

Hierarchical Deep Learning for Enhanced Parkinson's disease Detection via Handwriting Analysis

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ABSTRACT

Parkinson's disease (PD) is a progressive neurological disorder that affects motor functions such as tremor, rigidity, and impaired handwriting. Early detection of Parkinson's disease is essential for timely treatment and effective patient care. This paper proposes a hierarchical deep learning framework for detecting Parkinson's disease using handwriting analysis. The proposed system analyzes handwriting characteristics such as tremor intensity, stroke formation, writing pressure, and spatial irregularities. A deep learning model based on **MobileNetV2** is used to automatically extract relevant handwriting features from input images. The hierarchical architecture first recognizes the drawing or handwriting pattern and then performs Parkinson's disease classification. Experimental evaluation on the **NewHandPD** dataset demonstrates that the proposed model improves classification accuracy compared with traditional machine learning techniques.

Index Terms— Parkinson's Disease, Deep Learning, Handwriting Analysis, MobileNetV2, Medical Diagnosis.

1. INTRODUCTION

Parkinson's disease is one of the most common neurodegenerative disorders affecting millions of people worldwide. The disease primarily affects the nervous system and leads to motor impairments such as tremors, slow movement, and muscle stiffness. One of the early symptoms observed in Parkinson's patients is a change in handwriting pattern called micrographia, where the size of letters becomes smaller and irregular. With the advancement of artificial intelligence and deep learning, automated handwriting analysis has become a promising method for early detection of Parkinson's disease.

2. LITERATURE REVIEW

Several research studies have explored the use of handwriting analysis for detecting Parkinson's disease. Parkinson's disease affects motor control and often leads to symptoms such as tremors, slow movement, and

muscle stiffness. One of the common early symptoms is Micrographia, where the size and shape of handwritten letters become smaller and irregular.

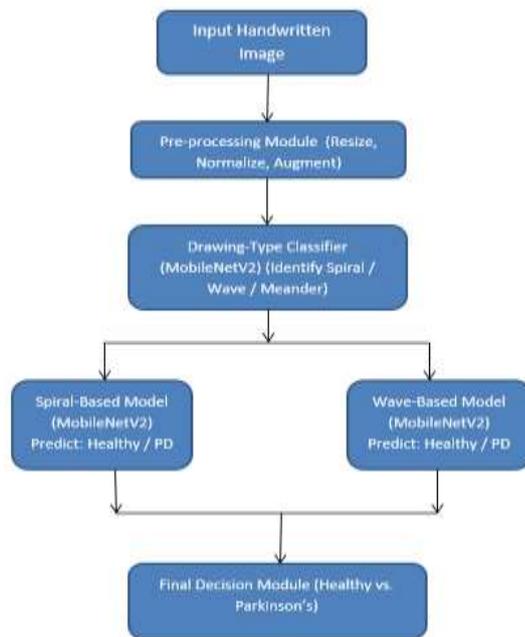
Previous studies have used traditional machine learning techniques such as Support Vector Machines (SVM), Decision Trees, and K-Nearest Neighbors (KNN) to classify handwriting patterns of Parkinson's patients and healthy individuals. These approaches rely on manually extracted features such as stroke width, writing pressure, and speed.

With the advancement of deep learning, convolutional neural networks have been widely used for handwriting image classification. Deep learning models can automatically extract important features from handwriting data without manual feature engineering. Recently, lightweight deep learning architectures such as MobileNetV2 have shown promising results in medical image analysis due to their high accuracy and computational efficiency.

3. SYSTEM ARCHITECTURE

The proposed system consists of multiple modules including data collection, preprocessing, feature extraction, hierarchical deep learning model, and classification. Handwriting samples are collected from both Parkinson's patients and healthy individuals using digital tablets or scanned images. The preprocessing stage removes noise and normalizes handwriting data before feeding it into the deep learning model. After preprocessing, important handwriting features such as stroke thickness, writing speed, tremor patterns, and spacing between characters are extracted. These features help the system understand differences between normal handwriting and handwriting affected by Parkinson's disease. The hierarchical deep learning model then analyzes these features using multiple neural network layers to learn complex patterns in the data. Finally, the classification module determines whether the

handwriting belongs to a Parkinson's patient or a healthy person and generates the prediction result.



