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
Associat 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, fMRI.

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-precessed, 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].

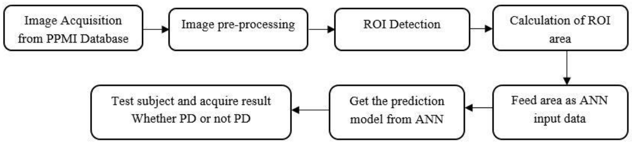

Fig. 1. Flowchart of the analysis carried out.

A. *Image acquisition*

The data is selected from PPMI database for the study, used to evaluate groups of people suffering from PD using advance imaging techniques to identify the biomarkers for better treatment of PD. United states, Europe, Australia, and Israel are the clinical sites. 200 DAT scan SPECT images from the database are taken for the study which contain both normal and PD subject images. The PD patients of SPECT images at prodromal stage and early visited were used to detect PD at early stage.

B. *Feature extraction*

The SPECT images available in the PPMI database are preprocessed and normalized data. Each SPECT scan in the database consists of 91 axial slices scanned from top to bottom of the head region. The range of slices: 38-43, (in most cases 40th axial slice) has been selected for the study as the ROI is more visible in these slices. The SPECT images are sharpened using unsharp masking keeping the standard deviation of Gaussian filter as 7. Then segmentation using adaptive thresholding is applied on the image to segment the caudate and putamen region, with active contour and Sequential Grass-Fire algorithm. As the background is not relatively uniform and has a large variation in the intensity, the adaptive dynamic thresholding technique is applied on the image keeping the binarization value between 0.7 to 0.8 for effective edge detection. Then the weighted mean of the neighborhood minus offset value for every threshold value is considered. As a result, it extract both putamen and caudate regions in binary form. Next, for noise cancelation, adaptive median filtering method is used as it has the advantage of not eroding the edges or other small structure in the image and also filters and smoothens the data while keeping the small and sharp details intact.

Active contour technique is used to select the boundary information by extracting the curvature extrema and arcs of constant curvature, thus permitting to extract a Euclidean skeleton representation of the region, hence, bypassing many discretization problems which is usually found in other skeletisation algorithms. Next, to detect the connected neighbor pixels, the sequential grass fire algorithm is applied. This algorithm starts the scanning from top left to complete it at the bottom right edge. It searches for the non-zero pixels, once found, it labels the object of the output as 1 and in the corresponding input image sets the same pixel as 0. Then further, the search is continued on the neighboring four to eight pixels if they connected to the present pixel and decides if it as an object pixel. Now, the extracted boundary pixels of both left and right caudate values are changed to its RGB color like (255, 0, 0: red), and the boundaries are marked for visualization. To find the area inside the bounded region, heuristic graph search algorithm is used. The connected pixels are summed as area and stored for further analysis.

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.

a) Data for prediction model : The features used for the prediction model is the area of putamen and caudate of both left and right regions of hemisphere of the brain that is found after processing SPECT images. For easy and faster calculation the area is scaled in pixel rangeing from 0-10 units. s is scaling factor of data,

$$s = \frac{\text{Area in pixels}}{6000} \quad (1)$$

b) Choosing activation function : The neural network model simply represented as,

$$z = \sum(w * \text{input}) + b \quad (2)$$

Sigmoid function is used as a activation function. This is what makes artificial neural network a simple sigmoid perceptron. The sigmoid function is,

$$sig(z) = \frac{1}{1 + e^{-z}} \quad (3)$$

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 (z) returns 0 for small numbers it indicates normal subjects, if sigmoid (z) returns 1 for large numbers it indicates Parkinson's disease subjects.

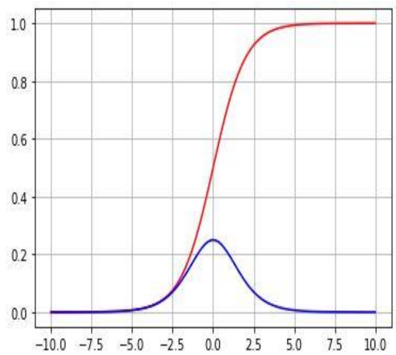

Fig. 2. Sigmoid curve and differential of sigmoid curve.

The derivative function is,

$$\frac{d}{dz}sig(z) = sig(z)sig(1 - sig(z)) \quad (4)$$

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,

$$C(w,b) = \sum(y(x) - t)^2 \quad (5)$$

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.

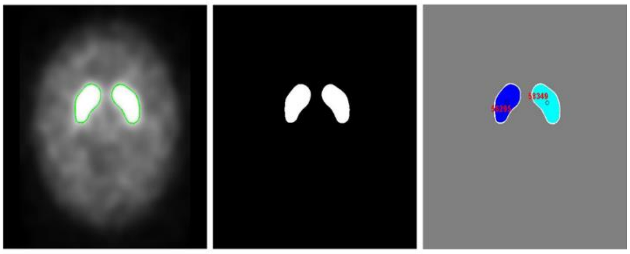

Fig. 3. (left image) Region of interest (ROI) detected, (middle image) corresponding binary image of normal subject and (right image) area of ROI.

