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Comparative Analysis of Parkinson's diseases diagnostic system

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Abstract **- Parkinson's disease (PD) is a neurodegenerative disease with no cure till date. Besides its characteristic motor symptoms, numerous non-motor symptoms have been reported to occur in the course of the disease. Parkinson's disease is also known as hypokinetic stiff syndrome in which loss of neuron in a region of brain called as substantia Nigra affects the motor neurons of central nervous system and this neurons are responsible for synthesizing the neurotransmitter dopamine which leads to many symptoms. To obtain a definitive diagnosis, the patient's medical history is analysed and the subject need to submit a series of clinical exams. In this study, we analyse different techniques to detect parkinson's diseases such as Breathing pattern, Handwriting Analysis, Hand Tremor, Freezing of Gaits. Recent research work indicates that Paxrkinson's diseases can be effectively diagnosed at an early stages by measuring the changes in handwriting. By analyzing various symptoms Parkinson's diseases can be predicted.**

Keywords **–** ***Parkinson's diseases, Handwriting analysis, Machine Learning, Motor Symptoms, Neuro diseases***

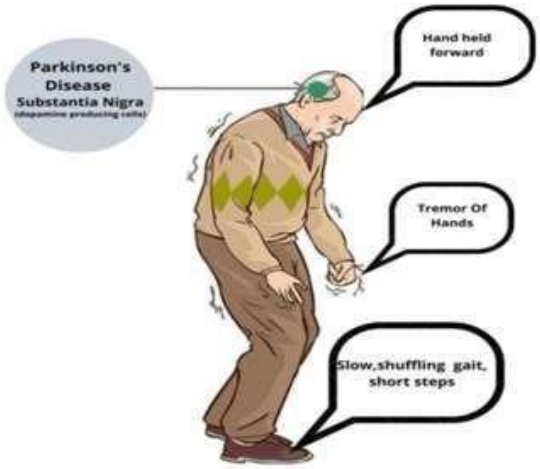

Fig 1 Symptoms of Parkinsons Disase[21]

I. INTRODUCTION

Parkinson's disease (PD) is one of the most widespread and most disabling neurodegenerative disorders;[1] The function of brain areas resulting in a gradual cognitive, behavioral and function are adversely affects so it resulting decline functionality. At present, there is no cure, and the progressive deterioration of the patient can only be somehow managed during disease progression. Nevertheless, early diagnosis of PD could be crucial from the perspective of proper medical treatment to be administered as well as to evaluate the effectiveness of new drug treatments at prodromal stages. Moreover, the assessment of signs and manifestations of this specific disease is useful for its diagnostic differentiation from similar disorders, and for monitoring and tracking its progression as the disease advances. With this aim, over the years, a growing interest of the community has been observed in computer-aided diagnosis. Such intelligent systems can effectively assist clinicians at the point of care, providing novel decision support tools, while reducing expenditure on public health.

Handwriting is a complex human activity taught in childhood and a daily activity that adults perform in various settings. In a handwriting task, people operate and integrate lower-level perceptual–motor and higher-level cognitive processes. Abnormal handwriting changes and specifically micrographia (abnormally small letter size) have been reported among PD patients. Previous findings also indicated that handwriting measures potentially differentiate between PD and healthy subjects, and identify various stages of PD and both

medication and intervention effects. Thus, measures of handwriting also may support PD identification.

II. HANDWRITING ANALYSIS

As we all know that there is special role in neurodegenerative diseases assessment can be covered by examining handwriting. Detection of Hypo-kinetic Rigid Syndrome handwriting patterns is productive for the diagnosis of Hypo-kinetic Rigid Syndrome. Nowadays, computer-aided methods based on computer vision points out the Hypo-kinetic Rigid Syndrome handwriting.

Handwriting problems can be related to the disease as well as to its severity, so changes in writing can be considered a prominent biomarker. For example, micrographic which means an abnormal reduction in writing size is typically associated with PD and it can be easily detected by conventional pen-and-paper tasks [2]. Dysgraphia which means a progressive disorganization and degeneration of the various components of handwriting has been observed in patients presenting mild to moderate AD levels[3].

Various handwriting measures such as height, width, jerk, velocity, speed, pressure on tip and many other parameters are measured to classify PD levels. Symptoms such as illegible writing, small writing, speech disorder, low voice, slow walking, depression and distressed moods are common in Parkinson's patients. These symptoms prevent people from carrying out their work and daily activities in a healthy way. For this reason, in the early stages of the disease, it causes the patient to isolate from business and social life. This situation causes the patients to be affected psychologically.

