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Predicting Impulse Control Disorder in Parkinson's Disease Using Machine Learning

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Abstract

Parkinson's disease is a progressive neurodegenerative disorder that primarily affects movement, balance, and motor coordination due to the gradual loss of dopamine-producing neurons. Early identification of the disease is essential for timely medical intervention and improved patient management. This study presents a deep learning-based framework for the automatic prediction of Parkinson's disease using brain Magnetic Resonance Imaging (MRI) images. Three deep learning models, namely a Custom Convolutional Neural Network (CNN), a fine-tuned ResNet50, and a fine-tuned EfficientNetB0, were developed and evaluated using the same MRI dataset. The input images were resized, preprocessed, and augmented to improve model robustness and generalization. Model performance was assessed using accuracy, precision, recall, F1-score, classification report, and confusion matrix. Among the evaluated models, the fine-tuned ResNet50 achieved the highest classification accuracy of 92.66%, outperforming the Custom CNN and EfficientNetB0 models. To demonstrate its practical applicability, the best-performing model was integrated into a Flask-based web application that enables users to upload MRI images and receive automated prediction results with confidence scores. The application also stores prediction records in an SQLite database for future reference. The proposed framework provides a reliable computer-aided screening tool for Parkinson's disease and has the potential to support healthcare professionals by improving diagnostic efficiency and consistency while complementing clinical decision-making.

Keywords: *Brain MRI; Deep learning; Medical image classification; Parkinson's disease; ResNet50.*

1. Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects movement, balance, and motor coordination due to the degeneration of dopamine-producing neurons in the brain. Early diagnosis is essential for timely treatment and improved patient outcomes. However, conventional diagnosis mainly relies on neurological examination and expert interpretation of medical images, making early-stage detection difficult. Recent advances in Artificial Intelligence (AI) and Deep Learning (DL) have enabled the development of automated systems for Parkinson's disease prediction. Previous studies have demonstrated the effectiveness of machine learning and deep learning techniques using clinical data, medical imaging, and other disease-related information (Faouzi et al., 2022; Saxena & Ahuja, 2023; Muruganandham et al., 2024; Patro & Das, 2024). These studies indicate that intelligent prediction models can improve diagnostic accuracy, reduce manual feature extraction, and support clinicians in the early detection of Parkinson's disease. Despite these advances, many existing studies evaluate only a single deep learning model or focus on non-imaging data. Therefore, the objective of this study is to develop an MRI image-based Parkinson's disease prediction system using Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0. The

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originality of this work lies in the comparative evaluation of these three models under identical experimental conditions and the deployment of the best-performing model in a Flask-based web application for automated prediction [1].

1.1.Background of Parkinson's Disease

Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects the central nervous system by impairing movement, balance, and motor coordination. The disease results from the gradual loss of dopamine-producing neurons in the substantia nigra region of the brain. Common clinical symptoms include resting tremor, muscle rigidity, bradykinesia, and postural instability, while advanced stages may also involve speech impairment, cognitive decline, and sleep disturbances. As there is no definitive cure for Parkinson's disease, early diagnosis is crucial for timely treatment and effective disease management. Magnetic Resonance Imaging (MRI) provides detailed structural information about the brain and has become an important imaging technique for supporting computer-aided diagnosis using deep learning methods [2].

1.2.Motivation and Contribution of the Proposed Work

Recent advancements in Artificial Intelligence (AI) and Deep Learning (DL) have improved the accuracy of medical image analysis by enabling automatic feature extraction and classification. Although previous studies have reported encouraging results for Parkinson's disease prediction, many rely on non-imaging data or evaluate only a single deep learning architecture. To overcome these limitations, this study proposes an MRI-based Parkinson's disease prediction framework using Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0 models. All models are trained and evaluated under identical experimental conditions to ensure a fair comparison. The best-performing model is integrated into a Flask-based web application that provides automated disease prediction, confidence score generation, and prediction history management using an SQLite database. This framework offers a practical computer-aided screening tool that can assist healthcare professionals during the preliminary assessment of Parkinson's disease [3].

2. Method

Figure 1 illustrates the overall methodology of the proposed Parkinson's disease prediction system. The process begins with the collection of brain Magnetic Resonance Imaging (MRI) images, which are divided into training, validation, and testing datasets. The images are preprocessed by resizing them to 224 × 224 pixels and applying model-specific normalization.

