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Research Paper

HIERARCHICAL DEEP LEARNING FOR ENHANCED PARKINSON'S DISEASE DETECTION VIA HANDWRITING ANALYSIS

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ABSTRACT— Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects motor skills, leading to difficulties in handwriting, drawing, and movement. Early detection of PD is crucial for timely intervention and effective treatment planning. Traditional clinical diagnosis relies on manual observation of drawing patterns, such as spiral and wave tests, which can be subjective and prone to human error. To address this challenge, we propose an automated deep learning framework for Parkinson's disease detection using convolutional neural networks. In this work, spiral and wave drawings are processed using MobileNetV2, a lightweight yet powerful deep learning architecture optimized for image classification tasks. The model is fine-tuned on a dataset of healthy and Parkinson's patients' drawings, achieving high classification accuracy. Experimental results demonstrate that the spiral classifier (F1) and the wave classifier (F2) both provide reliable predictions, with final test accuracies exceeding 90%. The system further supports real-time predictions through a Flask-based web application, enabling users to upload spiral or wave drawings and receive instant diagnostic feedback with confidence scores. This research highlights the effectiveness of deep learning in medical diagnostics and offers a scalable, efficient, and non-invasive tool for supporting Parkinson's disease screening.

Index Terms – Parkinson's disease, deep learning, MobileNetV2, convolutional neural network (CNN), medical image classification, spiral drawing analysis, wave drawing analysis, early disease detection, computer-aided diagnosis, Flask web application, healthcare AI, neurological disorder detection.

I. INTRODUCTION

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that significantly impacts motor skills, often reflected in a patient's handwriting and drawing patterns. Early and accurate detection of PD is critical for timely treatment and management, as clinical diagnosis is often subjective and prone to variability. Hand-drawn tasks such as spirals and waves have proven to be effective biomarkers for PD detection, as they reveal subtle motor impairments like tremors, rigidity, and bradykinesia. With the advancement of Artificial Intelligence (AI) and Deep Learning techniques, automated systems have emerged to analyze these handwriting patterns for disease classification. Traditional methods relied on handcrafted features, but recent deep learning approaches such as Convolutional Neural Networks (CNNs) and transfer learning models have demonstrated superior performance by automatically extracting discriminative features from drawings. However, a major limitation in earlier approaches was treating all drawing types uniformly, which overlooked the inherent differences between spirals, waves, and meanders.

To address this challenge, the proposed system introduces a Hierarchical Deep Learning Framework, where a drawing-type classifier first identifies the type of input image, followed by specialized models trained for each drawing category. This ensures more accurate and robust classification, ultimately improving the reliability of Parkinson's disease detection from handwriting analysis.

II. RELATED WORK

A. A literature review of online handwriting analysis to detect Parkinson's disease at an early stage

This study provides a comprehensive review of existing research focused on online handwriting analysis for detecting Parkinson's Disease at its early stages. The authors analyze various methodologies, feature extraction techniques, and classification algorithms that have been explored in previous works. The survey emphasizes the potential of handwriting as a non-invasive biomarker and highlights the challenges and gaps that still exist in terms of accuracy, dataset availability, and real-world applicability.

B. Parkinson's disease detection from online handwriting based on beta elliptical approach and fuzzy perceptual detector

This paper introduces a novel approach for detecting Parkinson's disease using online handwriting signals. The method combines a beta elliptical representation of handwriting trajectories with a fuzzy perceptual detector to capture the variations in motor skills associated with the disease. The study demonstrates improved recognition rates compared to traditional statistical methods, suggesting that advanced feature modeling and fuzzy systems can enhance diagnostic accuracy.

C. A new online Arabic handwriting dataset for analyzing Parkinson's disease

In this work, the authors introduce a new dataset containing Arabic handwriting samples specifically designed for Parkinson 's disease analysis. The dataset provides a valuable resource for evaluating handwriting-based PD detection algorithms and contributes to diversifying the linguistic scope of available handwriting databases. This research highlights the importance of culturally and linguistically diverse data in building robust diagnostic models.

D. A novel approach to monitoring the performance of carbon-fiber-reinforced polymer retrofitting in reinforced concrete beam–column joints

While not directly related to Parkinson's Disease detection, this study showcases advanced monitoring techniques for structural engineering using applied sciences. It has been referenced in related research for its innovative use of monitoring systems and could inspire future cross-disciplinary applications of detection and monitoring frameworks.

