Early Detection of Parkinson's Disease from Hand Drawings Using CNN and LSTM

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***Abstract*— Parkinson's Disease (PD) is a neural disorder that can affect your ability to regulate movements. The disease usually starts slowly at early stages and gets worse as time passes. If you have Parkinson's Disease, it will become difficult to maintain your body balance and coordination. As the time passes the disease gets worse and may cause trouble in talking, sleeping, having mental and memory problems and many other related symptoms. This paper proposes two deep learning models for detecting PD. The first model proposed is a Convolutional Neural Network (CNN) model trained on hand drawn images. The second model is a Long Short Term Memory (LSTM) model trained using time series signals of hand drawings. The proposed models are trained using the benchmark NewHandPD dataset which consists of hand drawn images and its corresponding time series signals of both the healthy and PD subjects.**

Keywords— *CNN, LSTM, Parkinson's Disease*

I. Introduction

Parkinson's Disease (PD) is a neural disorder that attacks the central nervous system or the brain and affects various body movements. There are nerve cells which can damage within the brain causing dopamine levels to drop and this results in the symptoms of Parkinson's disease. The various symptoms of this disease that can occur include slow movement, tremors, stiffness and loss of balance etc. It usually occurs at an older age but can also happen in youngsters. The exact cause of the disease is still not confirmed but results show that it is mostly genetic, although there can be other causes as well. It has also been found that Parkinson's disease has 5 stages with stage one being the least and stage 5 being the most severe stages. It is important to understand that Parkinson's disease should be detected at early stages because if not treated early, then untreated Parkinson's disease gets worse as time passes. Parkinson's disease may cause damage to all the brain functions and even an early death. Therefore, the aim of this research is to design a deep learning model that can detect Parkinson's disease at early stages with a good level of accuracy.

Over the years several machine learning(ML) and deep learning (DL) techniques were proposed to detect Parkinson's Disease in a person. Also there were different types of datasets used for this purpose. Some used image datasets, some audio while others used gait movements. One of the screening techniques used for Parkinson's disease is handwriting analysis. These are pen-paper tests used to identify abnormality in handwriting. These kinds of abnormalities can be identified long before the occurrence of the symptoms of Parkinson's Diseases and hence the handwriting analysis is an efficient tool for early diagnosis of Parkinson's Disease. With the development of computational tools, digitisers and tablets, the dynamics of the hand movement can be extracted and analyzed more effectively.

This paper proposes a two-dimensional convolutional neural network model and a LSTM model for detecting PD.

II. Related Works

The various modalities used for building classification models for Parkinson's disease are MRI images, voice, gait, handwriting, EEG, social media data etc. Ram`ırez et al. [1] proposed an autoencoder model for detecting Parkinson's disease from MRI images and showed good results of PD detection. Sivaranjini et al. [6] classified the MRI images of the healthy people and the people infected with Parkinson's Disease. The PPMI dataset was chosen for the classification task. This work achieved an accuracy of 88.90%. Leung et al. [10] aimed to develop an approach for diagnosis in patients with PD using a deep learning model. The chosen dataset was the PPMI dataset.

Johri et al. [3] proposed a hybrid model that includes 2 classifiers - VGFR Spectrogram Detector and Voice Impairment Classifier. Improper walking patterns (gait) images and speech impairment(voice) has been used as a dataset in this work. The proposed model uses a CNN based VGFR Spectrogram Detector for Distorted walking patterns and an ANN based Voice Impairment Classifier for speech. Shahid et al. [8] proposed a DNN model from voice data. Parkinson's assessment by UPDRS Dataset is made by taking voice recordings of 5875 patients from 10 medical centers within the US. Feature space reduction is performed and therefore the input features which were reduced are run through the DNN model. The model's accuracy of prediction is measured by using 3 parameters. These parameters are MAE, RMSE and coefficient of determination. Quan et al. [9] proposed a BiLSTM (bi-directional LSTM) model trained and validated using an audio dataset which was gathered by the gyenno science parkinson disease research center.

Oh et al. [5] used electroencephalogram (EEG) signals for PD detection. In this work, they used EEG signals. The implemented model is a 13 layered CNN and the model shows an accuracy of 88.25%. Cevik et al. [7] aimed to perform the sentiment analysis on the people with Parkinson's disease. They used tweets that were extracted through selenium crawlers. A total of 11043 tweets were collected and used. For the classification task CNN, RNN and LSTM were used. The accuracy achieved was 93.63%.

