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Performance Analysis of Handwriting Kinematics in Parkinson's Disease

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Abstract: **-**Parkinson's Disease is degenerative nerve disease which commonly found in aged people. The illness can put a lot of pressure on the body and make certain people more sensitive to infections that can be fatal. Parkinson's disease also has no cure at the moment. As a result, it is critical to discover Parkinson disease early in life in order to receive therapy. Using various machine learning and deep learning methodologies, we can anticipate Parkinson's disease. Speech, smell, stride, and handwriting are all involved. Traditional detection measures, such as smell and speech, can, however, be more difficult. For Parkinson disease identification, handwriting is a more efficient and time-consuming. An objective of this subject was to look back on progress of handwriting kinematic analysis in Parkinson's disease and to see how it has changed.

Keywords: *Neurodegenerative Disease, Parkinson Disease, Handwriting, Electronic pen and tab.*

1. Introduction

Parkinson's disease (PD) is a central nervous system degenerative disorder that affects the ability to govern movement. PD can cause trembling, muscle stiffness, trouble walking and maintaining balance and coordination. Speaking difficulties, sleep troubles, problems with thinking and memory, behavioural changes, and other symptoms may appear as the illness worsens. It occurs due to a variety of causes, including muscular stiffness and tremor caused by inadequate dopamine production activity. It is typically found in adults in their third decade of life. Parkinson's disease agitated an approximately 1 crore people globally. Between 41 people per 100,000 in their forties and more than 1,900 people per 100,000 in their eighties and nineties are affected by the disease. With increasing age, number of diagnosed people with Parkinson is increases. Also, Parkinson's disease affects an estimated 1 million persons in India. Before the age of 50, only 4% people get diagnosed properly. Due of the disease's huge financial impact on society and the nation, Parkinson's disease has recently attracted a lot of attention. There is now no cure for Parkinson Disease, and because the number of elderly people is growing at a rising rate and will continue to do so in the future, early detection and diagnosis is critical. Parkinson disease can be predicted in different ways, like handwriting, speech, gait, and smell. Various deep learning as well as machine learning algorithms are used to predict Parkinson's disease. Traditional methods of prediction face several obstacles, such as gait and speech; These signs may differ person to person and can be mistaken for those of many other conditions due to their similarity. The data collection utilized for this prediction should be free of background noise. Prediction through handwriting would be a more efficient and straightforward technique of detection in this approach.

2. Traditional Methods to Diagnose Parkinson Disease

Parkinson's disease can be predicted using a variety of criteria, including gait, smell, speech, and handwriting in the early stage. So, these are as follows.

2.1Parkinson's Disease Diagnosis through Handwriting

Parkinson disease prediction through handwriting is emerging research area. Parkinson disease prediction through handwriting contains four main steps i.e., Image processing, feature extraction, classificationand prediction. Data of Parkinson disease patient is taken as input for image processing. In image processing enhancement of image and extraction of information is done. Then prediction of normal and Parkinson disease patient is done by different classifier in classification step.

In Paper [1], Text mining is employed in this paper to discover a link between gait and Parkinson's illness. Using hierarchical clustering and K-mean clustering, comparable terms in the text are grouped. Data was gathered from 47 recent papers that had been pre-processed. To organize the data, a hierarchical technique and a centre clustering approach were applied. R programming was used for all text pre-processing, visualization, and clustering. The text was pre-processed by removing punctuation, stopping words, and removing frequent word endings. As a result, it may be concluded that gait is the most efficient method.

In Paper [2], The author of this paper used the Kaggle dataset, which has 102 samples of people's handwriting. Parkinson's disease diagnosis AI, Deep Learning, LSTM, CNN, LeNet Architecture, probability, and random processes were all utilized by the author. The spiral samples are used to classify the patients and people which are healthy using the LeNet design. The person is categorized into two groups based on their severity level: treated soon and treated immediately. Using probability and random processes, accuracy was found to be 93.63 percent.

In Paper [3], An intelligent computing-based strategy is employed to detect Parkinson disease in this paper. UCI's machine learning database provided the dataset. The handwriting database included 62 Parkinson's patients and 15 healthy people who were recorded in three distinct ways. Patients were classified into normal and Parkinson conditions using support vector machines, closest neighbour algorithms, and architecture neural networks. The accuracy of SVM, k-NN, and ANN was 37.5 percent, 100 percent, and 100 percent, respectively. During the comparison, it was discovered that k-NN is a good method for detection.

