CNN Model for Parkinson Disease Detection from Image Data

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Abstract

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterised histologically by the death of dopaminergic neurons in the substantia nigra pars compacta (SNpc) and the presence of Lewy bodies in various parts of the brain. The SNpc is a compact structure in the midbrain that plays a vital role in motor coordination and movement control by producing a chemical substance called dopamine. PD is the second most common neurodegenerative disorder after Alzheimer's disease, affecting 1% of the population over the age of 60 and reaching approximately 5% at 85. The prevalence is rising due to ageing populations. There is currently no proven disease-modifying therapy. The diagnosis of PD requires the presence of bradykinesia (slowness of movements) in addition to muscle rigidity or tremor or postural instability. Approximately 20% of patients do not develop a tremor. The manifestations of PD are not limited to motor impairments. Prompt diagnosis of PD is important in order to provide patients with appropriate treatment and information on prognosis. However, an accurate early diagnosis can be challenging because the movement symptoms can overlap with other conditions. Doctors make the diagnosis of PD based on clinical evaluation, interpreting information gained predominantly through history-taking and examination of the patient. Sometimes brain imaging may be requested to help support the clinical diagnosis, but there are currently no tests that are wholly sensitive or specific for Parkinson's. The rate of misdiagnosis of PD is approximately 10–25%, and the average time required to achieve 90% accuracy is 2.9 years. Autopsy is still the gold standard for the confirmation of the disease. Therefore, this work designed an advanced convolution neural network model to predict Parkinson disease from both image and voice data. In general, existing ML algorithms such as SVM, and Random Forest will not filter data multiple times so its prediction accuracy is less hence CNN is used in this work, which filter data multiple times using neuron values so its prediction accuracy can be better. This work uses WAVE and SINE images of normal and Parkinson disease patients for imaging data.

Keywords: Parkinson disease, artificial intelligence, predictive analytics, machine learning, deep learning.

1. Introduction

Parkinson's disease (PD) manifests as the death of dopaminergic neurons in the substantia nigra pars compacta within the midbrain. This neurodegeneration leads to a range of symptoms including coordination issues, bradykinesia, vocal changes, and rigidity. Dysarthria is also observed in PD patients; it is characterized by weakness, paralysis, and lack of coordination in the motor-speech system: affecting respiration, phonation, articulation, and prosody. Since symptoms and the disease course vary, PD is often not diagnosed for many years. Therefore, there is a need for more sensitive diagnostic tools for PD detection because, as the disease progresses, more symptoms arise that make PD harder to treat. The main deficits of PD speech are loss of intensity, monotony of pitch and loudness, reduced stress, inappropriate silences, short rushes of speech, variable rate, imprecise consonant articulation, and harsh and breathy voice (dysphonia). The range of voice related symptoms is promising for a potential detection tool because recording voice data is non-invasive and can be done easily with mobile devices.

PD is one of the most chronic neurodegenerative diseases in today's world as it effects of the -year-old. PD is a prototypical movement disorder, and primary symptoms of PD are tremor, rigidity or muscle stiffness, bradykinesia and postural instability and these symptoms are generally known as Parkinsonism Syndrome. Parkinson's disease (PD) is a chronic neurodegenerative disease of that predominantly affects the elderly in today's world. For the diagnosis of the early stages of PD, effective and powerful automated techniques are needed by recent enabling technologies as a tool. Deep learning (DL) algorithms based on various diagnostic methodologies have been developed to detect PD and resolve related diagnostic issues. This research study offers a complete assessment of published surveys and DL-based diagnosis methodologies for PD recognition. The techniques of DL-based diagnostic approaches for PD recognition, such as PD dataset pre-processing, extraction and selection of features, and classification, are all included in this survey.

In recent years, there has been a significant increase in the use of machine learning based computer-aided diagnosis (CAD) systems to diagnose diseases, sometimes even in early stages. There has also been an increase in utilization of such CAD systems for diagnosing PD from various modalities like speech signals, gait signals, magnetic resonance imaging (MRI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), Dopamine Transporter Scan (DaT Scan), tremor signal, handwriting signal, handwritten images, and various other clinical features (CF).

1.2 Problem Definition

The project aims to create a deep CNN model for the early detection of Parkinson's disease using medical images. It involves collecting and preparing a dataset, training the CNN model, and assessing its performance. Detecting Parkinson's disease at an early stage can significantly improve patient outcomes. The project's deliverables include a trained model, performance reports, and potentially a user-friendly interface. It's essential to consider data sources, constraints, and stakeholders throughout the project to ensure its success and relevance in the medical field.

