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PARKINSON'S DISEASE DETECTION THROUGH HAND DRAWINGS AND ALEXNET MODEL

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Abstract

Innovative methods based on deep learning and different types of data are very useful in diagnosing Parkinson's disease. Through this research, we present a new method for detecting Parkinson's disease using deep convolutional neural networks based on the AlexNet architecture. The proposed approach focuses on using hand drawings of injured or suspected people and then integrating the features extracted from these drawings to classify subjects. To evaluate the proposed method, we used spiral and wave patterns available in the Kaggle's repository. This database is obtained from patients with Parkinson's disease and healthy individuals. By combining the features of the two different hand drawing styles, we were able to significantly improve detection accuracy. The related experimental results show the effectiveness of this approach, as it achieved an accuracy of 96.67% on the test set, outperforming current methods that use fusion in classifiers to make decisions, which achieved an accuracy of 93.33%. However, the challenge of achieving a higher accuracy highlights the complexity of diagnosing Parkinson's disease from manual drawings.

Keywords: Parkinson's disease, AlexNet, wave diagrams, spiral diagrams

1. INTRODUCTION

Parkinson's Disease (PD) is a degenerative condition that progressively impacts the mobility of millions of individuals globally. It typically develops gradually, with symptoms worsening over time. The main manifestations of PD encompass tremors, characterized by involuntary shaking, typically initiating in the hands, fingers, or limbs during periods of rest; bradykinesia, marked by slowed movement, complicating everyday tasks and prolonging their completion; muscle rigidity, evidenced by stiffness and tension in muscles, contributing to discomfort and restricting movement; and postural instability, resulting in compromised balance and coordination, heightening the challenge of sustaining an upright stance and elevating the likelihood of falls [1].

Identifying PD in its early stages allows for prompt initiation of treatment. Although there is no cure for Parkinson's disease, treatments can help relieve symptoms and improve the patient's life. Starting treatment early may slow down disease progression and delay the onset of more severe symptoms [3].

MRI and CT scans are powerful tools for evaluating brain structure and ruling out other neurological conditions. Still, they can be expensive, and access to these imaging technologies may be limited in some regions or healthcare settings [3]. This can create barriers to timely diagnosis and treatment, particularly for individuals with limited financial resources or in rural areas.

Spiral and Wave Diagrams are unconventional yet insightful tools for assessing motor skills and tremor patterns in individuals, particularly in the context of PD. These diagrams can provide qualitative and quantitative information about motor function, including fine motor control and tremor characteristics [4].

In a spiral drawing task, individuals are instructed to trace a spiral pattern on a piece of paper. This task requires precise motor control and coordination. By analysing the resulting spiral drawings, healthcare professionals can assess the individual's motor skills, including tremor severity, amplitude, and frequency. Spiral drawings may be repeated over time to track changes in motor function and response to treatment [5].

Wave diagrams involve individual performing repetitive movements, such as finger tapping or hand waving, while sensors or accelerometers capture the movement data. These diagrams can provide detailed information about movement patterns, including amplitude, frequency, and regularity. By analysing wave diagrams, healthcare professionals can assess motor function and detect abnormalities, such as tremors or dyskinesia's [5].

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Spiral and Wave Diagrams are unconventional yet insightful tools for assessing motor skills and tremor patterns in individuals. Patients with PD often exhibit distinct motor irregularities, including tremors and difficulty in maintaining a smooth, coordinated movement. These abnormalities manifest in the drawings of spirals and waves produced by patients during diagnostic tests [6].

2. RELATED WORKS

Researchers and clinicians have recognized the potential of these drawings as biomarkers for PD. The irregularities, such as jaggedness, hesitations, and inconsistency in the patterns, provide valuable information about the patient's motor control and coordination. Integrating this qualitative data with advanced methods can enhance the diagnostic accuracy of PD.

In recent years, the integration of advanced technologies and artificial intelligence (AI) has greatly improved the accuracy and the efficiency of PD diagnosis [7-12].

Exploring handwriting features for classifying Parkinson's disease patients and healthy subjects represents a compelling area of research. Machine learning techniques have been extensively investigated for this purpose, offering a range of approaches to differentiate between patients with Parkinson's disease and healthy individuals based on these features. These include k-nearest neighbor, Support Vector Machine, Artificial Neural Network, XGBoost, Random Forest, and Decision Tree algorithms.. Each of these methods offers unique approaches to extracting patterns from handwriting data and distinguishing between individuals with PD and those without. They achieved an accuracy of 91% [5].