Khatamino et al. [2] designed a deep learning based model on a Handwriting based dataset. Spiral tests both static and dynamic are performed on the dataset for PD detection. In this

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work, both the visual and dynamic attributes of spirals are used. The approach used in this work achieved 88% accuracy value. Diaz et al. [11] created a classification model to identify the signs of early Parkinson's Disease using the sequential information of the handwriting of different patients. It made use of PaHaW as well as NewHandPD datasets for this approach. In this approach they fed the raw time series sequential signals through a 1D CNN layer and the resulting signals are passed through Bidirectional Gated Recurrent Units (BiGRUs). The accuracy achieved was 94.44% in the spirals and 91.11% in meanders. Parziale et al. [12] made an approach to compare the different algorithms of machine learning used to classify the levels of interpretability on the handwritings of PD patients. They used Cartesian Genetic Programming and Decision Tree to diagnose Parkinson's Disease at an initial stage. It gave an accuracy of 88% for the NewHandPD dataset. Parisi et al. [13] in their research used a hyper sin-h activation function with convolution neural network CNN on NewHandPD and HandPD datasets. It was compared against all the commonly used activation functions as well. Hyper sin-h was believed to increase the gap of separation from the drawings of spirals. The accuracy achieved was 81% and 91% for Hand and NewHand respectively. Xu et al. [14] in their work made an attempt to early diagnosis of parkinson's disease in a patient using dimensionality reduction and a machine learning model. The NewHandPD dataset was used for this purpose. Firstly, the raw images are preprocessed and features are extracted using principal component analysis for dimensionality reduction. Then the sample data obtained is run through a Support vector machine model for classification. The accuracy achieved were 70.86% for meanders and 77.45% for spiral images. Pereira et al. [16] in their experiment used the NewHandPD dataset to detect PD at an early stage using various pre-trained CNN models

Taleb et al. [4] proposed CNN and the CNN-BiLSTM techniques for Parkinson's detection. The used dataset is a collection of handwriting, speech and eye movements. For the CNN model, time series are encoded into images as input. CNN model has achieved 83.33% accuracy and the CNN-BLSTM model achieved 97.62% accuracy.

III. Proposed Methodology

This study proposes two DL models for detecting Parkinson's disease from handwritten images and their time-series signals..

A. 2D CNN Model

CNN is a deep neural network technique mainly used for images. The main advantage of CNN models is their ability to learn and recognize important features of images without user instruction**.** The handwriting image (spiral, circle or meander) is the input to the CNN model. The input image is preprocessed using image preprocessing techniques like reshaping and normalizing pixel values and fed into the 2D CNN model. The CNN model has 3 convolutional layers, 2 max pooling layers, followed by a flattening layer and 2 dense layers. The output of the model is binary categorical value which is 0 for PD patients and 1 for healthy. The proposed CNN model is shown in Fig. 1.

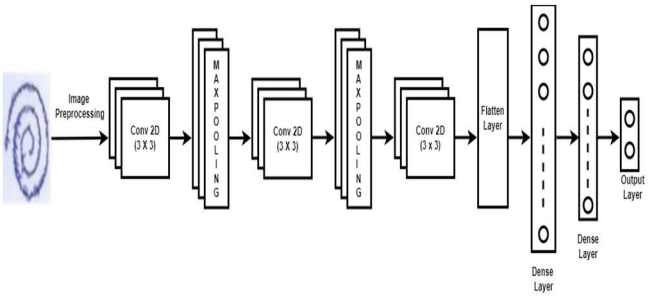

Fig.1 2D CNN Model

B. LSTM Model

LSTM is a DL technique used mainly for time series prediction. The input to the LSTM model is the time series signal corresponding to the hand drawings of spiral or meander. The input data is preprocessed and given to the LSTM. The proposed model has three LSTM layers followed by two dense layers. The output of the model is binary categorical which is 0 for patient and 1 for healthy. The proposed LSTM model is represented in Fig. 2.

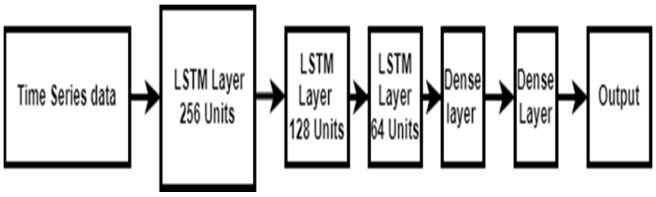

Fig.2 LSTM Model

IV. Implementation

The proposed models are implemented using Tensorflow and Keras.

