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PCNN - Firefly Based Segmentation and Analysis of Brain MRI

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Abstract- In this proposed method**,** the segmentation of brain Magnetic Resonance Images (MRI) has been carried out using Pulse Coupled Neural network (PCNN) and classification by Back Propogation Neural Network (BPNN) techniques. The proposed method includes five stages pre-processing, clustering, feature extraction, feature selection and classification. For extracting the features Non Sub-sampled Contourlet Transform (NSCT) method has been used. For feature selection optimized Fire-fly intelligence has been preferred. Finally, the selected features are given to BPNN to identify the input data either as normal or abnormal. The performance of the classifier was evaluated in terms of True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN) and the accuracy was found to be good.

Keywords**:** PCNN, NSCT, Feature extraction, feature selection. Fire-fly, MR Brain Image.

I. INTRODUCTION

Selvaraj and Dhanasekaran (2013) reviewed on tissue segmentation and feature extraction of MR Brain images. In their literature various current methodologies with advantages and dis-advantages have been discussed [1]. Iztok Fister *et al* (2013**)** carried out a comprehensive review of the evolving discipline of Swarm Intelligence, in order to show that the Fire-Fly algorithm could be applied to every problem arising in practice [2]. It encourages new researchers and algorithm developers to use this simple and yet very efficient algorithm for problem solving. It often guarantees that the obtained results will meet the expectations. Susana M.Vieira *et al*. (2013) explained a Modified Binary Particle Swarm Optimization (MBPSO) method for feature selection with the simultaneous optimization of SVM Kernel parameter setting and this approach is applied to predict the outcome of patients with septic shock [3].

Ashish Kumar Bhandari *et al.* **(**2014) employed two successful swarm-intelligence-based global optimization algorithms, Cuckoo Search (CS) algorithm and Wind Driven Optimization (WDO) for multilevel thresholding using Kapur's entropy [4]. Amita Kumari and Rajesh Mehra (2014) surveyed that the methodology in medical field consists of 4 steps: image processing, image enhancement, feature extraction and image classification. Image pre-processing is done with the help different gradient operator. Image enhancement step uses the noise removal and histogram equalization [5]. Wavelet based texture feature are extracted from normal and tumor regions. At last optimization was done with the help of PSO and SVM classifier. Abdenour Mekhmoukh and Karim Mokrani (2015) initialized a new image segmentation method based on Particle Swarm Optimization (PSO) and outlier rejection combined with a level set approach [6].

Nguyen Cong Long *et al.* (2015) computed a heart disease diagnosis system using rough sets based attribute reduction and Interval Type-2 Fuzzy Logic System (IT2FLS) [7]. The integration between rough sets based attribute reduction and IT2FLS aims to handle with high-dimensional dataset challenge and uncertainties. IT2FLS utilizes a hybrid learning process comprising Fuzzy C-Means clustering algorithm and parameters tuning by Chaos Fire-Fly and Genetic Hybrid algorithms. This learning process is computationally expensive, especially when employed with a high - dimensional dataset. But, in this proposed method fire-fly based optimization technique has been preferred, due to its fast convergence property.

II. PROPOSED METHODLOGY

In this proposed method, the input images are pre-processed by median filter then converted into gray scale and Pulse Coupled Neural Network (PCNN) based segmentation technique has been applied to separate the three tissues of brain. The Non Sub- sampled Contourlet Transform (NSCT) has been used to extract the features and the outcomes are optimized using Fire-Fly swarm intelligence then Back Propogation Neural Network (BPNN) approach was used to classify the output either as normal or abnormal. The following flowchart (figure 1.) represents the proceeding steps for the proposed methodology.