III. Dataset

A. PaHaW Dataset: Full form of PaHaW[4] is Parkinson's disease handwriting database" (PaHaW) which collects handwriting data of 37 PD patients and 38 age and gender-matched healthy control (HC) subjects. All participants were enrolled at the First Department of Neurology, Masaryk University, and the St. Anne's University Hospital, Brno, Czech Republic. All participants were educated as well as right-handed and reported Czech as their native language. This dataset doesn't consider bias of gender and age. Nobody had a history or presence of any psychiatric symptom or disease affecting the central nervous system, with the exception of Parkinsonism in the PD group. Patients were only examined in their ON-state while taking dopaminergic medication, and, prior to acquisition, they were evaluated by a qualified neurologist.

All participants were asked to complete eight handwriting tasks following:

1. Archimedes spiral;
2. Cursive letter l ;
3. The bigram le;
4. The trigram les;
5. cursive the word lektorka;
6. porovnat (\to compare");
7. nepopadnout (\to not catch");
8. Writing in cursive the sentence Tramvaj

B. UCI Parkinson's disease spiral drawings using digitized graphics tablet dataset[3] : Experiments have been performed on publicly available University of California, Irvine (UCI) Parkinson's disease spiral drawings using digitized graphics tablet dataset. Attributes taken as considerations are spiral drawing, pen tip velocity, pen pressure and other kinematics features. The dataset was created using a graphical tablet from 77 individuals including 62 Parkinson's patients. Main purpose of this dataset is to monitor and assess Parkinson's diseases progression by analyzing drawing and hand movement. Structure of dataset is as follows:

- Timestamps: Time points at which each data point was recorded.
- Pen Tip Coordinates: X and Y coordinates of the pen tip during the drawing.
- Pen Pressure: Pressure exerted on the tablet surface by the pen during the drawing.
- Azimuth and Altitude: Directional angles of the pen tip's movement.
- Rotation: Rotation of the pen tip during the drawing.
- Direction Changes: Number of times the direction of the pen tip changes.
- Pen Velocity: Speed of the pen tip during drawing.
- Biometric Features: Additional features related to the motor control and dynamics of the drawing process.

C. NewHandPD[4]: The NewHandPD database (Pereira, Weber, Hook, Rosa & Papa 2016) is basically extension of the previous HandPD corpus (Pereira, Pereira, Silva, Masieiro, Weber, Hook & Papa 2016). The first database consisted of images from two drawing tasks, i.e. the typical spiral cognitive test and a modified spiral (\meander") test performed by healthy individuals and people with Parkinson's disease. However, the new corpus, NewHandPD, contains both offline images and online signals (time-based sequences) of the two groups. The handwriting signals were acquired through a

technology other than a tablet, i.e. an electronic smart pen (BiSP).

Specifically, NewHandPD contains images and dynamic data from 31 patients and 35 healthy people. The gender of the participants was fairly balanced (39 males and 29 female), while most of them were right-handed writers (59 of 66 participants). They were asked to complete a handwriting-based test consisting of the following 12 exams:

1. Four tasks related to spirals;
2. Four tasks related to meanders;
3. Two circled movements (one in-air and another on-surface);
4. Two diadochokinesis tests (one with the left hand and the other with the right).

The electronic smart pen recorded the following temporal data in its six channels for each exam:

1. Microphone;
2. Finger grip;
3. Axial pressure of ink rell;
4. Tilt and acceleration in x direction;
5. Tilt and acceleration in y direction;
6. Tilt and acceleration in z direction.

D. MobiAct Dataset :

Wearable sensors are attached to different parts of body that collect different data from various parts of body that study movement characteristics and identify patterns so that it can be detected in daily lives. Features included in MobiAct Dataset are:

- **Triaxial Accelerometer Data**: Three dimension acceleration data gathered from various activities performed by subject.
- **Triaxial Gyroscope Data**: Three dimension angular velocity is taken in consideration.
- **Triaxial Magnetometer Data:** Magnetometer readings in three dimensions (X, Y, Z) capture the magnetic field intensity, aiding in understanding the orientation and positional changes of the subjects.
- **Activity Labels:** Each data sample is annotated with labels indicating the specific activity performed by the subject during data collection. Activities can include walking, jogging, sitting, standing, etc.