Deep learning (DL) techniques, particularly convolutional neural networks (CNNs), are frequently employed in PD detection due to their ability to effectively extract highly discriminative features from data. CNNs are especially well-suited for tasks like handwriting analysis in PD detection because they can automatically learn and extract relevant features directly from images of handwriting samples [11,12].

In the referenced [6], a comparative investigation was conducted on multiple ML and DL approaches for PD detection using spiral and wave tasks. This study aimed to provide valuable insights into the effectiveness of various ML/DL techniques for PD detection using handwriting tasks, to identify the most suitable approach or combination of approaches for accurate and reliable diagnosis of PD. Using the Random Forest algorithm, an accuracy of 81.3% and 80.03% was achieved for the spiral and wave images, respectively.

References [11,12] utilized spiral drawings, while References [13,14] employed wave drawings. In contrast, Reference [15] leveraged both spiral and wave hand drawing pattern conducted by individuals suffering from Parkinson's disease and healthy participants for classification purposes. When both spiral and wave data were fused together, the study reported an overall accuracy of 90 %. However, when the decisions made using spiral and wave data were fused, the overall accuracy significantly improved to 93.3 % [16]. This suggests that combining the information from both types of handwriting tasks led to a more accurate classification of Parkinson's disease (multi-modal classification with late fusion). However, achieving high accuracy rates remains a challenge due to the complexity and variability of PD symptoms.

In this paper, the features extracted from both spiral and wave data were combined to develop an automated system. This system was then trained using these fused features. By incorporating information from both types of handwriting tasks, the automated system aimed to improve the accuracy and reliability of Parkinson's disease detection. The fusion of features from spiral and wave data allowed the system to capture complementary information and potentially enhance its ability to discriminate between PD patients and healthy individuals. This approach reflects a comprehensive strategy of leveraging multiple sources of data to enhance the performance of the automated system for PD detection.

The paper's structure is as follows: Section 2 presents the proposed method, detailing the methodology adopted for Parkinson's disease detection. Section 3 comprehensively analyzes the study's results and offers an in-depth discussion of the findings. Finally, Section 4 presents the study's conclusions

2. METHODOLOGY

2.1. Database Description

The study's data was obtained from Kaggle's repository [17]. A total of 55 subjects participated, comprising 28 in the healthy group and 27 in the Parkinson's group. Each person underwent two tests: the spiral drawing test and the wave drawing test. The dataset comprises 204 images of spirals and waves, divided into 72 training and 30 testing images from 102 spiral images. Similarly, the wave images are divided into 72 training and 30 testing images. The dataset is pre-labeled as healthy-spiral, Parkinson-spiral, and healthy-wave, Parkinson-wave categories, as depicted in Figure 1. Further details are provided in Table I.

Table 1. Data base details

Image type	Training set		Test set		Total
	Healthy	PD	Healthy	PD	
Wave	36	36	15	15	102
Spiral	36	36	15	15	102
Total	72	72	30	30	204

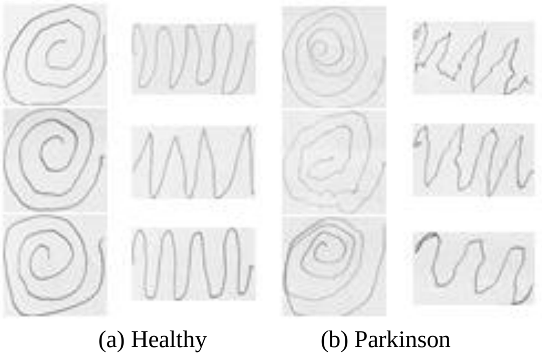


Fig. 1. Spiral and Wave Dataset

2.2. Model Development

While using 2D CNNs and voting-ensemble classifiers appears to be a strong method for diagnosing Parkinson's disease from hand drawings, achieving 100 % accuracy with this approach has been difficult [17]. To address this challenge, we propose employing 2D CNNs for feature extraction and then concatenating these features to pass to a classifier. This approach can improve the model's ability to extract and utilize relevant features, leading to more accurate diagnoses.

Our proposed approach involves three main steps: feature extraction using Alexnet CNN [18]. These features are then concatenated and passed to a classifier. We use fully Connected Layer and a single layer classifier (softmax). The pre-trained AlexNet model is used to extract features by removing the final classification layer and using the rest of the network as a feature extractor.