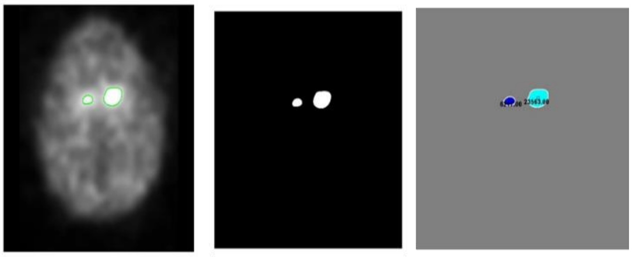

Fig. 4. (left image) Region of interest (ROI) detected, (middle image) corresponding binary image of Parkinson’s disease subject and (right image) area of ROI.

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 100-30000 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.

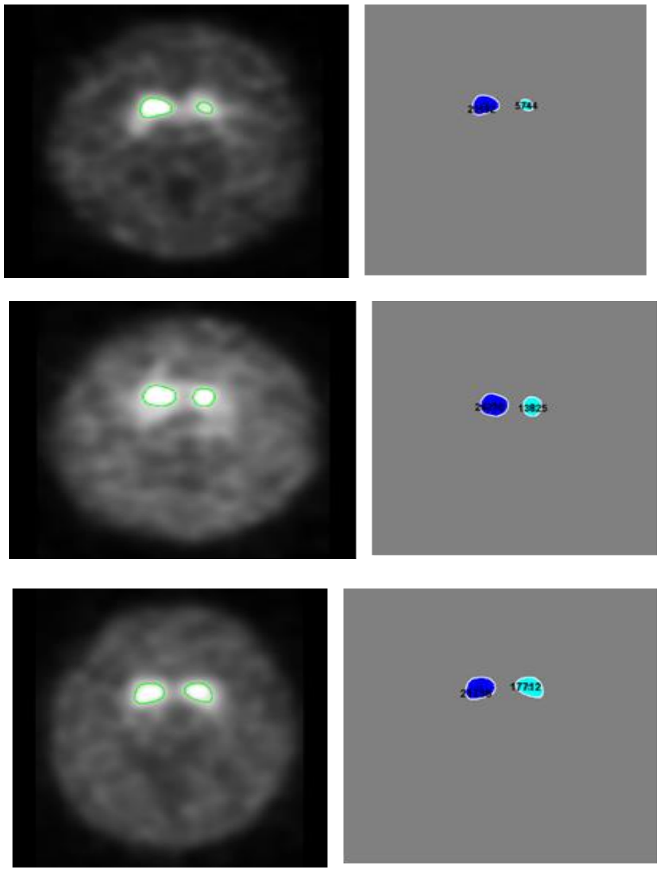

Fig. 5. Stages of PD subject progression.

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

TABLE I. AREA OF LEFT AND RIGHT HEMISPHERE IN NORMAL SUBJECTS

Patient ID	**PD/Normal**	**Area Right**	**Area Left**	**Threshold Used**	**Slice Used**
3004	N	46484	46933	0.75	40
3161	N	53810	52476	0.75	41

TABLE II. AREA OF LEFT AND RIGHT HEMISPHERE IN PARKINSON’S SUBJECTS

Patient ID	**PD/Normal**	**Area Right**	**Area Left**	**Threshold Used**	**Slice Used**
3018	P	9920	22931	0.80	39
3086	P	17031	7234	0.85	41

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 closerr 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 3. ARTIFICIAL NEURAL NETWORK OUTPUT OF SAMPLED DATA

PD/Normal	Area Right	Area Left	Scaled Right	Scaled Left	Prediction Value
N	46374	44609	0.71	0.68	0.003
P	274	25338	0.004	0.38	0.999

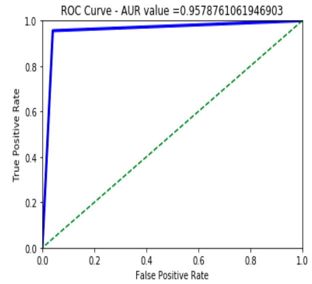

Fig.6. Shows Area under Curve (AUR) these are prediction output of artificial neural network.

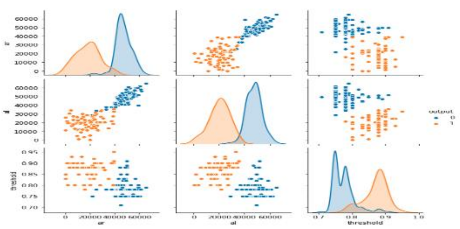

Fig.7. Plot of normal and PD subject's area right (ar), area left (al) and value of threshold used in ANN model. Blue represents normal subjects (0) and orange represents PD subjects (1).

