Parkinson’s Disease Detection using SPECT Images and Artificial Neural Network for Classification

Nalini T S
Master of Technology
Dept.of Electronics & Instrumentation
Sri Jayachamarajendra College of Engineering

Anusha M U
Assistant professor
Dept.of Electronics & Instrumentation
Sri Jayachamarajendra College of Engineering

Umarani K
Associate professor
Dept.of Electronics & Instrumentation
Sri Jayachamarajendra College of Engineering

Abstract— Dopamine transporter (DAT) SPECT imaging is widely used for the diagnosis of Parkinson’s disease (PD) for effective patient management regarding follow up of the disease and therapy of the patient. The purpose of the study is early detection of Parkinson’s disease using image processing techniques and Artificial Neural Network (ANN). The data used here is 200 SPECT images of which 70 images are of PD and 130 of normal subjects, taken from the Parkinson’s Progression Marker’s Initiative (PPMI) database. The area of caudate and putamen region from the image is calculated using the sequential grass fire algorithm. These features are fed to Artificial Neural Network (ANN) to classify normal and Parkinson’s disease subjects. The best performance achieved in the study is 95% accuracy. Along with this the recovery state of the diseased person was also observed by increase in the caudate and putamen regions.

Keywords— Parkinson’s disease, artificial neural network to detect Parkinson’s disease, area values of region of interest (ROI), Parkinson’s progression.

I. INTRODUCTION

Parkinson’s disease (PD) affect dopamine producing neurons in a specific area of the human brain called substantia nigra. It is long term disorder of the central nervous system. PD causes symptoms such as tremor, cognitive impairment, rigid muscles, loss of automatic movement and sleep disorders etc. More than 10 million people in the world suffer from Parkinson’s disease. The main problem in detecting the disease is that, the visible symptoms appear mostly at the later stage where cure no longer becomes possible. Till now there is no correct reason proved for the cause of Parkinson’s disease. Reasons, like genetic mutation, vitamin D deficiency, lewy bodies containing abnormal protein in substantia nigra are common. Detection of Parkinson’s disease (PD) is very essential for effective treatment of the Parkinson’s disease and patient management. However, earlier to the motor symptoms or onset of tremor, the dopaminergic neurons begin to change. Some premotor symptoms of Parkinson’s disease at an early stage includes difficulty in moving, decreases sense of smell, disorder in Rapid Eye Movement (REM) sleep, small handwriting etc. An early detection of PD is essential to avoid unnecessary medical tests, therapies, safety risks, costly screening like, MRI, IMRI.

Choi H. et al. established deep convolutional neural network model in creating an automated FP-CIT SPECT interpretation model that can differentiate PD patients from patients with no clear signs of PD. For interpretation of these images, CNN or deep convolutional neural network was used which learn image features from each set of training data [3]. J. Jankovic work was to show that there is no particular test to detect Parkinson’s disease, the disease must be diagnosed based on clinical criteria such as rest tremor, bradykinesia and rigidity [4]. F. Skidmore and M. Yang. Et al. worked in resting fMRI as a biomarker and diagnostic tool in PD. We were able to distinguish subjects with PD from controls and identify a preclinical subject before developed motor signs and symptoms of PD but analysis is performed with subjects in the “off medication” state [5]. K. N. R. Challa et al. made an approach to the machine learning algorithm is used to improve non motor symptoms of Parkinson’s disease such as rapid eye movement in sleep behavior disorder and olfactory loss along with Cerebrospinal Fluid measurements to detect Parkinson’s at early stage [6] [17]. Prashanth R. et al. established the SPECT images of healthy normal, early Parkinson’s disease (PD) and Scans without evidence of dopaminergic deficit (SWEDD) carry out shape analysis and surface fitting to compute discriminatory features. Distinguishing SWEDD from PD patient is very important because most of the unnecessary SWEDD subjects received and inappropriate treatment, with huge side-effects, for many years [7][18].

In this paper a model for detecting Parkinson’s disease using image processing TECHNIQUES and artificial neural network (ANN) IS PROPOSED. The Convolutional neural network (CNN) scheme was developed to accomplish this task. As this approach directly learns from the images, no segmentation or feature extraction is needed [1]. T2 weighted Magnetic Resonance Imaging (MRI) are selected and aligned using image registration technique. The performance of the proposed technique is evaluated using accuracy, sensitivity, specificity and AUC (Area under Curve) [2]. Image processing technique is used to segment the area of caudate and putamen regions. Subjects suffering from PD have caudate and putamen regions smaller than the normal subject. The area of caudate and putamen is calculated and given as features to ANN to PD subjects from normal subjects. As the PD subject recovers it is observed that the caudate and putamen regions increases, else it decrease, this can be
taken as a criteria to keep a check on the progression of the PD patient.

II. PROPOSED METHODOLOGY

The proposed methodology is shown in “Fig. 1”, here the SPECT images are taken from PPMI database. The image is first pre-processed, and region of interest (ROI), the putamen and caudate region are segmented. The area segmented regions of caudate and putamen are calculated and fed to the artificial neural network (ANN) as features. The ANN is trained with the training set and thus the prediction model is ready and further used to classify the PD subjects from the normal subjects [16].