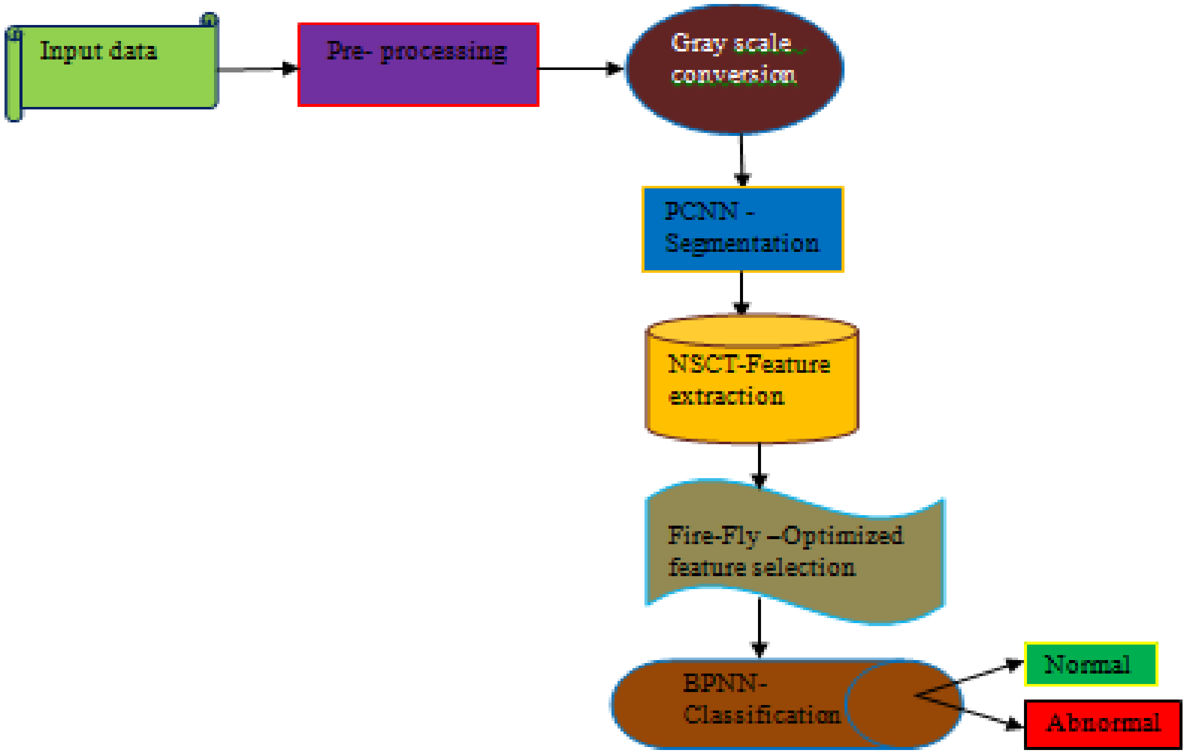

Fig. 1 Schematic diagram of the proposed methodology.

III. SEGMENTING PROCESS

Kuntimad and Ranganath (1999) explained that PCNN is a simplest form of neural network having a single layer with two dimensional array of laterally linked pulse coupled neurons [8]. The number of neurons in the network is equal to the number of pixels in the given image. Liu Xiao fang *et al.* (2008) explained about the architecture of this neuron model [9]. The Pulse Coupled Neuron model has three fields - Receptor field, Modulation field and an Output field.

A. Pulse coupled neural network technique (pcnn)

The Receptor field has two channels L-Linking channel and F- Feeding channel. The Feeding channel is fed directly from an external source, which is the image pixel intensity connected to the neuron. The Linking channel is fed by other neurons called neighbouring neurons to the Feeding channel neuron. The total number of input neurons will be the same as the total number of image pixel intensities. There is one-to– one correspondence between the input neurons and the image pixels. Jhon L. Johnson and Mary Lou Padgett (1999) narrate the working of such neuron in PCNN well. Each neuron is linked with its neighbouring neurons by linking strength (β) [10].

The equation for Feeding channel is given by,

$$F_{ij}(n) = e^{-\alpha_F} F_{ij}(n-1) + S_{ij} + V_F \sum_{kl} M_{ijkl} Y_{kl}(n-1) \quad (1)$$

The equation for Linking channel is framed as,

$$L_{ij}(n) = e^{-\alpha_L} L_{ij}(n-1) + V_L \sum_{kl} W_{ijkl} Y_{kl}(n-1) \quad (2)$$

The activation function equation has been written as,

$$U_{ij}(n) = F_{ij}(n)(1 + \beta L_{ij}(n)) \quad (3)$$

The equation for threshold is given as,

$$\theta_{ij}(n) = e^{-\alpha_\theta}\theta_{ij}(n-1) + V_\theta Y_{ij}(n-1) \quad (4)$$

The output equation is,

$$Y_{ij}(n) = \begin{cases} 1 & U_{ij}(n) > \theta_{ij}(n) \\ 0 & U_{ij}(n) \le \theta_{ij}(n) \end{cases} \quad (5)$$