A. Dataset Used

The NewHandPD dataset [15] was used to train and validate the proposed models. NewHandPD is an advanced version of HandPD dataset that comprises data of both Healthy individuals and Patients impacted by PD. The HandPD dataset contained only the handwritten drawings of the individuals as a content of the dataset. But the NewHandPD dataset contains not only the drawings but also their time series signals. This is captured by using a smart pen device which was used to draw these drawings and recorded the time series signals simultaneously. The time series data is an important classification basis for detection of PD because a person affected with PD will draw quite slower than a healthy person as PD affects the nervous system and shaking and trembling of the hands is a normal sign of the disease. The dataset was made by the São Paulo State University, Brazil. This dataset contains drawings of 66 people separated into two categories: Healthy and Patient. There are 35 healthy people and 31 PD patients. For every person, there are 9 pictures (4 spiral, 4 meander and 1 circle) and 12 signals (hand dynamics of 12 tests), which implies that both data can be used together to get more enlightening information about PD.For the proposed work the NewHandPD dataset is used to build two different models by utilizing the two different parts of the dataset. Fig. 3 shows the data sample of the dataset used.

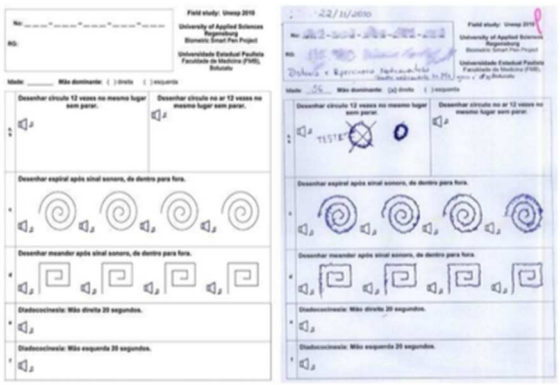

Fig. 3 Sample images (NewHandPD Dataset)

B. 2D CNN Model

The input to the proposed CNN model is the set of handwriting images. For that numpy array of the images are created. Then, each image is labeled as PD or Healthy. Another array of labels indicating the class type is also created. The images are reshaped in order to make them of the same size of 32x32. Then the data is shuffled and split into train and test data in the ratio of 75:25.

The 2D CNN sequential model is created using convolution, max pooling, dense and flatten layers. The size of the filter used is 3x3. The preprocessed image is passed through two convolution layers, each followed by Maxpooling. A filter of size 2x2 is used for Max Pooling. Two fully connected layers, sometimes known as dense layers, receive the output of the final convolution layer after it has been flattened. Activation function used is RELU. The model is fitted using 5 epochs and binary cross entropy. Also in the last dense layer sigmoid activation function is used since it is a binary classification problem.

C. LSTM Model

For creating the LSTM model, the dataset is converted into two numpy 1D arrays. One array is the input array of text files (time series) and the other numpy array is the output array consisting of integers 0(PD) and 1(healthy) as output. Then the time signals data is shuffled and split into train and test data in the ratio of 75:25. The LSTM sequential model is created with LSTM layers, dense layers and RELU activation functions. Cost function used is binary cross entropy and the optimizer is Adam and 10 epochs. Also, in the last dense layer sigmoid activation function is used as sigmoid values always range from 0 to 1.

D. Results

Four different experiments were conducted on the proposed models. Three experiments were conducted on the CNN model using three different types of images – circles, spirals and meanders. The fourth experiment was conducted on the proposed LSTM model on the time series of the drawings. The results of the experiments on the CNN model for circles, spirals, and meander images as well as the on the LSTM model are shown in Table 1.

TABLE I. RESULTS

Model	Data	Accuracy
2D CNN	Image (circles)	83.6%
2D CNN	Image (Spirals)	61.5%
2D CNN	Image (Meanders)	67.8%
LSTM	Time Series	78.7%

The proposed 2D CNN model implemented on NewHandPD dataset gives 83.6% of accuracy on circles image dataset, 61.5% of accuracy on spirals image dataset and 67.8% accuracy on meanders image dataset. The proposed LSTM model gives 78.7% of accuracy on the dataset composed of time series signals

V. Conclusion and Future Scope

This study suggests two deep learning models for detecting Parkinson's Disease using hand-drawn graphics. The suggested 2D CNN model is used on NewHandPD handwriting images and achieved an accuracy of 83.6%. Similarly, the LSTM model is implemented on NewHandPD time series signals and achieved an accuracy of 78.7%. In future, a hybrid model on images and time series can be created to get better accuracy.

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