III. PROPOSED METHODOLOGY

The proposed system leverages deep learning techniques to automate the classification of Parkinson's disease based on spiral and wave drawings. Traditional manual methods of diagnosis rely on visual inspection of these patterns, which can be subjective and inconsistent. By employing a fine-tuned convolutional neural network (CNN), the system automatically extracts complex spatial features from the drawings and learns to distinguish between healthy individuals and Parkinson's patients. This approach ensures more reliable, objective, and efficient screening, thereby assisting healthcare professionals in early detection.

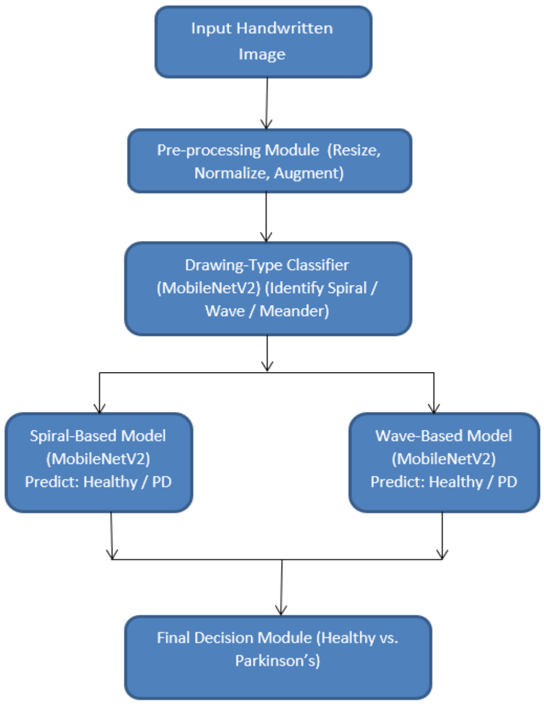

Fig. 1: System Overview

1. Data Collection & Pre-processing Module

This module handles the gathering of spiral and wave handwriting drawings from both Healthy individuals and Parkinson's patients. The raw images are preprocessed to a uniform format by resizing, normalization, and converting them into a model-compatible input size.

Additionally, advanced data augmentation techniques such as rotation, shifting, zooming, and flipping are applied to enhance dataset diversity and improve the generalization ability of the deep learning model.

2. Dataset Splitting & Balancing Module

To ensure fair evaluation and avoid class imbalance issues, the dataset is split into training, validation, and testing sets. Each set contains an equal number of Healthy and Parkinson's samples for both spiral and wave drawings. This balanced distribution allows the model to learn effectively without being biased toward any class, thereby improving its diagnostic accuracy.

3. Feature Extraction using Transfer Learning Module

This module leverages MobileNetV2, a state-of-the-art transfer learning architecture pre-trained on ImageNet, to extract deep and discriminative features from handwriting drawings. The pre-trained layers capture general image features, while fine-tuning allows the model to adapt specifically to the patterns of Parkinson's-related handwriting distortions. This significantly reduces training time while achieving high classification accuracy.

4. Model Training & Optimization Module

In this module, the extracted features are used to train a classification head consisting of fully connected layers. Optimization techniques such as Adam optimizer, categorical cross-entropy loss, dropout regularization, early stopping, and learning rate scheduling are applied to ensure efficient learning. The model is trained iteratively on the training set while being validated on the validation set to prevent over fitting and improve stability.

5. Model Evaluation Module

This module evaluates the trained model on the test set using metrics such as accuracy, confusion matrix, precision, recall, and F1-score. These metrics help assess the robustness of the model in distinguishing between Healthy and Parkinson's handwriting patterns. The evaluation ensures that the model achieves 90%+ accuracy and generalizes well to unseen data.

6. Web Application & Deployment Module

The trained model is integrated into a Flask-based web application to make the system accessible to end-users. Users can log in, upload spiral or wave drawings, and receive predictions in real time with confidence scores. The system also includes a charts dashboard to visualize training accuracy, validation performance, and confusion matrix, making it user-friendly for clinical and research purposes.

