of machine learning algorithms for the detection of Parkinson's disease, which was the goal of the study. As shown in the table, the precision, recall, f1-score, and accuracy scores of the Logistic Regression and Support Vector Machine (linear) models were the same. However, these values showed a low indicator compared to other models used in the study. The Decision Tree value was higher than the Logistic Regression and Support Vector Machine (linear) models in terms of precision, recall, and f1-score, but the accuracy values showed the same indicator, i.e. 89 percent. We can accept 89 percent as a high accuracy compared to the current works in this field. The high indicators in the study were achieved by the Random Forest and K-Nearest Neighbor models. The Random Forest model had precision 94%, recall 97%, f1-score 95%, and accuracy 92%. The K-Nearest Neighbor model is recommended for use in the diagnosis of Parkinson's disease, showing the results of the study with precision 94%, recall 100%, f1-score 97%, accuracy 95%, respectively. A comparative chart of machine learning models is shown in Figure 5 below.

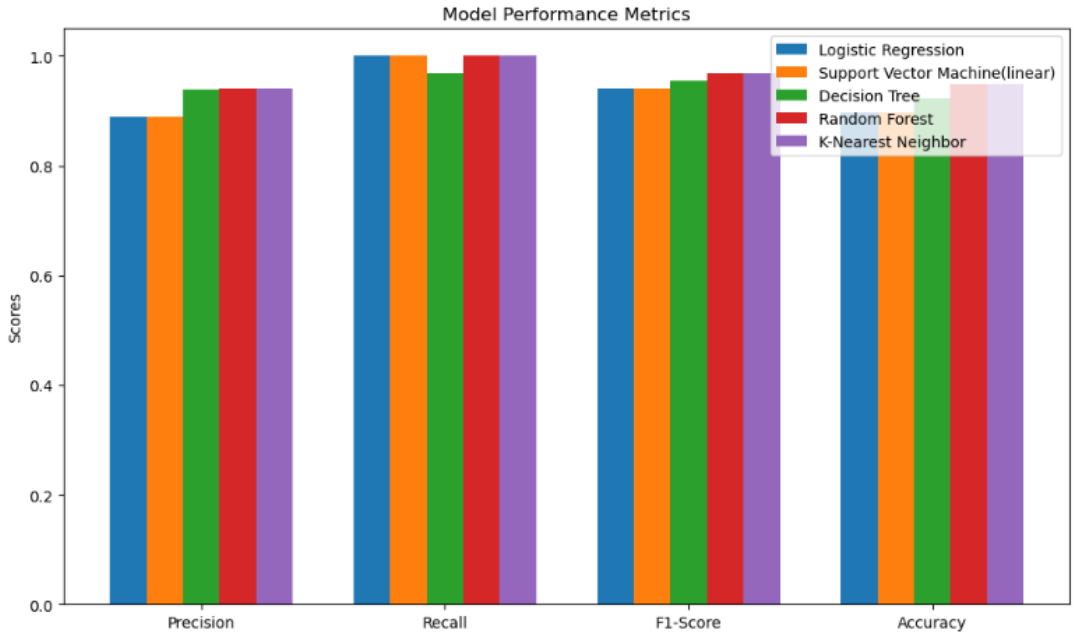

Figure 5. Comparative chart of model performance

Conclusion

The study analyzed the effectiveness and accuracy of machine learning algorithms for the diagnosis of Parkinson's disease. The data set preprocessing process improved the quality of the data. It became the basis for improving the predictive ability of the models. The results of the study showed that all the models used were able to diagnose Parkinson's disease to a certain extent, but their effectiveness varied depending on the indicators.

When comparing the performance of the algorithms, the Random Forest and K-Nearest Neighbor models achieved the highest accuracy indicators. In particular, the K-Nearest Neighbor model was distinguished by Precision 94%, Recall 100%, F1-Score 97%, and Accuracy 95%. These results allow us to recommend this model as a highly effective method for the diagnosis of Parkinson's disease.

Logistic Regression and Support Vector Machine (linear) models showed relatively low performance. They helped to identify the main trends in the diagnosis of the disease. Although the Decision Tree model also showed good results, its accuracy was lower than that of the Random Forest and K-Nearest Neighbor models.

Compared with current studies, the obtained accuracy rates (89%-95%) prove that machine learning methods are suitable for practical use in the diagnosis of Parkinson's disease. In addition, these results allow for early detection of the disease and support clinical decisions.

In the future, it is recommended to optimize the hyperparameters in the models, use a larger and more diverse dataset, and improve the results by using neural networks. These methods can further increase the reliability and accuracy of the diagnosis of Parkinson's disease.

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