IV. LITERATURE SURVEY

Researchers have used various ways of Parkinson's diagnosis such as speech signals, gait signals, electroencephalogram (EEG) signals, electromyogram (EMG) signals, magnetic resonance imaging (MRI) scans and single-photon emission computerized tomography (SPECT) scans.

Rohit L., Kawther A.[5], diagnosed Parkinson's disease using the handwritten spirals drawn by patients of PD in which Kinematic features were extracted from the raw time-series of dataset. The most discriminating features for diagnosis of Parkinson's disease have been selected using genetic algorithm and mutual information gain feature selection methods. The performance of four classifiers support vector machine, random forest, AdaBoost and XGBoost have been analyzed on full features and reduced features subsets[10]. The combination of mutual information gain feature selection method and AdaBoost classifiers show the best results with 96.02% accuracy. Donato Impedovo and Giuseppe Pirlo[6] adopted CAD system to analyze PD motor symptoms. These studies gives new finding as it depend on different datasets and different experimental setup. Number of tasks given to PD patients gives more accuracy than single writing tasks. Whereas dataset other than PaHaW gives accuracy of 97.50 by given tasks such as writing their own name. Classification models such as support vector machine (SVM) with a Radial Basis Function Kernel, Discriminant Analysis, Convolutional Neural Network, and Na¨ıve Bayes have been successfully used. Lucas S., Angeles Q. and Roberto M. have been applied series of clinical examination to PD patients[7]. The authors determined five main characteristics from the drawings made by patients. Their main objective was to determine the distance between the drawings and generate an Euclidean sum in order to determine whether a pattern of fine motor skills existed in a patient with PD. The work is distributed in 3 stages. (1) Pre-processing (2) Processing (3) Feature Extraction. The proposed algorithm can help to predict PD with an estimated accuracy of 94.83%, detection rate of 98.28%, and false alarm rate of 16.03%, and further aid individuals in receiving a functional treatment at an early stage. Minhazul Arefin, Kazi Mojammel Hossen, Rakib Hossen and Mohammed Nasir Uddin[8] use the FCNN model to check and verify parkinson affected patients to the utmost accuracy with image processing technique. They develop image processing based model to detect PD early since there is still no fixed valid tests for the detection of Parkinson Disease. From spiral template (ST) the proposed system extracts the handwritten trace (HT) because the images are not linked between them. The result shows that this methodology can find out 92.43% accurate PD patients with an inaccuracy of 7.57%. Megha Kamble, Prashant Shrivastava and Megha Jain[9] collected spiral drawing samples using digitized tablets. They observed samples in-air and on-surface kinematic variables which are taken out from data files generated for 25 patients and 15 healthy controls, using mathematical models. Results demonstrated nearly 91% classification accuracy to

separate PD patients from healthy controls by applying feature engineering and four machine learning (ML) classifiers Logistic Regression, C-Support Vector Classification (SVC), K- nearest neighbour(KNN) classifier and ensemble model Random Forest Classifier(RFC).[11,14]

This work avoids the handwriting samples for PD diagnosis as demographics features, literacy of person is important in case of handwriting, and so it cannot be considered as independent tool for PD diagnosis. Iqra Kamran, Saeeda Naz, Imran Razzak. Muhammad Imran[15] proposed methodology which is based on multiple handwriting datasets and used deep transfer learning-based algorithms. This approach achieved 99.2% accuracy on certain task of combined HandPD, New HandPD, and Parkinson's Drawing Datasets. In this methodology, dataset has been splitted into two parts 70:30. The overall proposed system is divided into pre-processing, data augmentation, and CNN architectures for feature learning, classification, and output[9]. Application of different data augmentation techniques including contrast, illumination, thresholding, flipping, and rotation to increase the sample space of the dataset, followed by convolutional layers and max-polling layers to extract salient visual features. So, the features were fine-tuned on a PD dataset.[16]