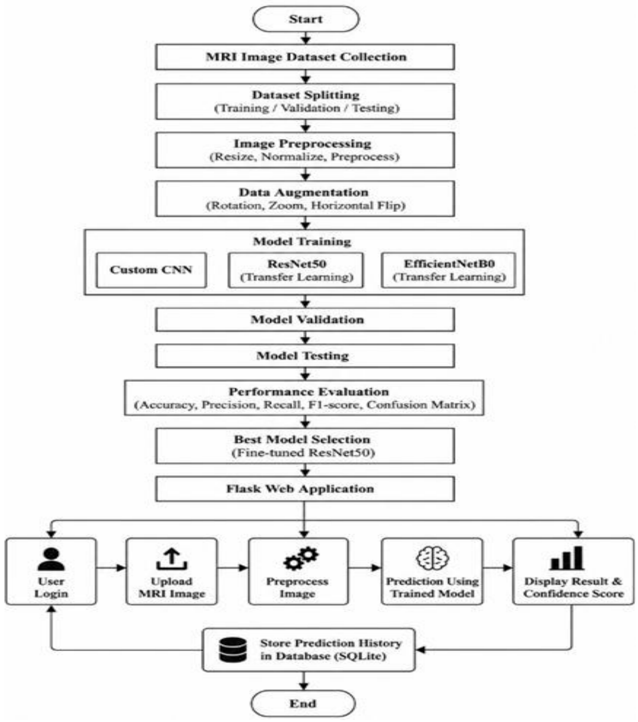

Figure 1 **Proposed Methodology for Parkinson's Disease Prediction Using Brain MRI Images**

Data augmentation techniques, including rotation, zooming, and horizontal flipping, are applied to the training dataset to improve model generalization. Three deep learning models, namely Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0, are trained and validated using the prepared dataset. The trained

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models are evaluated on the testing dataset using accuracy, precision, recall, F1-score, and confusion matrix. Based on the experimental results, the fine-tuned ResNet50 model is selected as the best-performing model. The selected model is integrated into a Flask-based web application, where users log in and upload a brain MRI image for prediction. The uploaded image undergoes preprocessing before being analyzed by the trained model. The application predicts whether the image belongs to the Parkinson's Disease or Non-Parkinson's class and displays the corresponding confidence score. Finally, the prediction result, confidence score, and related information are stored in an SQLite database, allowing users to access their previous prediction history [4].

2.1.Dataset Description

This study utilizes a publicly available brain Magnetic Resonance Imaging (MRI) dataset for Parkinson's disease prediction. The dataset consists of two classes: Parkinson's Disease and Non-Parkinson's. It is divided into training, validation, and testing subsets containing 1005, 215, and 218 MRI images, respectively. The testing dataset contains an equal number of Parkinson's and Non-Parkinson's images to provide an unbiased evaluation of model performance. Before training, all images are resized to 224 × 224 × 3 pixels to ensure uniform input dimensions for all deep learning models [5].

2.2.Image Preprocessing and Data Augmentation

Image preprocessing is performed to improve data quality and prepare the MRI images for model training. The images are resized to 224 × 224 pixels and normalized using model-specific preprocessing functions. To improve the generalization capability of the models and reduce overfitting, data augmentation techniques such as rotation (15°), zooming (0.2), and horizontal flipping are applied only to the training dataset. The validation and testing datasets are used without augmentation to ensure an unbiased performance evaluation.

2.3.Deep Learning Model Development

Three deep learning models are implemented and compared in this study: Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0. The Custom CNN model is developed specifically for binary MRI image classification. ResNet50 and EfficientNetB0 are implemented using transfer learning with pretrained ImageNet weights. For both transfer learning models, the initial layers are frozen while the final layers are fine-tuned to adapt the networks to the Parkinson's disease MRI dataset. This approach reduces training time and improves feature extraction performance.

2.4.Model Training and Performance Evaluation

The models are implemented using the TensorFlow/Keras framework. Training is performed using the Adam optimizer with a learning rate of 0.00001, a batch size of 32, and the binary cross-entropy loss function. Early Stopping is applied to prevent overfitting by monitoring the validation loss. Model performance is evaluated using accuracy, precision, recall, F1-score, classification report, and confusion matrix.

2.5.Web-Based Prediction System

The best-performing model is integrated into a Flask-based web application for automated Parkinson's disease prediction. Users upload a brain MRI image, which is automatically preprocessed and analyzed by the trained model. The application displays the predicted class and confidence score, while the prediction result, confidence score, and timestamp are stored in an SQLite database for maintaining prediction history [6].

3. Results and Discussion

3.1.Results

The proposed Parkinson's disease prediction system was evaluated using a brain Magnetic Resonance Imaging (MRI) dataset comprising 1005 training, 215 validations, and 218 testing images. Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0 were trained under identical conditions and evaluated using accuracy, precision, recall, F1-score, and confusion matrix.

