

Early Detection of Parkinson's Disease using Contrast Enhancement Techniques and CNN

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Abstract— Analysis of non-invasive biomarkers for detection of diseases is important for reliable clinical diagnosis. Progressive neurodegenerative disorders like Parkinson's Disease affect more than a million people each year in India. People suffering from Parkinson's Disease experience loss of motor control. It is identified as one of the most common symptoms of the disease and hence handwriting analysis can be used to detect and diagnose Parkinson disease patients. It has also been observed that handwriting impairment in Parkinson patients can be directly linked to severity of the disease. Therefore, detecting Parkinson disease at an early stage through handwriting analysis is possible. One of the possible approaches is processing sketches using machine learning techniques. This work aims to study this biomarker by analyzing the sketching patterns in the spiral and wave drawings by healthy subjects and patients suffering from Parkinson's disease. This work also presents an optimization of algorithms for feature extraction and classification. The proposed model showed an accuracy of 96.67% with a precision of 93.33% and recall of 100%. Thus, this method could be used for early detection of Parkinson's Disease.

Keywords— *Parkinson's Disease, Contrast Enhancement, BBHE, CNN, Neural Networks.*

I. INTRODUCTION

Parkinson's Disease is one of the most common CNS diseases in the world [1]. The estimated population of people above the age of 50 suffering from Parkinson's Disease in India by 2030 will be 0.69 million [2]. Parkinson's disease affects human motor movement. It is a progressive nervous system disorder. Dopamine levels in the body drop due to nerve cell damage in the brain which lead to the symptoms of Parkinson's Disease [3]. At the onset, a slight tremor is noticed in one hand. Tremors are a common symptom however as the disorder progresses, it causes stiffness or slowing of movement (bradykinesia) and loss of postural reflexes [4].

The Hoehn and Yahr rating scale is widely used by doctors to classify the severity of symptoms of Parkinson's Disease. The five stages of the Hoehn and Yahr scale help doctors evaluate how far the disease has advanced. Stage 0 indicates no signs of disease. Symptoms like tremors and difficulty in movement, generally exclusive to one side of the body (unilateral) are observed at stage 1. At stage 1.5 the patient experiences unilateral symptoms plus axial involvement (neck and spine). Stage 2 is considered to be a moderate form of Parkinson's, and the symptoms are much more noticeable than those experienced in stage 1. Patients experience symptoms on both sides of the body without impairment of balance. At stage 2.5, patients experience mild

symptoms on both sides of the body, with recovery when the doctor stands behind the person and asks them to maintain their balance when pulled backwards (pull test). At stage 3, patient needs assistance to prevent falling on pull test, but are physically independent. It can be regarded as a mild to moderate bilateral disease. Stage 4 patients experience severe disability, but are still able to walk or stand unassisted. Stage 5 patients find it impossible to stand or walk due to advanced stiffness in the legs which causes freezing upon standing, they may need a wheelchair or are bedridden unless assisted [5].

Clinical methods like Magnetic Resonance Imaging (MRI), transcranial Doppler ultrasonography, positron emission tomography (PET), single-photon emission computed tomography (SPECT), morphometric MRI studies, tractography, functional MRI and perfusion imaging are used for detecting and identifying type of parkinsonism [6]. These methods usually have to be performed by doctors and are painstaking for the patients. Identifying accurate biomarkers is an important research goal for neurodegenerative diseases [7]. Many works have used speech processing, handwriting recognition and gait analysis for detection of Parkinson's Disease [8]. Parkinson's prediction based on speech uses sustained vowels and natural speech and requires high level of signal processing [9, 10]. By performing gait analysis, motor symptoms can be detected [11]. In comparison to these methods, handwriting analysis proves to be a simple, quick and efficient way to diagnose Parkinson's Disease.

Patient's symptoms and quality of life can be significantly improved with early diagnosis and proper medication as there is no cure for Parkinson's Disease. An analysis of handwriting and sketching abilities of patients and micrographia is used for early-stage diagnosis of Parkinson's disease [12]. Handwriting analysis is also an effective indicator for detection of Parkinson's disease. Handwriting of a person can be influenced by a number of factors such as education and language proficiency however sketching of a shape such as the spiral has been found to be a non-invasive and an independent parameter for measurement of onset of symptoms [13]. Hence it may be considered as an objective, easy to administer non-invasive test to measure motor dysfunction in Parkinson disease (PD).

II. METHODOLOGY

A. Data Acquisition and Augmentation

The dataset used in this paper is acquired from Kaggle [14]. This dataset contains 102 images of spiral drawings and 102 images of wave drawings. The dataset is already divided into training and testing parts which contain 72 images and 30

images respectively. The dimensions (height and width) of the spiral images are 256x256 pixels. The wave images have a width of 512 pixels and are of varying height. The need of augmentation arises due to the small size of dataset.