In Paper [4], The author of this article employed a dataset of 28 Parkinson patients and 28 healthy people in distinct patterns. Data was collected in a variety of patterns and then pre-processed with various noise and artefacts. The relative number of loop extremes, the impulse correlation coefficient, approximative entropy, multiscale entropy, writing power rate coefficient, and combining the features were all investigated. It was found that there are various simple, inexpensive, and non-invasive aspects accessible for accurate Parkinson diagnosis.

In Paper [5], Using inertial sensors detection of bradykinesia is done. Individuals were divided into three groups based on the existence of bradykinesia symptoms: those with Parkinson's disease, those with Parkinson's syndrome, and those in good health. In the Normal people group, there were 44 participants, 23 males and 21 females. The Parkinson Disease group had 18 individual and the Parkinson Syndrome group had 16 participants. The methods used were feature parameter extraction, model construction, and model performance evaluation. present a Parkinson's disease wearable automatic detection device that is easy to handle and doesn't damage individuals.

Challenges

- Feature extraction is difficult from blurred images.
- While feature extraction process sometimes unwanted noise is also added.
- Strokes of Handwriting changes from person to person.
- Cursive handwriting is difficult for processing.

2.2Parkinson's Disease Diagnosis through gait and movements

By withdrawing multiple features of movements, gait analysis is exploring it's potential related with chronic diseases. It is quite challenging to identify short-term and long-term gait characteristics and to investigate the relationship between movement signals and disease. The input is first gathered through sensors, accelerometers, and gyroscopes. The less efficient data or feature is reduced throughout the processing and normalization step. The dense and spatial characteristics are extracted during the feature extraction step. Different applications and techniques are used to process the features. With the help of vectors of features and some predictive algorithms, we categorize people as having Parkinson's disorder or being in good condition.

In Paper [6], In this research, a neural technique is suggested to categories Parkinson's disease patients utilizing Long-Short Term Memory (LSTM) neural networks and particular gait cycle temporal features. They used the gait cycle dataset provided on PhysioNet1. The dataset was created using vertical Ground Reaction Force (VGRF) measurements taken from sixteen sensors fixed beneath the feet of 72 healthy people and 93 patients. To minimize the input dimensions, the dataset goes through a subtraction and normalization process. The input sequence data is temporally analysed using the LSTM layer, and dense features are extracted using RELU and ELU. Finally, the binary classifier determines whether theindividual is healthy or patient. The proposed system's accuracy ranges from 97.66 percent to 97.78 percent.

In Paper [7], A gait sensing platform was introduced in this work, which can capture gait signals of human movement and distinguish patients from healthy. The mixed data of 386 volunteers were collected, including 218 normal people and 168 individuals affected with Parkinson. 3 different types of motion parameters are extracted based on the features provided by proposed platform: information of demography, spatial and temporal motion parameters, and turning movement features. We employed Naive Bayes, kNN, SVM, decision tree, linear discriminant analysis (LDA), quadratic discriminant analysis, adaboost, subspace method, and random forest to detect Parkinson's illness. In conclusion, As compared to the other eight methods random forest model is best with a 92.49 percent accuracy rate.

In Paper [8], The glove-like prototype, which is based on Arduino-Uno communication and programming, is used. A tri-axial accelerometer ADXL335 is implemented as a sensor. The sensor accelerometer is used to generate a signal of resting tremors in the terms of acceleration from the patient's forearm, wrist, and fingertip. Using a USB cable, the Arduino is connected to the computer. To collect the signals from the above-mentioned body parts, the accelerometer and Arduino Uno are installed to the glove. Using MATLAB IDE's capability, the periodogram of tremor and amplitude of the tremors are analysed by using amplitude plots and periodograms. This proposed prototype is a wearable medical gadget that can be used to analyse tremors in people with Parkinson disease and to help with a successful treatment.

In Paper [9], This research proposes a machine learning-based classification system that divides subjects into FoG, pre-FoG, and no-FoG categories. Three tri-axial accelerometer sensors with accelerometers, gyroscopes, EEG sensors, EMG, force and to track gait, bending sensors were worn on the back of the body, hip, and ankles. 4 different approaches are used to extract features: PCA, kernel PCA, LDA and kernel LDA. To decrease and extract features, dimensionality reduction is used. The k-NN classification system was utilized to divide gait into three categories: pre-gait freezing, no- gait freezing, and with gait freezing. With an average sensitivity of 94.1 percent and the specificity 97.1 percent, the suggested system can predict gait freezing by recognizing pre- gait freezing.