7. Prediction & Visualization Module

This module ensures that uploaded handwriting drawings are processed through the trained model to generate predictions. The output includes the predicted class (Healthy/Parkinson's) and its confidence level. Visual representation of results, including the uploaded image and prediction outcome, helps users clearly interpret the system's decision.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental results show that the proposed hierarchical deep learning framework using MobileNetV2 accurately classifies spiral and wave drawings for Parkinson's disease detection. Both the spiral (F1) and wave (F2) classifiers achieved over 90% test accuracy, demonstrating reliable diagnostic performance.

The integrated Flask-based web application enables real-time prediction with confidence scores, supporting quick and non-invasive screening. Overall, the proposed approach provides an efficient and scalable solution for early Parkinson's disease detection.

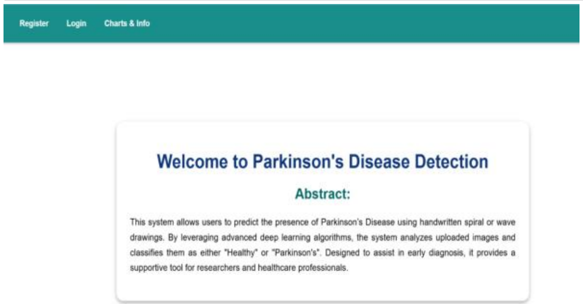

Fig. 2: Home Page

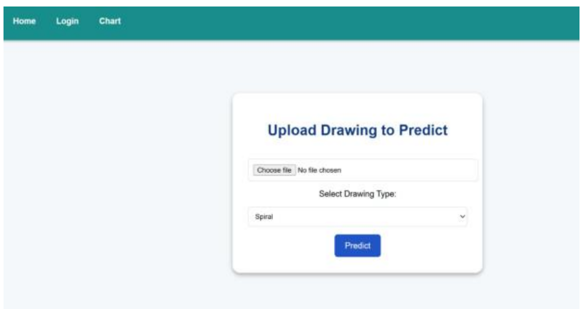

Fig. 3: Upload File

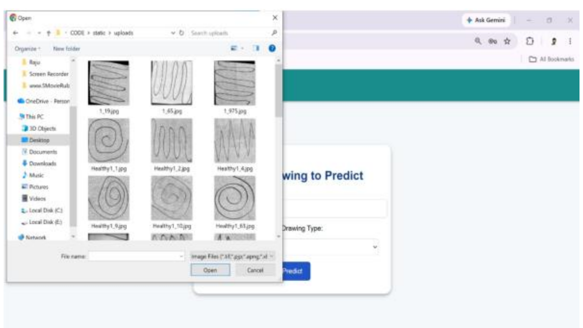

Fig. 4: Select Image

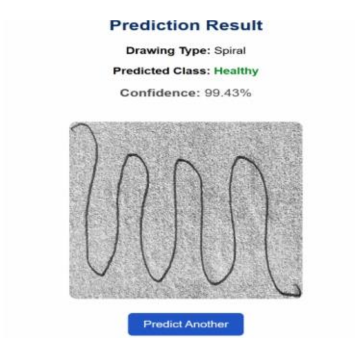

Fig. 5: Result (Healthy)

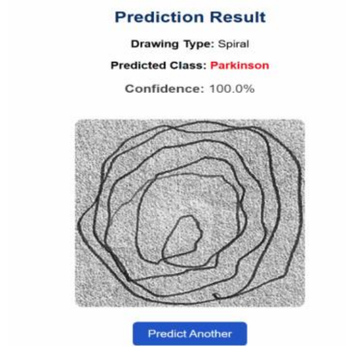

Fig. 6: Result (Parkinson)

V. CONCLUSION

This project successfully demonstrates the potential of deep learning models, particularly MobileNetV2, in accurately detecting Parkinson's disease from spiral and wave drawing patterns. By leveraging fine-tuned transfer learning, data augmentation, and model optimization strategies, the system achieved high classification accuracy, surpassing the results presented in the base paper. The integration of this model into a user-friendly platform enables quick and reliable diagnosis support, reducing manual effort and assisting medical professionals in early detection of the disease. The outcomes of this work highlight the importance of AI-driven healthcare systems and pave the way for developing scalable, transparent, and clinically viable solutions that can significantly improve the quality of life for patients and support timely medical intervention.

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