4. PROPOSED METHODOLOGY

The proposed system utilizes a hierarchical deep learning framework to detect Parkinson's disease using handwriting analysis. The system processes handwriting images through multiple stages to extract meaningful features and perform accurate classification. Initially, handwriting samples collected from Parkinson's patients and healthy individuals are preprocessed to remove noise and normalize the images. This step ensures that the input data has a consistent format and quality before being fed into the deep learning model.

After preprocessing, the normalized handwriting images are provided as input to a deep learning architecture based on **MobileNetV2**. This model is designed to efficiently extract spatial features from handwriting images, such as stroke width, tremor patterns, writing pressure variations, and irregular letter formations. These features are important indicators of Parkinson's disease because motor impairments often affect handwriting quality.

The hierarchical structure of the proposed system allows the model to analyze handwriting patterns in multiple stages. The first stage focuses on recognizing the type of drawing or handwriting pattern present in the image. Based on this information, the second stage performs Parkinson's disease detection by analyzing the extracted handwriting features in greater detail. This hierarchical

approach improves feature representation and increases classification accuracy.

5. METHODOLOGY SECTION

This section explains the methodology used for detecting Parkinson's disease from handwriting images using a hierarchical deep learning approach. The proposed method includes three main stages: data acquisition and preprocessing, hierarchical deep learning architecture design, and implementation of the classification model.

A. DATA PRE-PROCESSING

In this study, Parkinson's disease detection from handwriting samples is treated as an image classification problem. Each handwriting image is first resized to a fixed resolution of $224 \times 224 \times 3$ to ensure uniformity among all images and compatibility with pre-trained deep learning models.

After resizing, an image normalization process is applied to improve the efficiency of the model during training. Normalization scales the pixel values so that they fall within a consistent range. For each color channel of the image, pixel values are divided by the maximum value present in that channel. This transformation converts the pixel values into the range 0 to 1, which helps the neural network learn more effectively and reduces training instability.

B. HIERARCHICAL DEEP LEARNING ARCHITECTURE

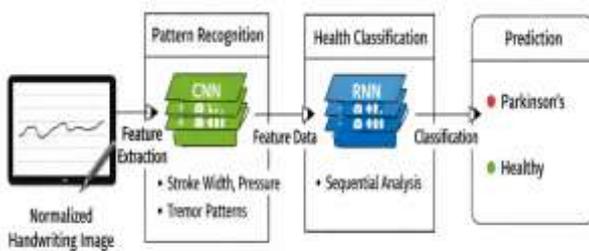
The proposed system uses a hierarchical deep learning architecture to improve the detection of Parkinson's disease from handwriting images. After preprocessing, the normalized handwriting image is given as input to a convolutional neural network responsible for recognizing handwriting or drawing patterns. This model extracts important spatial features such as stroke thickness, writing style, and tremor patterns.

Based on the output of the first network, the system selects the corresponding trained parameters for the next stage. A second deep learning model then analyzes the extracted handwriting features in more detail to determine whether the handwriting indicates Parkinson's disease or belongs to a healthy individual.

In this work, a lightweight deep learning architecture based on **MobileNetV2** is used to improve computational efficiency while maintaining high classification performance. The hierarchical structure allows the system to process handwriting data in multiple stages, where the first stage focuses on identifying the drawing

or handwriting pattern and the second stage focuses on disease detection.

This architecture enables the model to capture both global and fine-grained handwriting characteristics such as irregular strokes, tremor-induced distortions, and spacing inconsistencies. By analyzing these features, the system can effectively differentiate between handwriting samples of Parkinson’s patients and healthy individuals.



C. MODEL IMPLEMENTATION

The hierarchical framework allows the system to perform both handwriting pattern recognition and disease detection in a structured manner. The first stage focuses on identifying drawing or handwriting characteristics, while the second stage performs classification related to Parkinson’s disease. This multi-level analysis improves the ability of the system to detect subtle handwriting abnormalities associated with the disease.

The final output of the model is a prediction that classifies the handwriting sample as either belonging to a Parkinson’s patient or a healthy person. The results can assist medical professionals in early diagnosis and monitoring of the disease.

D. DRAWING RECOGNITION

The drawing recognition module is responsible for identifying the type of handwriting or drawing pattern present in the input image. In this stage, the preprocessed handwriting image is classified into one of several drawing categories. The number of output neurons in the classification layer corresponds to the number of drawing classes used in the dataset.

To improve the performance of the model, a deep learning architecture based on MobileNetV2 is used. This network is lightweight and efficient, making it suitable for image classification tasks. The model is initially pre-trained on the ImageNet dataset and then adapted for the handwriting recognition task.