In Paper [10], There are four main types of gait problems in Parkinson's disease: rigidity, dystonia, insufficient leg strength, and gait freezing. There are 29 PD objects in the experiment. Using a surface myoelectric signal instrument and a plantar pressure collection device, gait data such as angular velocity, acceleration, myoelectric signal, and plantar pressure are gathered. The analysis procedure is separated into two stages: sitting and walking. The electrical signals or feature signals were analysed using IEMG, AEMG, and RMS, and all of the patients were rated using the H&Y and UPDSR rating scales. The KNN algorithm is used to classify patients. Among different algorithms, the model's average classification accuracy is 85.7 among different algorithms.

In paper [11], Data is acquired utilizing a variety of methods, including a moticon device sensor insole, a wristband, a BQ Aquaris E4.5 smartphone, and the Android SDK. Data from a variety of sources is included in the processing. These resources can be used to create a data file that looks like a medical file. The findings come from 64 Parkinson disease patients. Huntington illness, ALS and no idiopathic gait signs of five minutes. There are 93 people with PD and 73 Individuals with good health in the gait database for PD. Different body movement signals from the gait dataset is loaded and run, depending on the patient's interest. These patterns are retrieved and fined by a neural network, then analysis of normality is done.

In paper [12], The convincingness analysis of applying therapeutics with bio-electronic stimulation using resting tremor features was conducted on eight persons distress with PD. In paper diagnosis of Parkinson's disease is done by bioelectronic stimulation therapeutics. Resting tremors recorded by the hands that are used to execute the analysis while using bio-electronic stimulation therapeutics to treat PD. Eight patients are wearing a wearable device in this photograph. This device analyses hand movements. Then it examines the frequency band components of tremor prior-to bio-electronic stimulation therapeutics. AND is based on this that it is determined whether or not this approach is adequate for treatment.

Challenges

- Accurately extracting temporal and spatial gait coefficient and exploring the correlation amid interest disease and gait features has been a difficult problem.
- A "gait" report is long, the data is unclear, and it includes a clinical interpretation, all of which are not found in other clinical tests.
- Among the most challenging signs of PD is gait issues. There are certain concerns and subjectivities when judging Parkinson's disease because of the detonation and uncertainty of gait issues.
- We have no way of knowing which body parts will be useful in fixing sensors, accelerometers, and gyroscopes in order to obtain data in a more compact and efficient manner.

2.3Parkinson Disease diagnosis through Speech Analysis

Parkinson prediction through Speech is time consuming and is easy way to identify it. By different researches it is showed that about 90% people are showing speech disorders who have Parkinson Disease. Speech of People with Parkinson Disease is more of monotone rather than have the usual inflections. Parkinson prediction through speech mainly consist of steps i.e., Data preparation, feature vector extraction, classification and evaluation.Input of Parkinson Disease Patient dataset is given to the data preparation phase in which data cleaning, selection and production of training data and testing data is done. Feature vector extraction transforms raw data into numerical features. For classification of data different machine learning classification techniques are used. Evaluation is crucial step in which accuracy, precision and recall is done. And finally result of detection is obtained. Below are some works done in this area.

In paper [13], author has used dataset of 40 subjects in which 18 PWP and 22 control subjects.The database contained each participant's single sustained [a] and [m] phonation. Author have applied Relief-F feature reduction to the feature set. To differentiate Control subject and PWP author have used SVM classifier along (RBF) kernel. The quality of binary classifier is measured by Matthews Correlation coefficient (MCC). Author have used Anderson-Darling normality test to adjudicate divide the trait. Spearman correlation coefficient test is used to evaluate the strength of interrelation of UODRS-III score with reduced features. Accuracies obtained from proposed system are 93% and 70% for sustained character /m/ and /a/ respectively.

In paper [14], author have used clip-on microphone (Audio- Technica ATR- 3315) to record the samples of voice. There are following sets of data in given database: 1) Healthy Control Dataset (HC) of 190 samples. 2) Depressed Speech Dataset (DSD) of 55 samples. 3)Parkinson Speech Dataset (PSD) of 76 samples. Changes in speech were determined by automatic detection method. Low-level descriptors were used to measure the pressure amplitude. Input classification method used was RoT whose value were normalized between -1 to 1. The accuracy of given system is ranging from 74% to 81%.