2. Literature Survey

Haq et al. [1] discussed the various datasets used to evaluate the suggested PD recognition algorithms to better understand these datasets. The model evaluation metrics and cross-validation techniques used by different studies in this domain have also been explored in this survey. Considering the evaluated literature, this work also examined hot upcoming research issues and related solutions. Finally, this work came up with several trends and areas for future study that will aid progress in automatic disease recognition, particularly in detecting Parkinson's disease and its implementation in E-healthcare systems.

Clayton et al. [2] introduced convolutional neural networks to learn features from images produced by handwritten dynamics, which capture different information during the individual's assessment. Additionally, this work makes available a dataset composed of images and signal-based data to foster the research related to computer-aided PD diagnosis. The analysis of handwritten dynamics using deep learning techniques showed to be useful for automatic Parkinson's disease identification, as well as it can outperform handcrafted features.

Tanveer et al. [3] presented a comprehensive review of papers from 2013 to 2021 on the diagnosis of PD and its subtypes using artificial neural networks (ANNs) and deep neural networks (DNNs). This work presented detailed information and analysis regarding the usage of various modalities, datasets, architectures, and experimental configurations in a succinct manner. This work also presented an in-depth comparative analysis of various proposed architectures. Finally, presented several relevant future directions for researchers in this area.

In [4], Dash et al. implemented machine learning (ML) methods to address these difficulties and to refine the diagnosis and assessment procedures of PD, for the classification of PD and healthy controls or patients with similar clinical presentations. ML is a subfield of artificial intelligence (AI) that is increasingly applied to several medical diagnosis tasks, including to diagnose a wide range of diseases. This chapter provided an overview of the application of ML techniques and introduces some key concepts for PD diagnosis.

Nilashi et al. used Incremental support vector machine to predict Total-UPDRS and Motor-UPDRS [5]. This work also used Non-linear iterative partial least squares for data dimensionality reduction and self-organizing map for clustering task. To evaluate the method, this work conducted several experiments with a PD dataset and present the results in comparison with the methods developed in the previous research. The prediction accuracies of method measured by MAE for the Total-UPDRS and Motor-UPDRS were obtained respectively MAE=0.4656 and MAE=0.4967.

In [6], Vilda et al. proposed methodology availed that the use of highly normalized descriptors as the probability distribution of kinematic variables of vowel articulation stability, which has some interesting properties in terms of information theory, boosts the potential of simple yet powerful classifiers in producing quite acceptable detection results in Parkinson Disease.

Maachi et al. [7] proposed a novel intelligent Parkinson detection system based on deep learning techniques to analyze gait information. This work used 1D convolutional neural network (1D-Convnet) to build a Deep Neural Network (DNN) classifier. The proposed model processes 18 1D-signals coming from foot sensors measuring the vertical ground reaction force (VGRF). The first part of the network consists of 18 parallel 1D-Convnet corresponding to system inputs. The second part is a fully connected network that connects the concatenated outputs of the 1D-Convnets to obtain a final classification. This work tested the algorithm in Parkinson's detection and in the prediction of the severity of the disease with the Unified Parkinson's Disease Rating Scale (UPDRS).

Shivangi et al. [8] introduced two neural network-based models namely, VGFR Spectrogram Detector and Voice Impairment Classifier, which aimed to help doctors and people in diagnosing disease at an early stage. An extensive empirical evaluation of CNNs (Convolutional Neural Networks) has been implemented on large-scale image classification of gait signals converted to spectrogram images and deep dense ANNs (Artificial Neural Networks) on the voice recordings, to predict the disease.

Pahuja et al. [9] discussed three types of classifiers, namely, Multilayer Perceptron, Support Vector Machine and K-nearest neighbor on the benchmark (voice) dataset to compare and to know which of these classifiers is the most efficient and accurate for PD classification. The Voice input dataset for these classifiers has been obtained from UCI machine learning repository. ANN with Levenberg–Marquardt algorithm was found to be the best classifier, having highest classification accuracy (95.89%).