Where, M_{ijkl}, W_{ijkl} are weighing factors, α_F, α_L, α_θ are weakened (decaying) time constants, V_F, V_L, V_θ are inherent electric potential. 'F_{ij}' is Feeding input, 'L_{ij}' is Linking input, 'U_{ij} 'internal activation function, 'θ' is threshold signal, 'β' is the linking strength and 'n' is the total number of iterations. B.Thamaraichelvi *et.al*. (2014). The parameters are tuned to the values of n=20, A_F =0. 001, A_θ =0. 2, V_F = 0.01, V_L = 1.00, V_θ = 20, β = 3, α_F = 0.001, α_L = 1.00, α_θ = 0.2. Fig.2 depicts the constructional details of PCNN model [11].

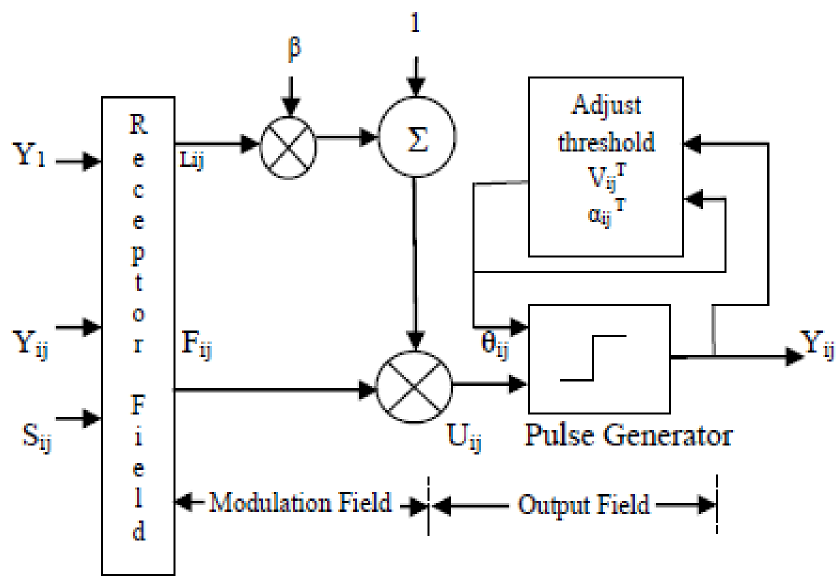

Fig. 2 PCNN Model

B. Pcnn proceeding steps

1. The parameters of the pulse coupled neural network are initialized.
2. The total number of iterations n_{max} =20.
3. For each iteration, the parameters of the equations 1-5 are calculated and made n=n+1.
4. If n < n_{max} step 3 was repeated. Finally, the output y_{ij} was estimated.

Since, it is the simplest form of neural network, which can be used for the segmentation process, is also included for this analysis.

IV. NSCT TECHNIQUE

Contourlet Transform in general is not a shift invariant. In order to overcome the drawback of contourlet transform NSCT has been introduced. To remain the multiscale properties of the images the non-sub sampled pyramid structure replaces the Laplacian pyramid in contourlet. He Xiaolan, Wu Yili (2013) analyzed that the directional information are captured by the Non-sub Sampled directional filters [12]. The structure of NSCT is divided into Non- sub Sampled Pyramid Filter Bank (NSPFB) and Non-sub Sampled Directional Filter Bank (NSDFB). Fig. 3 explains the decomposition process of NSCT.