The fusion of features from Spiral and Wave Diagrams is a crucial step in creating a comprehensive representation that captures the nuanced motor irregularities associated with Parkinson's Disease. Combining features from these two distinct types of data enhances the diagnostic accuracy of machine learning models, such as the AlexNet Neural Network. Figure 2, illustrates the complete system architecture with an outline of a general architecture as follows:

- Data Input: Hand drawings (spiral and wave diagrams).
- Feature Extraction: Use pre-trained AlexNet to extract features from spiral and wave diagrams.
- Feature Concatenation: Concatenate the features extracted from spiral and wave diagrams to create a combined feature representation.
- Classifier: Feed the combined features into a fully connected layers classifier.
- Output: The output of the classifier indicates the prediction for Parkinson's disease diagnosis.

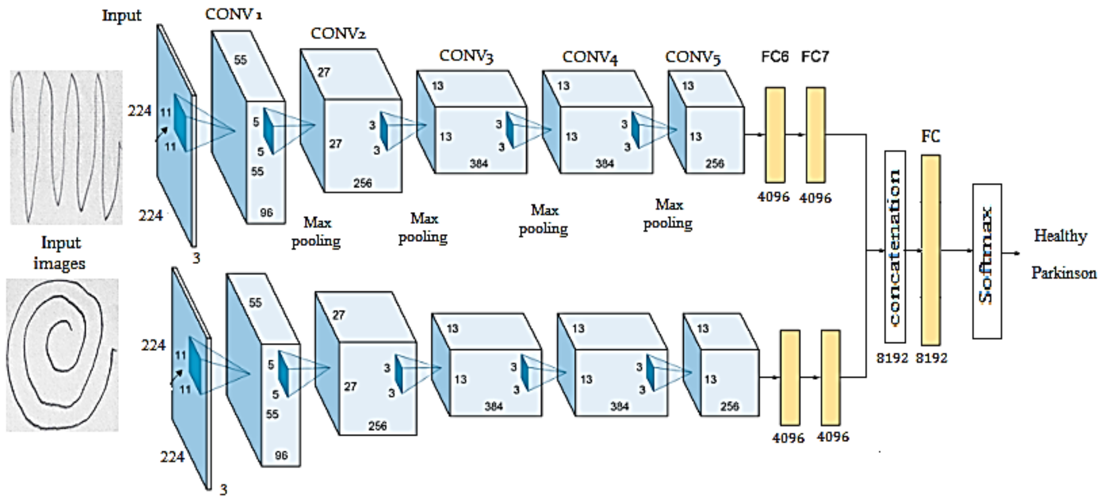


Fig. 2. Methodology Architecture

2.3. Evaluation

We evaluated the performance of our proposed method using five metrics: accuracy (Acc), sensitivity (SN, also known as recall (R), precision (P), specificity (S), and F1-score (F). These metrics were computed using the following formulas [16]:

$$Acc = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

$$R = \frac{TP}{TP+FN} \quad (2)$$

$$P = \frac{TP}{TP+FP} \quad (3)$$

$$S = \frac{TN}{TN+FP} \quad (4)$$

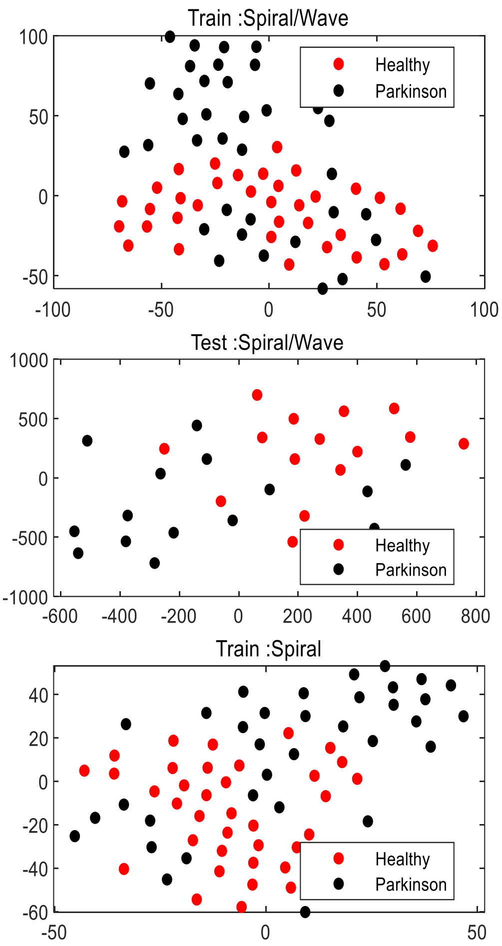
$$F = 2\frac{P.R}{P+R} \quad (5)$$

In the context of Parkinson's disease detection, True Positive (TP) indicates instances where the classifier correctly identifies individuals with the disease. True Negative (TN) represents cases where the classifier correctly identifies individuals without the disease. False Positive (FP) signifies instances where the classifier incorrectly labels healthy individuals as having Parkinson's disease. False Negative (FN) indicates cases where individuals with Parkinson's disease are incorrectly classified as healthy.