In paper [15], LSVT Voice Rehabilitation dataset were used by author. LSVT Dataset contained range of biomedical speech signal processing algorithm of 14 Parkinson disease Patient. Dataset contain total Attributes about 309 and instances are 126. Dimensionality reduction approaches used in this system are PCA and CFA along with class prediction models, Logistic regression as well as Decision Tree. Dimensionalityreduction is done by reducing the data from higher p-dimensional vectors space to a lower k-dimensional factor space. By predicting answer classes using the class forecasting technique on extracted properties, the trained model is constructed. By this approach numbers of factors are reduced from 309 to 9. Proposed system achieved the best performance for dimensionality reduction. Accuracy obtained from proposed system are 92.2% for CFA-LR.

In paper [16], The data set used was consist of 195 voice recording collected from 31 people in which in which 8 was healthy and 23 was Parkinson disease patient. Classification methods are used to evaluate the performance. Data preparation uses this dataset of feature vector derivation. These feature vectors are classified with the help of three classification method i.e., 1) Decision-Tree 2) Naïve-Bayes 3) Neural-Network. In this proposed system author has compared neural network results. By this proposed system it is conclude that due to the model enhancement errors and accuracy might be change.

In paper [17], Author have described previously done studies on Parkinson Disease and common methods of classification. Different machine learning algorithms used are SVM, Linear SVM, Random tree, ANN, K-NN, SVM (RBF), Neural network, IBK, XGBoost, and AdaBoost. Etc. And different Deep Learning algorithms used were DBN, CNN, DNN, NN classifier and LSTM Etc. By this survey author has conclude that Random Forest is the best method of classification as compared to other which gives above 99% accuracy. In Deep learning neural network classifier gives the highest accuracy which is 99.49%. As a result, many machine learning (ML) and deep learning (DL) algorithms produce effective results for PD prediction.

Challenges

- Speech recognition system should be language independent.
- There is limitation on size of study population.
- Collected dataset should contain samples without any background disturbance e.g., Noise. For easy and accurate extraction of characteristics of speech.
- Discovering optimal set of speech characteristics which should be used for classification.

2.4Parkinson Disease diagnosis through smell analysis

In paper [18], In this database, there are seven patients with Parkinson's disease and twelve healthy individuals. No scented goods, such as soap, body scents, or body perfumes, were allowed to be used by the seven people. We conducted sensor testing to assess the fragrance signatures over four distinct time periods (ten, twenty, thirty, and forty minutes). When testing, the Adafruit CCS811 was found to deliver reliable readings by inserting swab in any region for 30 minutes or more. The best time was computed using this information. This methodology is completely dependent on smelling healthy people and Parkinson's patients. This technology analyses the components of a person's perspiration to see if he's suffering from a disease.

In paper [19], the authors have implemented well organized method used for Measurements for pressure distribution, acceleration, weight-bearing, balancing, and sequences of motion were obtained by sensor insole which was developed using moticon. Heart rate patterns, body movements, body temperature, and sleep duration are all monitored continuously. The wristband detects this. The method adopted is that the clinicians' app will supply all of the patient's reports. Any expert doctor can interact with any patient. This software will also provide numerous recommendations for the patient's overall health. Data is captured utilizing a variety of ways, including a moticon device sensor insole, a wristband, and a smartphone, the BQ Aquaris E4.5 also the Android SDK. By including extra data from a gyro meter and employing approaches such as randomization, the method for assessing dyskinesia, bradykinesia, gait, and posture is enhanced.

In paper [20], Deep brain stimulation can be used to diagnose people with PD. It is one of the options for PD treatment of individuals at a more advanced stage of the condition. Parkinson's disease could be treated with DBS and medications. Unified Parkinson Disease Rating Scale often used rating scales for determine the severity of PD (UPDRS). For diagnosing PD in earlier stages, it also employs the ABHITA Rating Scale, Yahr Rating Scale and the Hoehn Rating scale. Implementation of the method: The UPD Rating Scale Technique is utilized to create a versatile and comprehensive tool for determining the degree of disability in PD patients. This employs the Hoehn Rating scale and Yahr Rating Scale as well as the ABHITA Rating Scale.

In paper [21], By understanding the capability of IOT device which plays a vital role in treating the chronic diseases interest toward IOT is growing. They explain the outcomes of arrangement to predict the capability of IOT in future. In this paper symptoms were divided into four groups a] psycho-social symptoms b] Motor, or movement c] non-motor symptoms d] cognitive symptoms. It was found that majority of the attendees already implemented IoT technologies in their houses. IOT devices such as Alexa and Siri were most commonly discussed. They are trying to articulate that could Alexa could be useful in proposing new results for treating speech and voice disorders.