Augmentation methods like rotation and vertical and horizontal flipping are applied to increase the size of the dataset. The spiral images are rotated 360 degrees and wave images are rotated in 5 degrees on either side. The images are also flipped vertically and horizontally to further increase the dataset size. The augmented dataset contains more than 10000 spiral images and more than 5000 wave images. These images are pre-processed before using them to train the model.

B. Data Preprocessing

In some patients, due to the severity of the disease, their ability to draw decreases drastically and the resulting drawing is very light as compared to others. To enhance such images, contrast enhancement techniques are used which enhance the features required for feature extraction. The most popular contrast enhancement techniques are Histogram Equalization (HE), Adaptive Histogram Equalization (AHE), Contrast Limited Adaptive Histogram Equalization (CLAHE), Brightness Preserving Bi Histogram Equalization (BBHE) and Min Max Stretching (MMS) [15]. These techniques are compared using the “Mean Squared Error” or MSE metric.

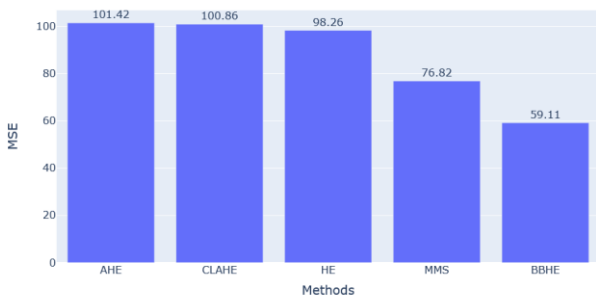


Fig. 1. Comparison between different methods of contrast enhancement.

Fig. 1 shows the different contrast enhancement techniques and their MSE. It has been already reported by Yadav et al., least MSE indicates the optimal method among the set of contrast enhancement techniques [16]. The MSE values obtained in this study are 101.42, 100.86, 98.26, 76.82 and 59.11 for AHE, CLAHE, HE, MMS and BBHE respectively. The Brightness Preserving Bi Histogram Equalization or BBHE technique showed the least MSE and hence it is the most optimal method. All the images were pre-processed using this technique and were used to train the model. Fig. 2 shows the original and pre-processed images.

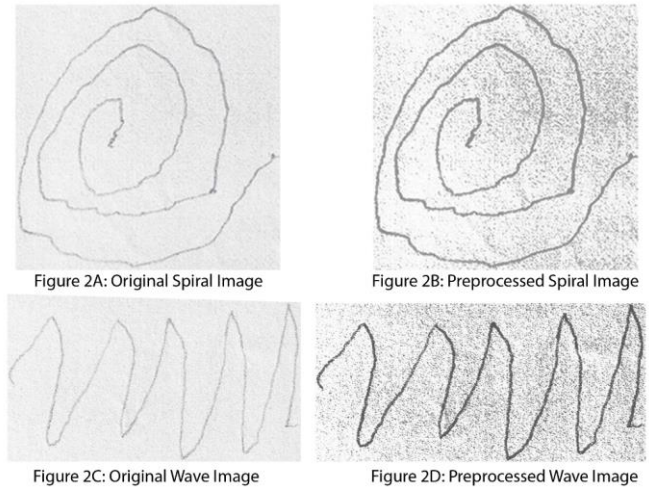


Fig. 2. Image Preprocessing

C. Model Development and Architecture

Many different machine learning methods can be used for feature extraction and classification of Parkinson disease. A simple and efficient method for feature extraction is Histogram of Oriented Gradients (HOG) [17]. For image classification tasks, machine learning models like SVM and KNN and Neural Networks have proven to be effective [18]. Deep learning architectures like Xception[19], InceptionV3[20], NASNet[21] and many other architectures are also used for image classification.

In this work, a histogram of gradients (HOG) feature extractor was used with SVM and KNN, showed accuracy of 73.05% and 73.33% respectively. Neural networks like Xception, NASNet, InceptionV3 with pretrained ImageNet weights and for feature extraction and Fully Connected Neural Networks were used for classification. These models obtained an accuracy of 87.22%, 89.52%, 92.84% respectively. The proposed approach uses two Convolutional Neural Network Architectures for feature extraction and Fully Connected Neural Network for classification.