3. RESULTS AND DISCUSSION

We evaluate our method using a dataset of hand drawings from PD patients and healthy controls. This section evaluates our proposed early fusion multimodal classification approach, which consists of three key steps. First, we use the AlexNet CNN for feature extraction. Next, these features are concatenated and fed into a fully connected layer classifier followed by a single-layer classifier (softmax). Our proposed method was implemented using MATLAB R2020 for simulation on a laptop running Windows 10, equipped with 16 GB of RAM and an Intel Core-i7 8000 U processor.

To thoroughly analyze this high-dimensional dataset, we utilized the t-SNE (t-Distributed Stochastic Neighbor Embedding) method. This technique reduced the dataset's dimensionality to two dimensions, allowing for the visualization of complex data structures in a more interpretable manner. The t-SNE visualization was generated using the cosine distance metric, which resulted in favorable clustering outcomes. Figure (3) illustrate the successful concatenation of Spiral and Wave Diagrams into a single vector using the early fusion multimodal approach. It confirms the separability of the two classes.



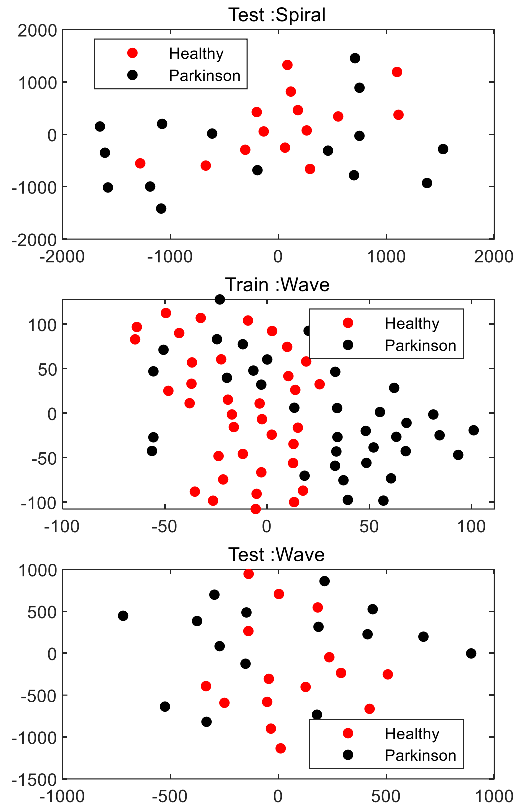


Fig. 3. t-SNE visualization for wave, spiral and combined wave/spiral data set

Figure (4) shows the convergence curves of AlexNet model. As we can see, the AlexNet model reaches full training accuracy in just two epochs. Achieving a test accuracy of 96.67% is also quite high and indicates that the model is generalizing well to unseen data.

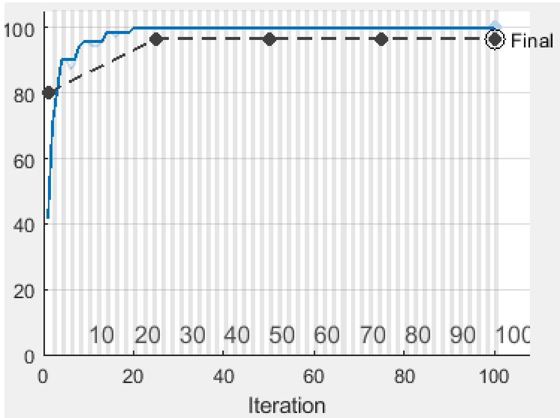


Fig. 4. Convergence curve for training and test processes

To assess the effectiveness of our proposed method, we conducted a comparative analysis with recent studies employing CNNs and the same database for Parkinson's disease detection. This evaluation was based on the five criteria mentioned above. In making this comparison, we took into consideration spiral hand drawing [11], wave images [12], mixture of both images [15] and multi-stage classifier [16]. A detailed comparison is presented in Table II and Figure (5). The radar chart provides a visual representation of how well the proposed approach performs relative to these metrics compared to other studies.