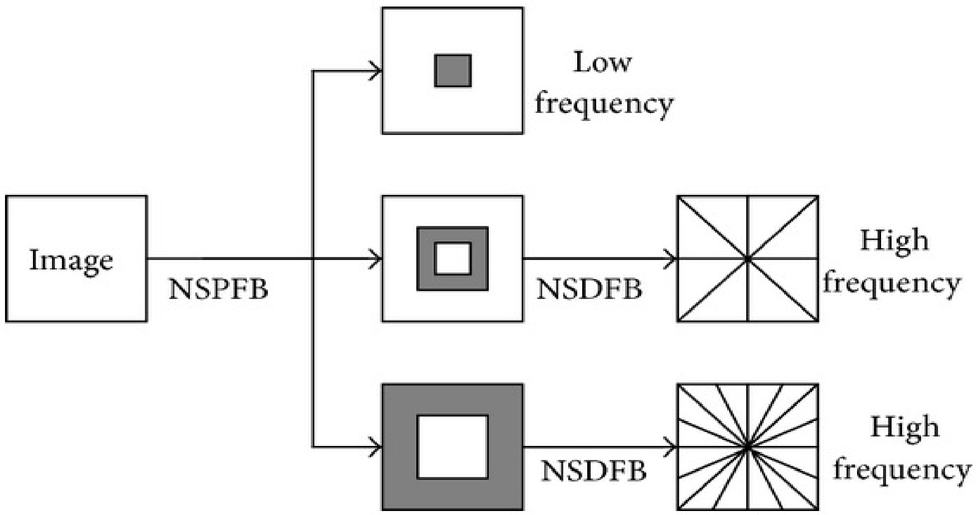

Fig. 3 Decomposition of Image using NSCT

VI. FIRE-FLY (FF) METHOD

The Fire-Fly algorithm is one of the important tools in swarm intelligence and utilized successfully in the area of optimization. It is a meta-heuristics algorithm and developed by Xin-She-Yang. It is inspired by the behavior of Fire-Flies. In general, the Fire-Flies produce a 'cold light' with no infrared or ultraviolet frequencies. The light intensity of each Fire-Fly is proportional to the quality of solution and each Fire-Fly needs to move towards the brighter Fire-Flies. Xin-She Yang (2014) narrates that the movement depends on balancing between two major components: Exploration and Exploitation [13]. Exploration is the process of discovering the diverse solutions within the search space [14]. Exploitation means focusing the search process towards the best solution, thus exploiting the information found so far [15].

Iztok Fister *et al*. (2013) made the assumptions as,

1. All the Fire- Flies are unisex.
2. Brightness is determined by the Objective function.
3. Attractiveness is proportional to the brightness and inversely proportional to distance.

The movement of Fire-Fly 'i' is attracted towards another more attractive (brighter) Fire-Fly 'j' is determined as follows,

- **Movement**

$$x_i^{k+1} = x_i + \beta_0 e^{-\gamma r_{ij}^2}(x_j - x_i) + \alpha(rand - 0.5) \quad (6)$$

Where $\beta = 0.2$, α = 2.

r – Distance between any two Fire-Flies.

β_0 – Attractiveness at r = 0.

γ – Fixed light absorption co-efficient. (γ = 0, in the absolute clear air, γ = ∞, in foggy air.)

- **Distance (r)**

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \quad (7)$$

d – no. of dimensions.

VII. RESULT AND DISCUSSIONS

The selected image is of size "512x512" and thickness "1" mm in each. The images are pre-processed with the help of median filter. A kernel of size '3x3' has been preferred and applied over the entire image to collect the details about the neighbour-hood pixels. In segmentation, three intensity levels are created for the brain tissues like GM, WM and CSF respectively. The accuracy of the segmentation was evaluated based on the terms TP,TN,FP,FN. The following figure depicts the outcome of the application of PCNN clustering. Fig. 4(i) shows the real input images, fig. 4(ii) depicts the median filtered images and fig. 4(iii) reveals the outcome of PCNN approach. Table 1. gives the quantitative evaluation of the proposed clustering technique for normal brain images. Fig. 5(i) shows the real input images, fig. 5(ii) gives the outcome of median filtering process and fig.5 (iii) clearly represents the outcome of the preferred clustering for abnormal images. Table 2 gives the evaluation of the selected clustering technique for abnormal MR images. Fig.6 narrates the interpretation of input features on the basis of time for FF algorithm. Fire-Fly algorithm often converges quickly. It takes only 0.055 milliseconds to optimize the incoming feature set.