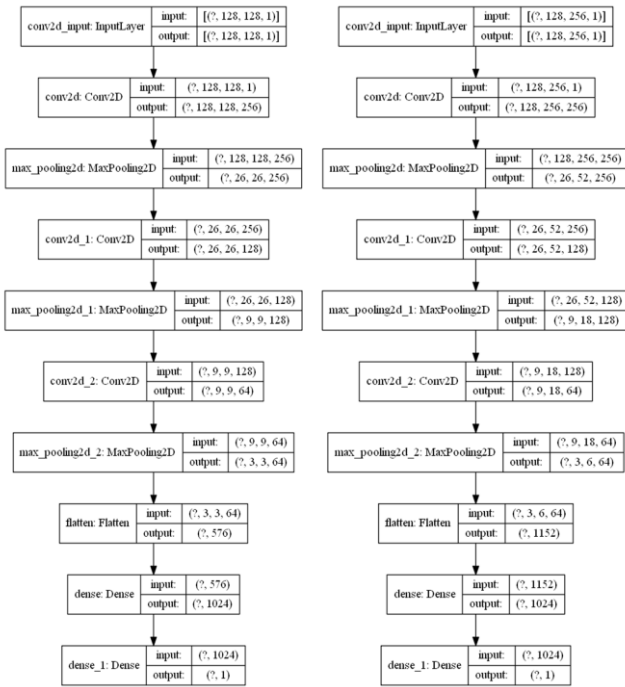


Figure 3A: Spiral Model Architecture Figure 3B: Wave Model Architecture

Fig. 3. Developed Model Architecture.

Fig. 3 shows the developed model architecture. The model was trained for 100 epochs with the same learning rate. The optimizer used in this method is the Adam Optimizer. An early stop protocol was used that stops the model training if the validation loss does not decrease after 5 epochs.

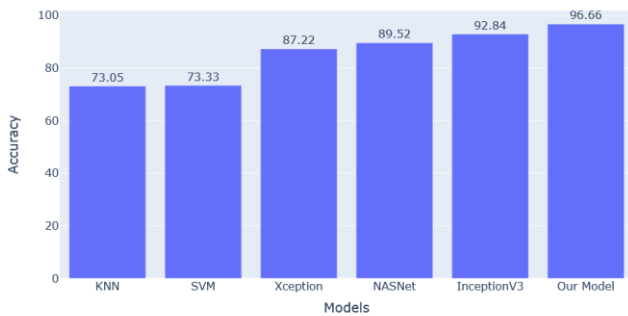


Fig. 4. Comparison between different methods of Feature Extraction and Classification.

Fig. 4 shows the comparison between different neural network architectures and their accuracies. It is clearly observed that the developed model outperforms these models in feature extraction and classification.

III. RESULTS AND DISCUSSION

Many researchers have done different studies on Parkinson detection using CNN on Images. A custom Neural Network trained using Dynamic and Static spiral images to detect Parkinson obtained an overall accuracy of 87% [22]. Finetuned VGG-19 model used on the Parkinson's Drawing dataset obtained an accuracy of 88.5% on the dataset [23]. AlexNet obtained an accuracy of 92.14% on the spiral images and 90% on the wave images [24]. Multistage Classifier model used for

detection of Parkinson's Disease obtained an overall accuracy of 93.33% [25].

In this work, the developed methodology and dataset, showed an overall accuracy of 96.67%. It has been observed that the results are in good agreement with the previously reported works. The significant improvement in the accuracy can be attributed to the optimal contrast enhancement technique used and that two different CNN models were used for predicting the spiral and wave patterns respectively. The condition that it should not classify Parkinson patients as healthy is satisfied.

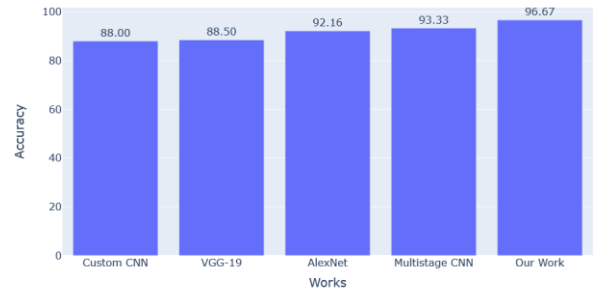


Fig. 5. Comparison between the accuracies obtained in the previous works and this work.

IV. CONCLUSION

The machine learning architectures using non-invasive biomarkers found to be an effective method for early detection of Parkinson's disease. The developed models for spiral and wave sketches perform satisfactorily in classifying the sketches of healthy and Parkinson patients. The models obtained an overall accuracy of 96.67%, precision of 93.33% and a recall of 100%. The model does not misclassify any Parkinson patient in the data used in this study as healthy. The developed model can be employed in real life scenarios and stable production environments.

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