Lavalle et al. [10] researched on Parkinson disease (PD) detection has shown that vocal disorders are linked to symptoms in 90% of the PD patients at early stages. Thus, there is an interest in applying vocal features to the computer-assisted diagnosis and remote monitoring of patients with PD at early stages. The contribution of this research is an increase of accuracy and a reduction of the number of selected vocal features in PD detection while using the newest and largest public dataset available. The best resulting accuracy is obtained by using a support vector machine and it is higher than the one, which was reported on the first work to use the same dataset. In addition, the corresponding computational complexity is further reduced by selecting no more than 20 features.

In [11], Zhang et al. investigated the mobile health (for short mHealth) technology for preventive medicine, particularly in chronic disease management. Notably, many types of research have explored the possibility of using mobile and wearable personal devices to detect the symptom of PD and shown promising results. It provided opportunities for transforming early PD detection from clinical to daily life. This survey paper attempted to conduct a comprehensive review of mHealth technologies for PD detection from 2000 to 2019 and compared their pros and cons in practical applications and provides insights to close the performance gap between state-of-the-art clinical approaches and mHealth technologies.

In [12], Alzubaidi et al. aimed to explore and summarize the applications of neural networks to diagnose PD. PRISMA Extension for Scoping Reviews (PRISMA-ScR) was followed to conduct this scoping review. To identify the relevant studies, both medical databases (e.g., PubMed) and technical databases (IEEE) were searched. Three reviewers carried out the study selection and extracted the data from the included studies independently. Then, the narrative approach was adopted to synthesis the extracted data.

3. Proposed System

In this project we are designing Advanced Convolution Neural Network based Machine Learning algorithm model to predict Parkinson disease from both Image and voice data. All existing ML algorithms such as SVM, Random Forest will not filter data multiple times so its prediction accuracy is less so we have used CNN algorithm which filter data multiple times using NEURON values so its prediction accuracy can be better.

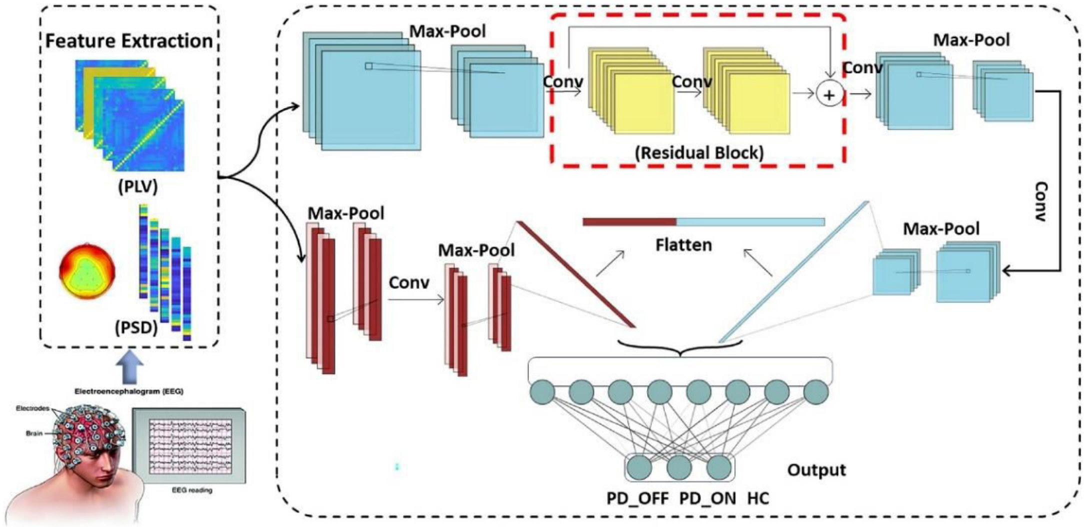


Figure 1: Proposed PD detection system architecture.

4. Results and Discussion

Figure 2 illustrates the graphical user interface (GUI) of proposed CNN-based Parkinson disease detection application. It shows the layout of buttons, text fields, and other components that users interact with when using this application. Figure 3 shows the accuracy of the pre-trained CNN model after it has been loaded, which helps to understand the reliability of the model's predictions.

Figure 4 depicts the architecture of deep CNN model layer by layer. It shows the convolutional layers, pooling layers, fully connected layers, and other components of model, along with the specifications. Figure 5 shows some examples of the test data used to evaluate the performance of proposed deep CNN model. It includes a few images that represent the input data the model is tested on.

Figure 6 displays examples of images that have been input into trained CNN model, along with the model's predictions for each image. This is a visual representation of how well the model is performing in predicting whether an individual has Parkinson's disease based on their drawings.