3. Comparative Study of Different Approaches on Parkinson Disease Detection

Various methods have been explored to differentiate those with PD and those who are normal. Each method has its own set of benefits and drawbacks. For identifying people with pd, each method employs a different set of parameters (features) and classifiers. The table below shows a comparison of the above-mentioned methodologies for recognizing Parkinson.

Table 1. Comparison of above methodology

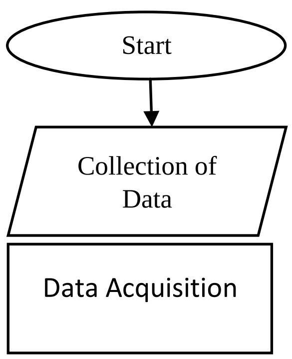
Sr. No.	Approach	Parameter Used	Accuracy
1.	Parkinson disease detection through handwriting.	Spiral windings and meanders writing.	93.63%
2.	Parkinson disease detection through Gait or Movements.	Legs, hip, wrists, back, ankle, forearm, fingertip movements.	92.49% to 97.78%.
3.	Parkinson disease detection through voice or speech.	Speech rates, Pitch, energy, noise ratio, Shimmer, jitter.	92.2%
4.	Parkinson disease detection through smell.	Nose, sweat.	Efficient

4. Proposed System

The condition known as Parkinson's disease (PD) is a progressive neurological disorder. It affects a nerve cell in the brain responsible for body movement. Parkinson's disease can be predicted using a variety of criteria, including gait, smell, speech, and handwriting in the early stage. However, handwriting is more suitable than the others since it is easier to apply different machine learning algorithms to handwritten samples and collecting data for handwriting is easier. we are collecting data using electronic pen and tablet which measures the pressure and movement during writing. Differences were easily discovered by the machine when handwritten data was collected in the shape of a spiraldrawing and algorithm were applied.