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3.1.1. Custom CNN Model

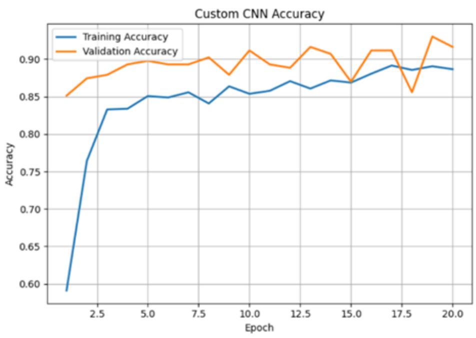

Figure 2 Training and validation accuracy of the Custom CNN model

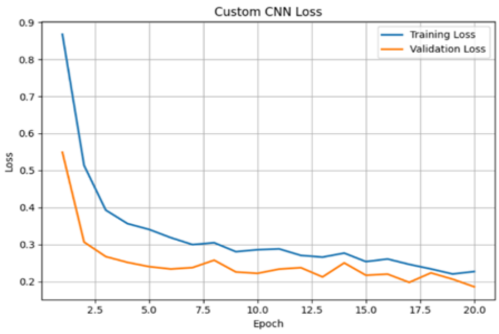

Figure 3 Training and validation loss of the Custom CNN model

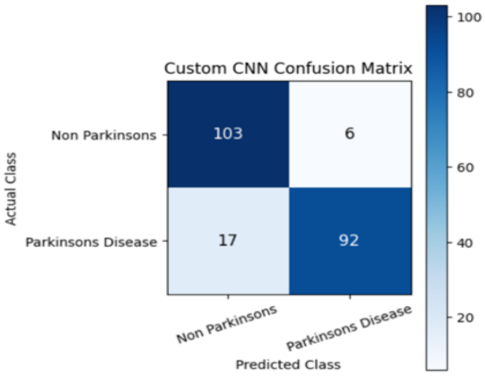

Figure 4 Confusion matrix of the Custom CNN model

Figures 2–4 illustrate the performance of the Custom CNN model. The training and validation accuracy increased steadily across epochs, while the loss values decreased consistently, indicating effective model learning. The confusion matrix shows that the model correctly classified 103 Non-Parkinson's and 92 Parkinson's MRI images. The Custom CNN achieved a test accuracy of 89.45%, providing competitive performance but slightly lower accuracy than ResNet50 [7].

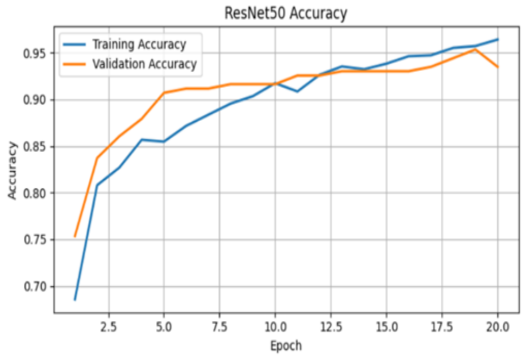

Figure 5 Training and validation accuracy of the fine-tuned ResNet50 model

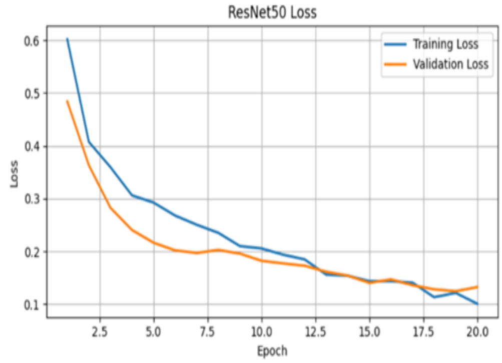

Figure 6 Training and validation loss of the fine-tuned ResNet50 model

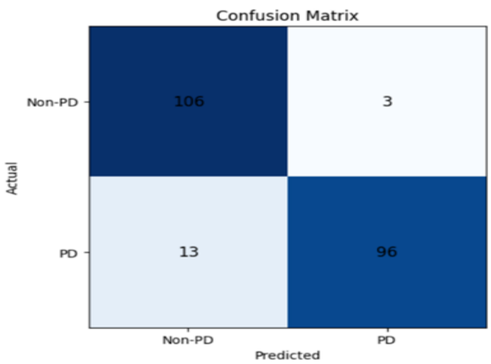

Figure 7 Confusion matrix of the fine-tuned ResNet50 model

Figures 5–7 present the training and validation

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accuracy, training and validation loss, and confusion matrix of the fine-tuned ResNet50 model. The accuracy curves indicate continuous improvement during training, while the loss curves show stable convergence with decreasing training and validation loss. The confusion matrix demonstrates that the model correctly classified 106 Non-Parkinson's and 96 Parkinson's MRI images, with only a small number of misclassifications. The ResNet50 model achieved the highest test accuracy of 92.66%, indicating superior classification performance [8].