In Figure 7, x-axis represents training epoch and y-axis represents accuracy and loss values and with each increasing epoch, its accuracy getting increased, and loss is decreasing. At the final epoch, accuracy reached closer to 1 and loss reached closer to 0.

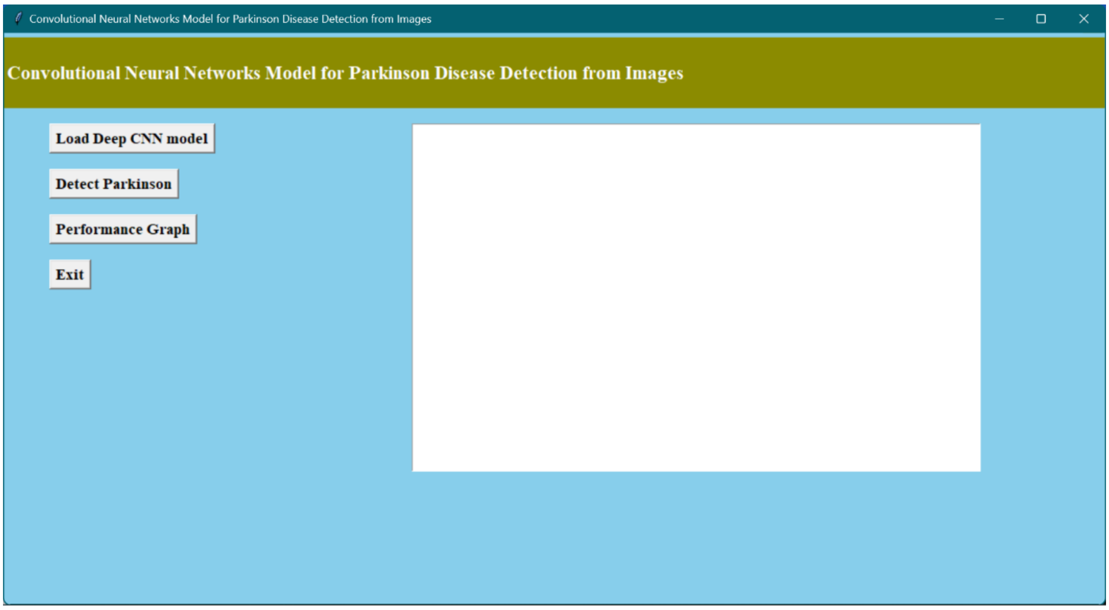


Figure 2: User interface of proposed CNN-based Parkinson disease detection from images.

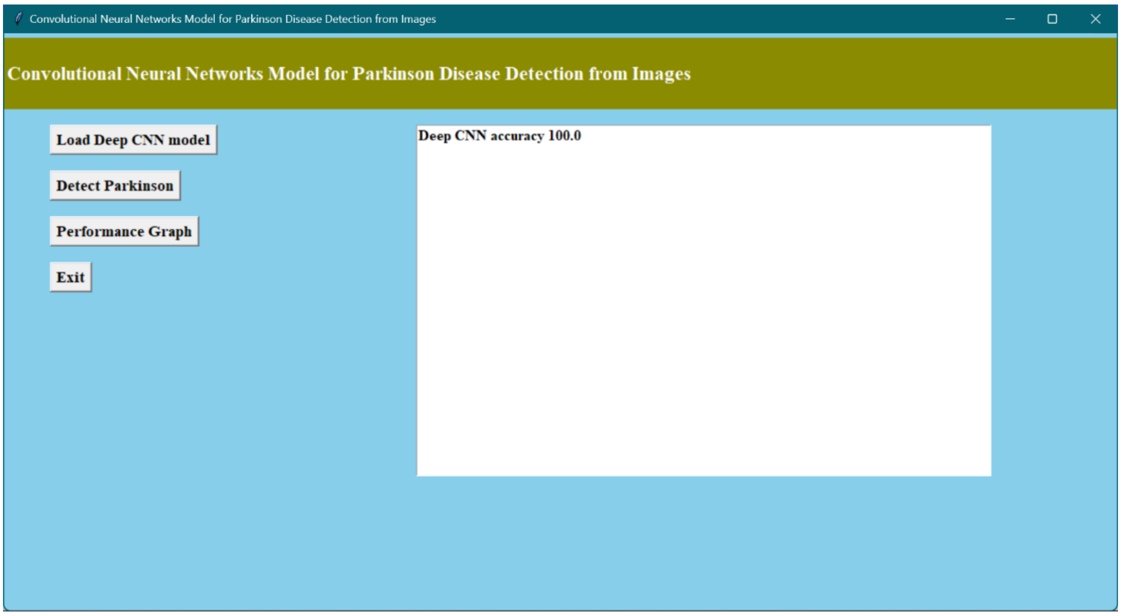


Figure 3: Illustration of UI with Deep CNN model accuracy after loading the pre-trained model.