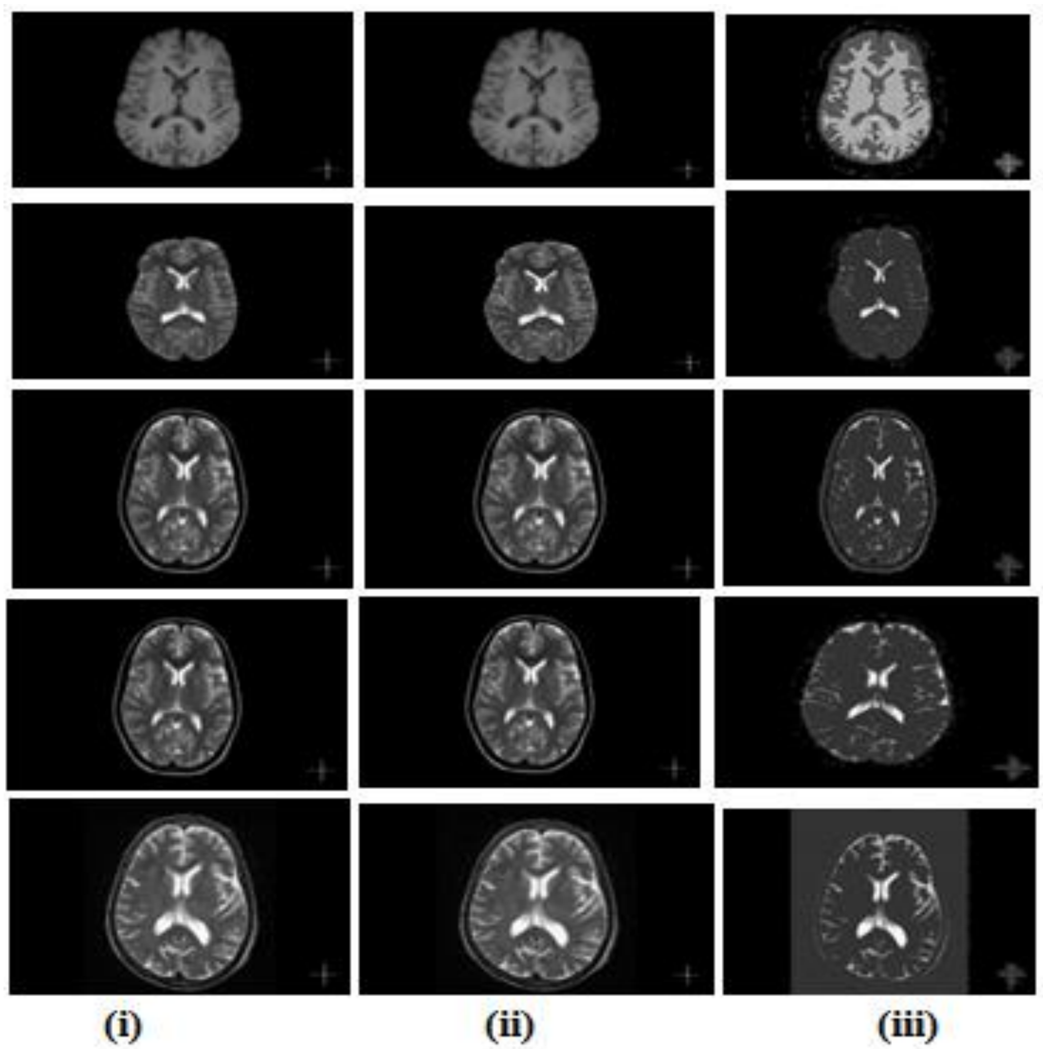

Fig. 4 Normal MR Brain Image Analysis using PCNN. (i) Five Real Input Images (ii) Median Filtered Images (iii) Segmented Images.

Table 1 Quantitaive Evaluation for Normal MR Brain Images (iii) PCNN Technique

Images	Sensitivity %	Specificity %	Accuracy %	Similarity	MCR %
1	94.86	92.56	93.86	0.71711	6.14
2	90.28	89.55	88.52	0.5441	11.48
3	94.2	91.63	90.48	0.6112	9.52
4	92.56	91.24	92.62	0.6954	7.38
5	91.14	89.26	89.24	0.43229	10.76

Table 2 Quantitaive Evaluation for Abnormal MR Brain Images (iii) PCNN Technique

Images	Sensitivity %	Specificity %	Accuracy %	Similarity	MCR %
1	96.25	94.23	95.55	0.5521	4.45
2	98.45	96.24	97.59	0.62554	2.41
3	99.04	97.56	98.02	0.7854	1.98
4	99.28	97.65	97.53	0.6992	2.47
5	94.65	90.54	91.89	0.4871	8.11