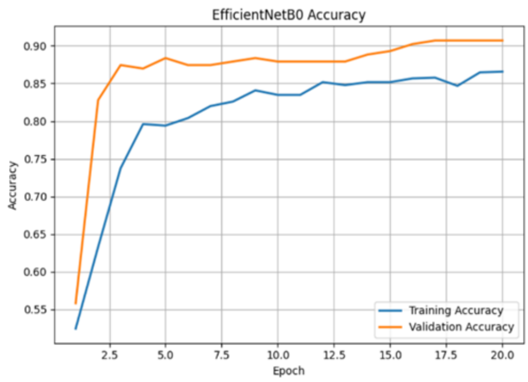

Figure 8 **Training and validation accuracy of the fine-tuned EfficientNetB0 model**

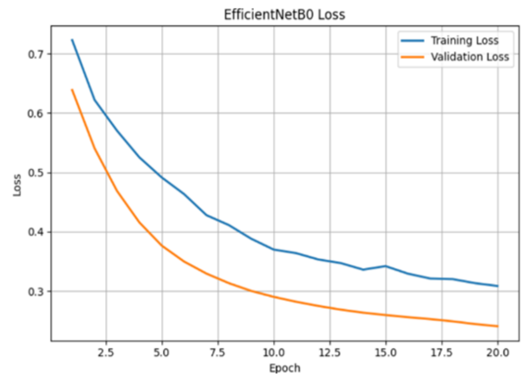

Figure 9 **Training and validation loss of the fine-tuned EfficientNetB0 model**

Figures 8–10 present the experimental results of the fine-tuned EfficientNetB0 model [9]. The model exhibited consistent convergence during training, with gradually increasing accuracy and decreasing loss values. The confusion matrix shows that 100 Non-Parkinson's and 90 Parkinson's MRI images were correctly classified, resulting in a test accuracy of 87.16% Shown in Table 1.

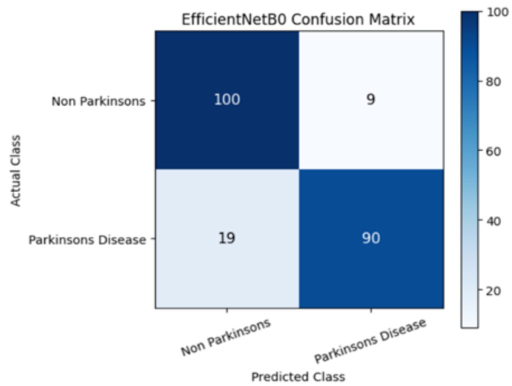

Figure 10 **Confusion matrix of the fine-tuned EfficientNetB0 model**

Table 1 **Performance Comparison of Deep Learning Models**

Model	Test Accuracy (%)
Custom CNN	89.45
Fine-Tuned ResNet50	92.66
Fine-Tuned EfficientNetB0	87.16

The comparative results indicate that the fine-tuned ResNet50 achieved the highest classification accuracy and demonstrated the most reliable performance for Parkinson's disease prediction using brain MRI images.

3.2.Discussion

The experimental results demonstrate that all three deep learning models successfully learned meaningful features from brain MRI images for Parkinson's disease prediction. However, differences in network architecture resulted in variations in classification performance. The fine-tuned ResNet50 achieved the highest accuracy (92.66%) because its residual learning architecture facilitates efficient feature extraction and stable gradient propagation during training [10]. This resulted in better convergence and fewer classification errors than the other models. The Custom CNN also produced competitive performance, achieving 89.45% accuracy. Although its simpler architecture enabled effective learning, it was less capable of capturing complex structural features present in MRI images, leading to slightly lower classification performance. The fine-tuned EfficientNetB0 achieved 87.16% accuracy and demonstrated stable training behaviour. However, its lower performance may be attributed to the characteristics of the available MRI dataset and the limited number of training samples used for fine-tuning. Overall, the results indicate that appropriate image preprocessing, data augmentation, and transfer learning contribute significantly to improving classification performance. The successful deployment of the fine-tuned ResNet50 model in a Flask-based web application further demonstrates the practical applicability of the proposed framework as a computer-aided decision-support system for Parkinson's disease screening.

Conclusion

This study presented a deep learning-based Parkinson's disease prediction system using brain Magnetic Resonance Imaging (MRI) images. Three models, namely Custom Convolutional Neural Network (CNN), fine-tuned ResNet50, and fine-tuned EfficientNetB0, were implemented and evaluated under identical experimental conditions. Experimental results demonstrated that the fine-tuned ResNet50 model achieved the highest classification accuracy of 92.66%, outperforming the other models. The integration of the best-performing model into a Flask-based web application enables automated MRI image prediction with confidence score generation and prediction history management. The proposed system can serve as a computer-aided decision-support tool for Parkinson's disease screening and may assist healthcare professionals in early disease detection. Future work may focus on larger multi-center MRI datasets and advanced deep learning architectures to further improve prediction accuracy and robustness.

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