5. Implementation

5.1Architecture



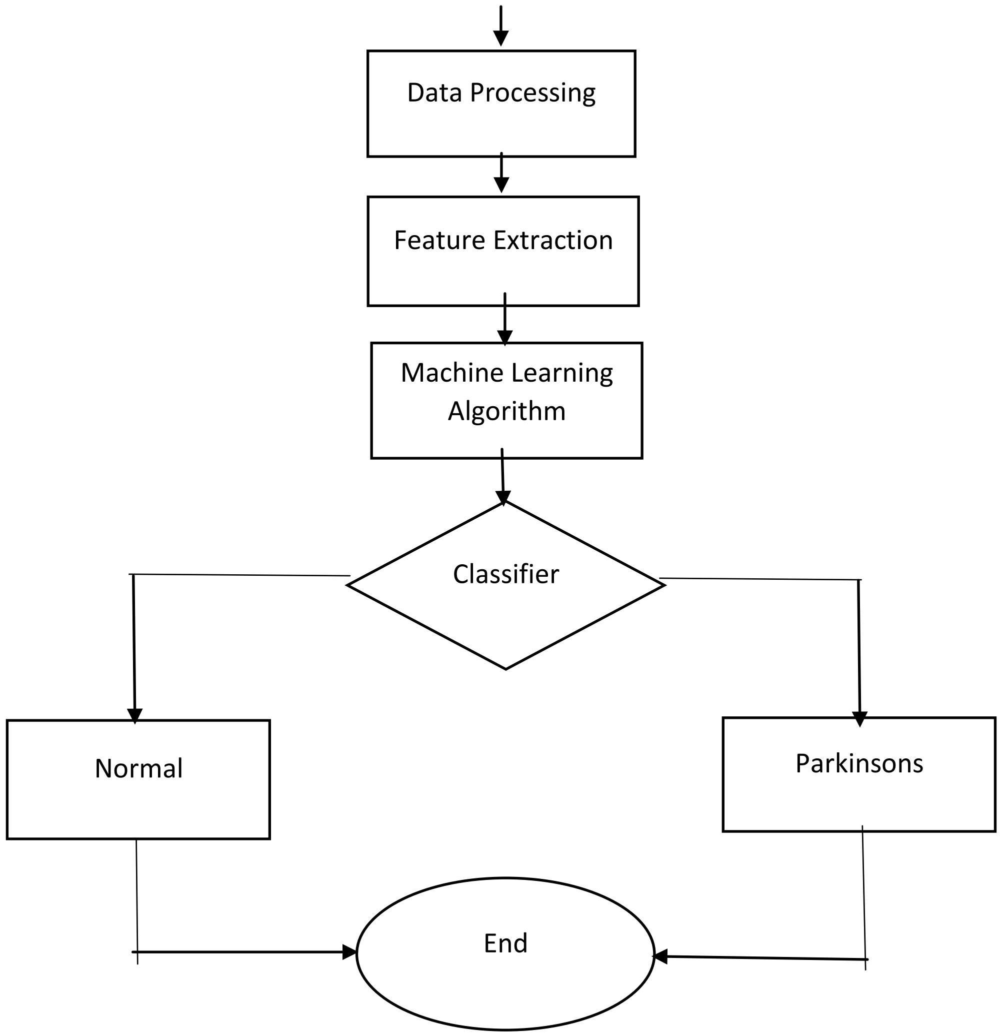


Fig. 1. Architecture

5.2Collection of data

We have used Meander HandPD dataset from the Kaggle which contains the handwritten meander drawing of people. The dataset consists of 92 individuals, of which 18 are healthy and 74 are sick. The dataset has 368 images total, including 72 images in healthy group and 296 images in patient group. We have kept only numerical columns and removed rows and columns that would lead to Data frame being singular. We have reduced columns for matrix inversion.

5.3Algorithms

We have used Logistic regression, KNN and Random Forest classifier and analysed result of our model. We have got different accuracy for all model which is as follows:

Logistic Regression

Instead of fitting a regression line in logistic regression, we must fit a S-shaped logistic function that forecasts two maximum values. The logistic function's curve displays the probability of something, such as whether or not individuals have PD. In logistic regression, the threshold value concept has been used to determine the probability of either 0 or 1. Examples include numbers that tend to 1 above and 0 below the threshold value. Table 2 displays the accuracy of the logistic regression model at 72.97%.

Table 2. Classification Report of Logistic Regression

	Precision	recall	f1-score	support
0	0.20	0.33	0.25	3
1	0.94	0.88	0.91	34
accuracy			0.84	37
Macro avg	0.57	0.61	0.58	37
Weighted avg	0.88	0.84	0.86	37

KNN

The KNN method uses a similarity metric. We have selected random K value for our model and calculated Euclidean distance. By using Euclidean distance taken the K nearest neighbour. We tallied the number of data points belonging to each category among these k neighbour. Then by calculating error rate we have got best K=2 value for our model. By using that K value, we got accuracy 91.89% which is mentioned in Table 3.

Table 3. Classification Report of KNN

	Precision	recall	f1-score	support
0	0.82	0.90	0.86	10
1	0.96	0.93	0.94	27
accuracy			0.92	37
macro avg	0.89	0.91	0.90	37
weighted avg	0.92	0.92	0.92	37

Random Forest

The random forest classification algorithm creates a set of decision trees from a subset of training data that is randomly selected. It merely consists of a group of decision trees drawn from a randomly selected subset of the set used for training, which are then utilized to make the final determination of whether the subject is healthy or not. Each decision tree has a sizable variation, but because we combined them all simultaneously, the variance is lowered because each decision tree has been flawlessly trained using that particular sample of data. As a result, there are now multiple decision trees that are used to determine the output instead of just one. To obtain the ultimate result in a categorization challenge, many voting classifiers are used. displayed in Table 4.

Table 4. Classification Report of Random Forest

	Precision	recall	f1-score	support
0	1.00	0.90	0.95	10
1	0.96	1.00	0.98	27
accuracy			0.97	37
macro avg	0.98	0.95	0.96	37
weighted avg	0.97	0.97	0.97	37

	0	1
0	9	1
1	0	27

Fig. 2. Confusion Matrix of Random Forest

5.4 Comparison

Using different classifiers, varying accuracy is obtained. Thus, by comparing different algorithms like Logistic Regression, KNN and Random Forest, we came to the conclusion that random forest, with its 97.29% accuracy, is the most suitable method for our model.

6. Future Scope

- By using different algorithm, we have obtained different accuracy among which 97.29% is our highest accuracy, future work can be done by using other different algorithm and can be tried to increase accuracy.
- For cursive and other types of handwriting, more relevant procedure and algorithms can be devised.
- Apart from the English language, an algorithm can also be designed for handwriting in other languages.

7. Conclusion

Parkinson's disease is most common chronic neurological illnesses among the elderly. Various features are used to detect people; however, handwriting is rarely used. So, using a machine learning algorithm on handwriting, we can anticipate Parkinson’s illness early on, and an early diagnosis will lead to successful treatment. This would slow the rate of progress in those who distressed, allowing to recover more quickly.

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