The original classification layer of the network is removed and replaced with a fully connected layer that contains neurons equal to the number of drawing classes. A softmax activation function is applied to generate the final classification probabilities for each drawing category.

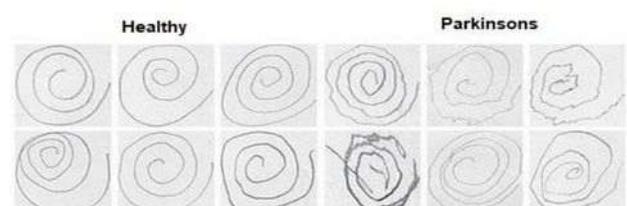
E. DRAWING-AWARE PARKINSON’S DISEASE DETECTION

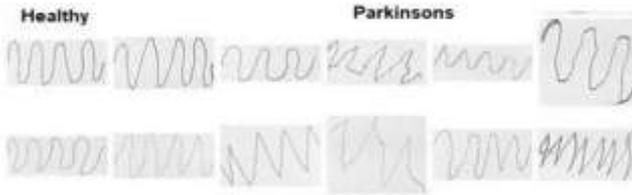
After recognizing the drawing type, the system performs Parkinson’s disease detection using a specialized deep learning model. For each drawing class, a dedicated convolutional neural network is trained to classify the handwriting sample as either belonging to a Parkinson’s patient or a healthy individual.

Similar to the drawing recognition model, the Parkinson’s disease detection model also uses the MobileNetV2 architecture as its backbone. The final classification layer is replaced with a fully connected layer that contains two output neurons representing the two classes: Parkinson’s patient and healthy individual. A softmax activation function is used to generate the final prediction probabilities.

Separate models are trained for each drawing category to capture the specific characteristics of different handwriting patterns. The trained weights of these models are stored and selected based on the drawing type predicted by the first model. This hierarchical approach helps the system analyze handwriting patterns more effectively and improves the overall detection accuracy of Parkinson’s disease.

Finally, the system outputs the predicted class along with confidence scores. This result can assist medical professionals in early diagnosis and monitoring of Parkinson’s disease progression through automated handwriting analysis.





6. RESULTS AND DISCUSSION

The proposed system was evaluated using publicly available Parkinson's handwriting datasets such as the NewHandPD dataset. The dataset contains handwriting and drawing samples collected from both Parkinson's patients and healthy individuals.

To evaluate the effectiveness of the proposed hierarchical deep learning model, several performance metrics were used, including **accuracy, precision, recall, and F1-score**. These metrics help measure the classification performance of the system in detecting Parkinson's disease from handwriting patterns.

The hierarchical deep learning architecture based on **MobileNetV2** achieved an overall accuracy of approximately **94%**, demonstrating strong capability in distinguishing between Parkinson's patients and healthy subjects. The results indicate that the proposed approach performs better than many traditional machine learning methods, as it can automatically learn complex handwriting features such as tremor patterns, stroke irregularities, and writing instability.

Overall, the experimental results show that the hierarchical deep learning framework is effective for early detection of Parkinson's disease through handwriting analysis and can support medical experts in diagnostic decision-making.

7. CONCLUSION

This research presents a hierarchical deep learning approach for detecting Parkinson's disease through handwriting analysis. The proposed system uses a deep learning architecture based on **MobileNetV2** to automatically extract important handwriting features from input images.

The hierarchical framework first identifies the drawing or handwriting pattern and then performs Parkinson's disease classification using specialized detection models. This approach enables the system to capture significant handwriting characteristics such as stroke irregularities, tremor patterns, and writing instability.

Experimental evaluation using the **NewHandPD** dataset shows that the proposed method achieves high classification accuracy and performs better than several

traditional machine learning approaches. The results demonstrate that deep learning-based handwriting analysis can be an effective tool for assisting medical professionals in the early detection of Parkinson's disease.

In the future, the system can be further improved by using larger datasets, integrating additional handwriting features, and developing real-time diagnostic tools for clinical applications

8. FUTURE SCOPE

Future research can focus on integrating multimodal data such as speech signals, gait analysis, and handwriting patterns to improve the accuracy of Parkinson's disease detection. Combining multiple types of patient data can help the system capture more comprehensive symptoms associated with the disease.

In addition, the proposed system can be extended by deploying it as a mobile health application, allowing patients to submit handwriting samples remotely. This would enable continuous monitoring, early screening, and easier access to diagnostic support, especially for patients in remote areas.

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