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

The authors sincerely thank PPMI – a public private partnership-which is funded by the Michael J. Fox Foundation for Parkinson's research and funding partners.

REFERENCES

[1] M. P. Adams,B. Yang, A.Rahmim,J. Tang, "Prediction of outcome in Parkinson's disease patients from DAT SPECT images using a convolutional neural network," Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC), vol. 18.pp. 10-17,Nov.2018.

[2] P. M. Shah, A.zeb, U.Shafi, S. F. A.Zaidi, M. A. shah, "Detection of Parkinson Disease in Brain MRI using Convolutional Neural Network," Inventive ComputationTechnologies (ICICT), International Conference on,vol. 80 ,pp. 368-373, 2018.

[3] H. Choi, S. Ha, H. Im, S. Paek and D. Lee, "Refining diagnosis of Parkinson's disease with deep learning-based interpretation of dopamine transporter imaging", NeuroImage: Clinical, vol. 16, pp. 586-594, 2017.

[4] J.Jankovic, "Parkinson's disease: clinical features anddiagnosis," J.Neurol. Neurosurg.Psychiatry , vol. 79, pp.368-376, 2017.

[5] F. Skidmore, M. Yang, L. Baxter, K. V. Deneen, J.Collingwood, G. He, K. White, D. Korenkevych, A. Savenkov,K. Heilman, M. Gold, and Y. Liu, "Reliability analysis of the resting state can sensitively and specifically identify the presence of Parkinson disease," NeuroImage, vol. 75, pp. 249–261, 2013.

[6] K. N. R. Challa, V.S. Pagolu, G. Panda, "An Improved Approach for Prediction of Parkinson's Disease using Machine Learning Techniques,".International conference,vol. 16.pp. 1446–1451, 2016.

[7] R. Prashanth, S. D. Roy, P.K. Mandal, S. Ghosh, "High Accuracy Classification of Parkinson's Disease through Shape Analysis and Surface Fitting in 123I-Ioflupane SPECT Imaging," Journal Article,vol. 21,pp.794 – 802, 2015.

[8] R. Prashanth, S.D. Roy, P. K. Mandal, S. Ghosh, "Automatic classification and prediction models for early Parkinson's disease diagnosis from SPECT imaging,".Expert systems with Applications, vol. 41.pp. 3333-3342, 2014.

[9] F. Skidmore, M. Yang, L. Baxter, K. V. Deneen, J.Collingwood, G. He, K. White, D. Korenkevych, A. Savenkov,K. Heilman, M. Gold, and Y. Liu, "Reliability analysis of the resting state can sensitively and specifically identify the presence of Parkinson disease," NeuroImage, vol. 75, pp. 249–261, 2013.

[10] D. Surangsrirat and C.Thanawattano, "Android Application for Spiral Analysis in Parkinson's Disease," Conference paper, vol. 79, pp. 368-376, 2012.

[11] F. Oliveira, D. Faria, D. Costa, M. Castelo-Branco and J. Tavares, "Extraction, selection and comparison of features for an effective automated computer-aided diagnosis of Parkinson's disease based on [123I]FP-CIT SPECT images", European Journal of Nuclear Medicine and Molecular Imaging, 2017.

[12] J. Bobin, J. L. Starck, J. M. Fadili, Y. Moudden and D. L.Donoho, "Morphological Component Analysis: An adaptive thresholding strategy," in IEEE Transactions on Image Processing, vol. 16, no. 11, pp. 2675-2681, Nov. 2007.

[13] A. Polesel, G. Ramponi, and V. Mathews, "Adaptive unsharp masking for contrast enhancement," Proceedings of International Conference on Image Processing, vol. 9, no. 3, pp.505–510, Mar. 2000.

[14] F. Leymarie and M. Levine, "Simulating the grassfire transform using an active contour model", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 14, no. 1, pp. 56-75,1992.

[15] A. Polesel, G. Ramponi, and V. Mathews, "Adaptive unsharp masking for contrast enhancement," Proceedings of International Conference on Image Processing, vol. 9, no. 3, pp. 505–510, Mar. 2000.

[16] K.Uma Rani and Mallikarjun S Holi, "Automatic detection of neurological disordered voices using mel cepstral coefficients and neural networks" Proceedings IEEE Point-of-Care Healthcare Technologies(PHT),pp.76-79,Januray.2013.

[17] Parameshachari B D et. al "Epileptic Seizure Detection Using Machine Learning"1st International Conference on Emerging Trends in Engineering, Innovative Science and Management (ICETEISM-2019) organized by East West Institute of technology, Bengaluru in association with TIE on 18th May 2019.

[18] Prabu, S., M. Lakshmanan, and V. Noor Mohammed. "A multimodal authentication for biometric recognition system using intelligent hybrid fusion techniques." Journal of medical systems 43.8 (2019): 249.