Table 2. Data base details

Metrics %	Spiral [11]	Wave [11]	Mixture [15]	Multi-stage [16]	Proposed
ACC	93.33	90	91.67	93.33	96.67
R	100	93.33	96.67	100	100
P	88.24	87.50	96.30	88.24	93.75
S	86.67	86.67	96.67	86.67	93.33
F	93.75	90.32	96.48	93.75	96.77

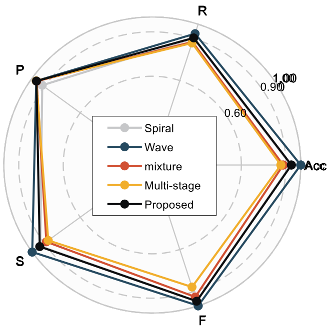


Fig. 5. Radar chart for comparison metrics

From Table II, it can be seen that the proposed approach provides the highest accuracy and F1 score. Exploring the confusion matrices shown in figures (6,7), we can see that two healthy cases classified as Parkinson's disease occurred in the monomodal case using spiral images. In the case of wave images, in addition to the above false predictions, another Parkinson's case is classified as healthy. Using both datasets, one healthy case is classified as Parkinson's, and four Parkinson's are classified as healthy. The diagnosis in this case becomes worse. In the proposed method only one healthy classified as Parkinson's was occurred and is shown in figure (8).

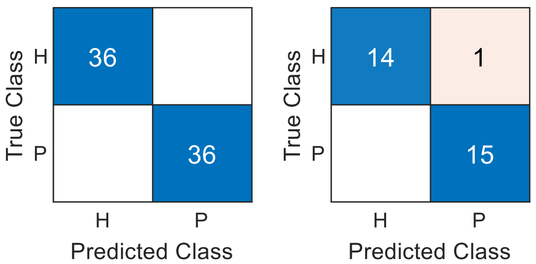


Fig. 6. Confusion matrices for the proposed method (train and test)

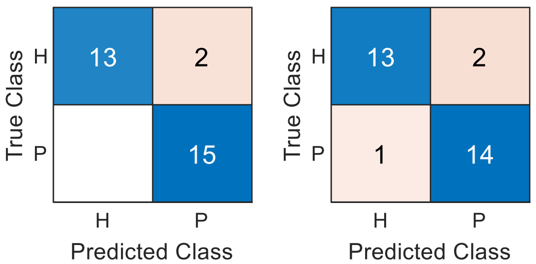


Fig. 7. Confusion matrices for references [11, 15]

In Parkinson's disease, high sensitivity is indeed desirable to avoid missing any true positive cases, ensuring that individuals who have the disease are correctly identified. On the other hand, high specificity is also important to avoid misdiagnosing individuals who do not have the disease, reducing unnecessary stress, costs, and potential side effects of unnecessary treatments or interventions. Upon reviewing the results, it is evident that the proposed method achieved a remarkable sensitivity of 100% and a specificity of 93.33%. These results indicate that the method is highly effective in accurately diagnosing Parkinson's disease, with minimal risk of misdiagnosis.

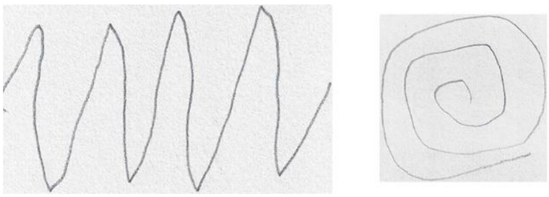


Fig. 8. Miss-classified sample

The results obtained show that using CNNs to extract features from both hand drawings and then fusing these features increases the capabilities of the proposed method for diagnosing PD. However, more research is needed to improve the accuracy and generalizability of our approach. Possible future directions include exploring different CNN architectures, incorporating additional features, and improving the ensemble method.

4. CONCLUSION

This paper proposed a novel approach based on AlexNet architecture to detect Parkinson's disease. The approach focuses on integrating features extracted from both spiral and wave hand drawing images obtained from patients with Parkinson's disease and healthy individuals. Combining these features could potentially improve the accuracy of detection. The fusion of features from both spiral and wave drawing patterns seems to be a promising strategy for enhancing the detection performance. Our approach achieves an accuracy of 96.67 % on the test set, outperforming existing methods. However, 100 % accuracy remains elusive, indicating the complexity of diagnosing PD from hand drawings. This study contributes to the advancement of PD detection methodologies, highlighting the potential of CNNs and multimodal data integration in medical diagnosis.

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