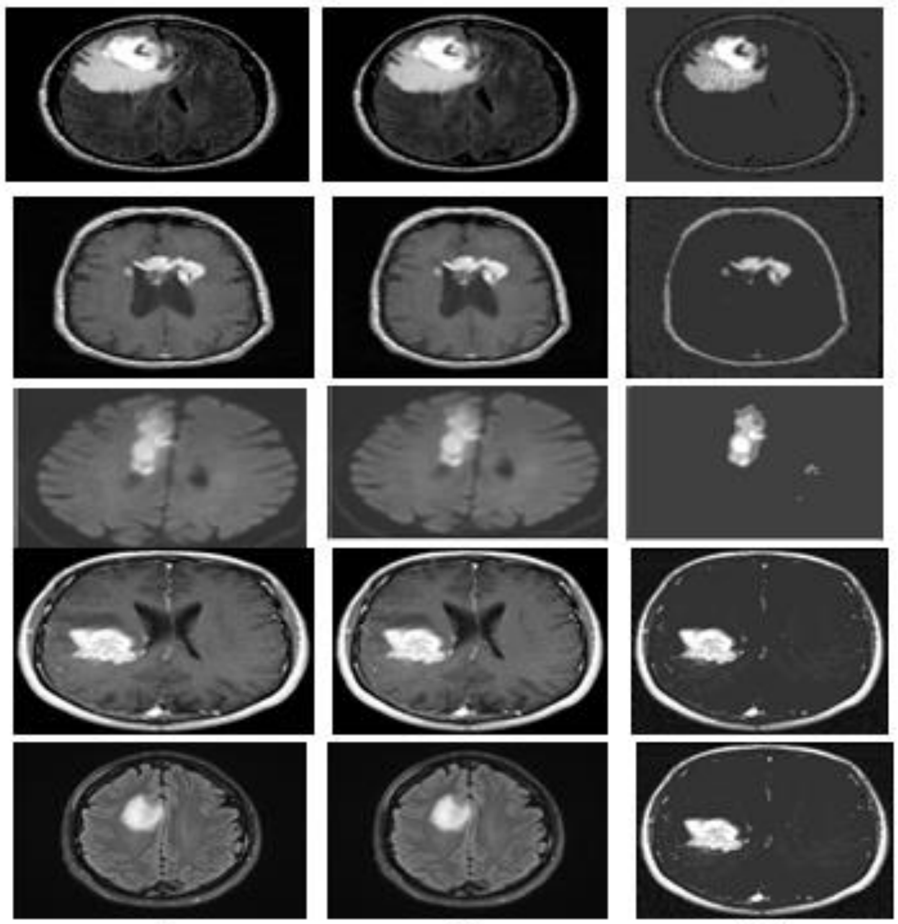

Fig. 5 Abormal MR Brain Image Analysis using PCNN. (i) Five Real Input Images (ii) Median Filtered Images (iii) Segmented Images.

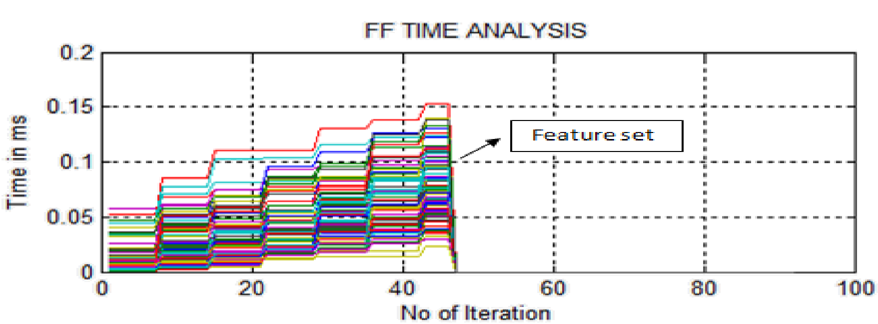

Fig. 6 Feature Selection set for FF.

then the optimized features from the Fire-fly process are given to the Feed-forward Back-propogation Neural network classifier to classify the input data either normal or abnormal. The classifier accuracy was calculated through selectivity and sensitivity and it was found to be good.

VIII. CONCLUSION

This method summarizes the concepts of PCNN based segmentation of MR brain images along with the process of feature extraction through NSCT, feature selection by optimized Fire-fly algorithm and classification using BPNN techniques. The outcomes of each process were discussed well and the accuracy of segmentation and classification were found to be good when compared with other processes. The future work is to analyse the process of BPNN classification and comparison with other existing methods.

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