C. Classification of Parkinson’s disease using Artificial Neural Network

Artificial Neural Network is an information processing system that is inspired from biological neural networks in animal brains. With the extracted features, that is the area of Putamen and Caudate of left and right hemisphere of the brain, using artificial neural network a prediction model is trained, then using supervised training method, the model is trained for the given dataset.

\[ z = \sum (w * \text{input}) + b \]  
\[ s = \frac{\text{Area in pixels}}{6000} \]  
\[ s(g(z)) = \frac{1}{1 + e^{-z}} \]

The sigmoid curve of “Fig. 2,” shows that the function used to represent the prediction model \( z \), whose boundary is set is represented as prediction model it can be any number and if Parkinson’s disease larger the number and smaller the number when no Parkinson’s disease. Sigmoid function returns 0 for small numbers it indicates normal subjects, if sigmoid function returns 1 for large numbers it indicates Parkinson’s disease subjects.
The derivative function is,
\[
\frac{d}{dx}\text{sig}(z) = \text{sig}(z)\text{sig}(1 - \text{sig}(z))
\] (4)

Another reason for using sigmoid function is the simplicity in finding its derivative which is necessary for the learning function.

c) Costing function and training: The artificial neural network was trained on a known dataset using supervised training. The cost function determines the cost based on difference between found results and desired output. The learning is the determination of weights for processing elements and the optimizing weight based on the cost function. The cost function is defined as,
\[
C(w, b) = \sum(y(x) - t)^2
\] (5)

Above equation gives cost of individual neurons and used for guided output.

III. RESULTS

1. Image processing results

After preprocessing the SPECT images caudate and putamen edge are marked using automated method or manually. After detecting the edges the segmented area of ROI of caudate and putamen regions, the area of these regions is calculated. “Fig. 3,” and “Fig. 4,” shows some samples of SPECT images of segmented regions and their corresponding binary form of images and area values of binary images.

![Fig. 3](image1)

![Fig. 4](image2)

For more accurate detection of the SPECT images in the binary form of the caudate and putamen regions the variable threshold method is used. The area values of the ROI of segmented SPECT images for test subjects with Parkinson’s disease varied from 100-300000 pixels considering the left and right hemisphere together. For left hemisphere area ranged from 100-2000, and for right hemisphere area ranged from 1000-39000 pixels considering them individually. On the other hand, for healthy subject’s area values of the ROI varied from 40000-60000 pixels considering left and right hemisphere together, for left hemisphere area ranged from 40000-50000 for right hemisphere area ranged from 40000-60000 pixels considering them individually. The left and right area values calculated are stored for further use. The reduction in area shows, loss of dopamine transporter in putamen and caudate regions in case of Parkinson’s affected patients.

The “Fig. 5,” shows Parkinson’s disease progressive recovery stages which shows the increase in caudate and putamen areas of a PD subject.

![Fig. 5](image3)

Tables 1 and 2 shows results of the features extracted from SPECT images of normal and Parkinson’s disease subjects.

<p>| TABLE I. AREA OF LEFT AND RIGHT HEMISPHERE IN NORMAL SUBJETS |
|---------------------------------|-----------------|-----------------|-----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Patient ID</th>
<th>PD/Normal</th>
<th>Area Right</th>
<th>Area Left</th>
<th>Threshold Used</th>
<th>Slice Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>3004</td>
<td>N</td>
<td>46484</td>
<td>46933</td>
<td>0.75</td>
<td>40</td>
</tr>
<tr>
<td>3161</td>
<td>N</td>
<td>53810</td>
<td>52476</td>
<td>0.75</td>
<td>41</td>
</tr>
</tbody>
</table>

<p>| TABLE II. AREA OF LEFT AND RIGHT HEMISPHERE IN PARKINSON’S SUBJECTS |
|---------------------------------|-----------------|-----------------|-----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Patient ID</th>
<th>PD/Normal</th>
<th>Area Right</th>
<th>Area Left</th>
<th>Threshold Used</th>
<th>Slice Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>3018</td>
<td>P</td>
<td>9920</td>
<td>22931</td>
<td>0.80</td>
<td>39</td>
</tr>
<tr>
<td>3086</td>
<td>P</td>
<td>17031</td>
<td>7234</td>
<td>0.85</td>
<td>41</td>
</tr>
</tbody>
</table>

2. Results from artificial neural network

The features which are the area values of caudate and putamen of both left and right hemisphere of the brain from SPECT images are used train prediction model using artificial neural network. Then the test data is given to the trained
model. If the prediction values lies closer to 1 suggests PD and values closer to 0 suggests normal. Based on prediction values the subjects are allowed to their respective prediction region.

<table>
<thead>
<tr>
<th>PD/Normal</th>
<th>Area Right</th>
<th>Area Left</th>
<th>Scaled Right</th>
<th>Scaled Left</th>
<th>Prediction Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>463.74</td>
<td>444.09</td>
<td>0.71</td>
<td>0.68</td>
<td>0.003</td>
</tr>
<tr>
<td>P</td>
<td>274</td>
<td>253.38</td>
<td>0.004</td>
<td>0.38</td>
<td>0.999</td>
</tr>
</tbody>
</table>

**REFERENCES**


**IV. CONCLUSION**

Now a days Parkinson’s disease detection is gaining its important everywhere. Especially early diagnosis of PD is becoming more challenging, because it is a tremor disorders and this symptom may lead to misdiagnosis of the disease. This paper presents a classification model for detection of PD, which helps the doctors for an easy and quick diagnosis. The features taken for the study are, area values of region of interest (ROI) of caudate and putamen region, extracted using image processing techniques.

These features given to a predictive artificial neural network (ANN) model classifies the normal and Parkinson’s disease subjects with good prediction values. Along with identification of Parkinson’s disease subjects, the progressive stages of the recovering subjects has also been performed. Thus, it can be concluded that this method takes very less time with the use of simple artificial neural network leading to reduction in the number of lengthy clinical tests and doctor’s time. Future research considers more dataset along with features extracted from the SPECT images to give even more reliable accuracy.

**V. ACKNOWLEDGMENT**

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