References	Feature Classification	Classification Techniques	Dataset	Accuracy
Rohit L., Kawther A.	Genetic Algorithm	SVM, RFC, AdaBoost, XGBoost	SMOTE	92.05%
Donato Impedovo and Giuseppe Pirlo	On Surface and in-air features	SVM, Radial Basis Function,	PaHaW	97.50%
Lucas S., Angeles Q. and Roberto M.	Dots Per Inch of various drawing. ANN and FLS	OPF, SVM and a Bayesian	10 PD diagnosed Pts data	94.83%
Minhazul Arefin, Kazi Mojammel	RNN and CNN	Bidirectional Gated Recurrent Units (BiGRUs)	PaHaW and NewHandPD	92.43%
Megha Kamble, Prashant Shrivastava and Megha Jain	Dynamic Spiral Test (DST)	LR,KNN,SVC, RFC	Spiral Drawing	91%

Table 1 Comparative Analysis of Parkinson's diseases diagnostic system

More Performance Metrics:

True positive (TP) denotes the actual Parkinson's patients who were correctly predictive Parkinson's. False positive (FP) denotes the actual healthy individuals who were wrongly predictive Parkinson's. True negative (TN) denotes the actual healthy individuals who were predictive healthy. False negative (FN) denotes the actual Parkinson's patients who were wrongly predictive healthy.

Accuracy: Proportion of correctly classified instances out of the total instances. Suitable for balanced datasets.

$$\text{Accuracy} = \left(\frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{TN} + \text{FN}}\right) * 100\%$$

Sensitivity: Proportion of true positive predictions among all actual positive instances.

$$\text{Sensitivity} = \left(\frac{\text{TP}}{\text{TP} + \text{FN}}\right) * 100\%$$

Specificity: Proportion of true negatives predictions among all actual positive instances.

$$\text{Specificity} = \left(\frac{\text{TN}}{\text{TN} + \text{FN}}\right) * 100\%$$

Precision: Proportion of true positive predictions among all positive predictions made.

$$\text{Precision} = \left(\frac{\text{TP}}{\text{TP} + \text{FP}}\right) * 100\%$$

F1-score: Harmonic mean of precision and recall, useful for imbalanced datasets.

$$\text{F-measure} = 2 \text{ X} \frac{Sensitivity \text{ K } Precision}{Sensitivity + Precision}$$

ROC AUC: Area under the Receiver Operating Characteristic curve, measures the ability of the model to distinguish between classes.

AUC ranges from 0 to 1, where higher values indicate better performance.

V. RESEARCH GAP

Methodologies which describe earlier have a limitation that it can be used to diagnose Parkinson's but could not find its severity. Not only handwriting analysis but also more symptoms such as speech signals and gait pattern can be worked as diagnosed tool.[23] Many researchers have adopted

databases/datasets built by collecting data themselves. These datasets are different in tasks, size (in general very reduced), acquisition devices, etc. The lack of a big dataset involving a statistically significant number of patients, as well as, a set of significant tasks, greatly limits research development. Datasets should also include "suspected" patients.[22] Multiple symptoms must be included. Feature evaluation/selection could also be moved to a per-user or per-class (to be defined) or per-zone perspective. In other words, given a specific task, a set of features could be used in order to distinguish healthy versus nonhealthy, another one to classify stages of the disease. Classification of person such as healthy and non-healthy should be non-restrictive. More data needs to be collected from healthy individuals and those diagnosed with PD to make the more complete data for more in- dividuals presenting with PD in the trembling form. The system needs to be incorporated into a web platform with the goal of being accessible from any location and by any individual without the need of installation. A mobile platform needs to be developed.

VI. CONCLUSION

Parkinson's is a chronic and progressive disease that adversely affects the patient's life. Parkinson's is still noncurable, so if it is diagnosed in the early stages then the patient's life can improve by proper medication, exercise and treatment. The early symptom of this disease is slowness and tremor which affects the handwriting of patients. Genetic algorithm and mutual information gain feature selection methods were used for the selection of the most discriminating features. Four classifiers support vector machine, random forest, AdaBoost, XGBoost were used for classification[25]. The performance of the system is evaluated in terms of accuracy, sensitivity, specificity, precision and F-measure. Analysis of Spiral Drawing with time series results improvement in detection. Analysis of more parameter based on handwriting such as speed, velocity, jerk, pressure on tip, x-direction, y-direction and more useful for extraction of features and by applying algorithm we can detect parkinson's diseases. Hypokinetic rigid syndrome or PD is a type of widespread diseases that affects millions of lives every year in which males are extra regularly affected than girls at a ratio of around 3:2 Whereas it is found that in human beings earlier than the age of 50, it's far referred to as early-onset PD The average existence expectancy following prognosis is among 7 and 15 years. Treatment of PD is essential for the neuroscience field.

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