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 62, 62, 32)        896
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 31, 31, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 29, 29, 32)        9248
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 14, 14, 32)        0
_________________________________________________________________
flatten_1 (Flatten)          (None, 6272)              0
_________________________________________________________________
dense_1 (Dense)              (None, 256)               1605888
_________________________________________________________________
dense_2 (Dense)              (None, 2)                 514
=================================================================
Total params: 1,616,546
Trainable params: 1,616,546
Non-trainable params: 0
_________________________________________________________________
None
```

Figure 4: Layer-wise summary of proposed deep CNN model.

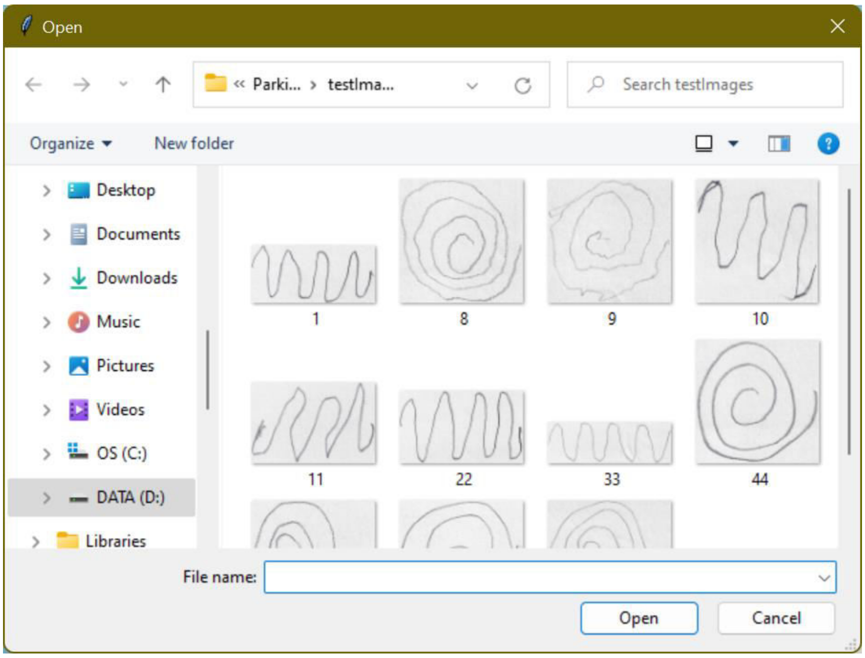
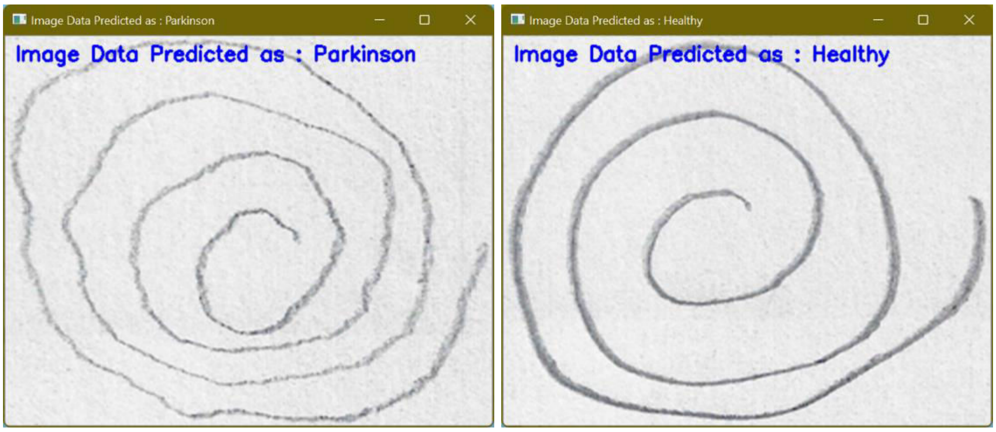


Figure 5: Sample test data used for evaluating the pre-trained proposed CNN model.



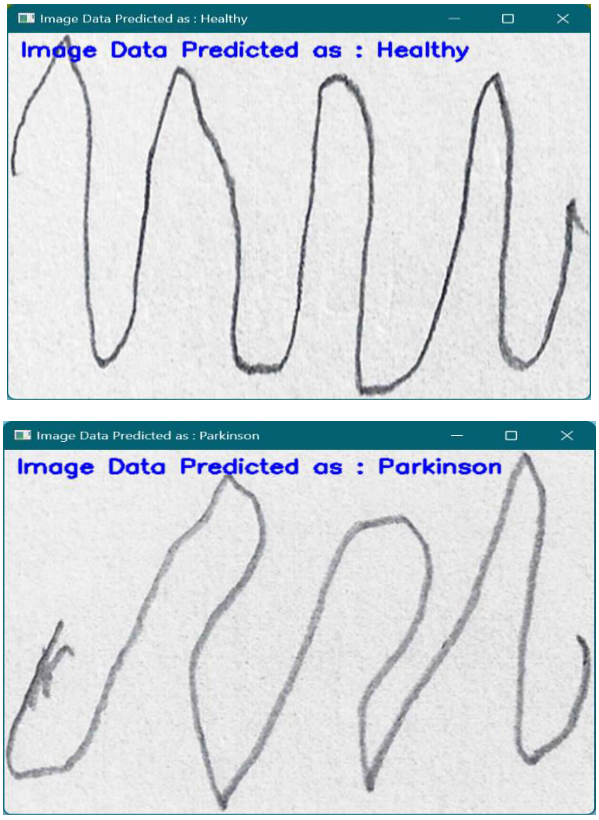


Figure 6: Sample predicted images using proposed CNN model.

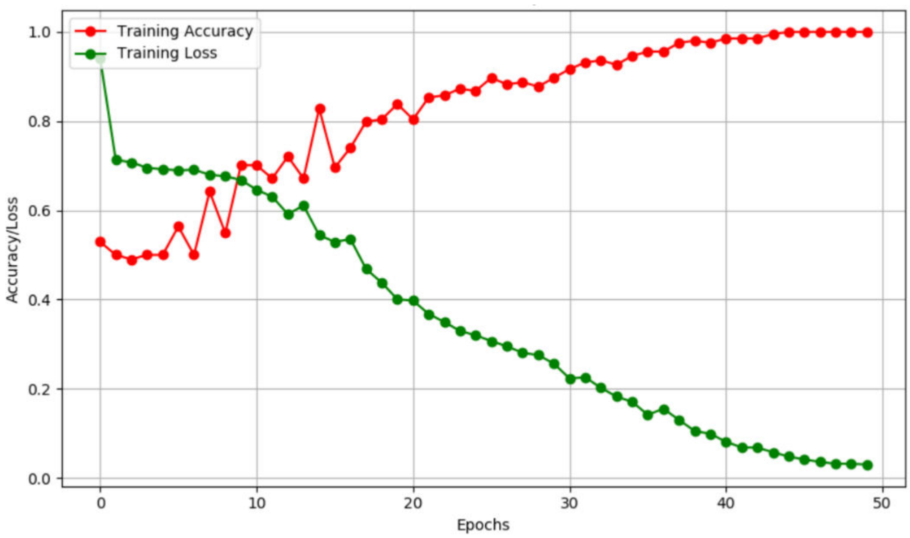


Figure 7: Performance analysis of obtained accuracy, and loss using proposed CNN model.

5. Conclusion

This work has successfully developed a user-friendly graphical interface for Parkinson's disease detection using a pre-trained CNN model. The application allows users to load a pre-trained deep CNN model, enabling quick and efficient disease detection without the need for model training from scratch. Then, users can select an image, which is then processed, resized, and fed into the CNN model for disease detection. The model's predictions are displayed, helping in the early diagnosis of Parkinson's disease. In addition, this includes a feature to visualize the model's training performance through accuracy and loss graphs, aiding in the assessment of model reliability. Further, the GUI provides a user-friendly experience, making the technology accessible to medical professionals and researchers. Finally, this application offers a text display for relevant information, including model accuracy, enhancing user understanding.

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