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Handwritten Image Analysis to Identify Parkinson Disease using Fuzzy C-means, GLCM and ANFIS Classification

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Abstract: This study proposes a method to identify Parkinson disease classifying patients as normal or abnormal using the latest machine learning algorithms. The image is acquired, converted to gray scale, preprocessed using Wiener filter. Canny edge detection method is used which involves image smoothing, gradient operation, non maxima suppression, hysteresis thresholding and connectivity analysis. Then image is segmented using fuzzy C-means. Features are extracted using GLCM technique and ANFIS classification is used to classify patients as normal or abnormal. Experimental results proves that patients suffering from neurological disease can be effectively detected using this method. A total of 167 spiral images were used out of which 56 were normal patient and 111 were abnormal collected from various sources. A classification accuracy of 99% is achieved.

Key words: Archimedian spiral, deblurring, Wiener, GLCM, substantia nigra, technique

INTRODUCTION

Parkinson's Disease (PD) is the largest neurodegenerative disorder next to Alzheimer's disease. PD occurs when the neurons in an area of the brain called as the substantia nigra weaken or die. Dopamine, a chemical supposed to be produced by these dying neurons sends messages to the part of the brain that controls movement and coordination. Nearly 1 billion people worldwide are living with neurological disorders. Doctors diagnose 60,000 new cases each year. An estimated 6.8 million people lose their life due to neurological disorder (Anonymous, 2007). PD onset begins as early as before 50 years though the average age is 60 years. Men are one and a half times more likely to have Parkinson's than women.

Clinical Decision Support System (CDSS) for medical applications emerged as a result of recent developments in the field of machine learning and artificial intelligence. Classification systems increases accuracy and reliability of diagnoses minimizing errors and making efficient diagnosis. The idea of this study is to classify the patients as normal and Parkinson thereby helping the doctors in decision making.

MATERIALS AND METHODS

Spiral drawing is a widely used clinical tool in assessment of tremor (Aguilar *et al*., 2008). Handwritten spirals have been used clinically to evaluate movement disorders and specifically have been applied to study writing speed and tremor subjectively. Spiral analysis thus may be used an objective method of evaluating Parkinson disease severity, extracting detailed motor features from the standard clinical spiral drawing task (Saunders-Pullman *et al*., 2008). Hence, dataset consists of Archimedean spiral drawn by parkinsonian and healthy patients. A empty paper template containing printed lines and square box along with Archimedean spiral is used. Individuals are asked to trace the Archimedean spiral. Patients suffering from neurological disease display lot of jerks in the image.

Following are the steps that needs to be carried out for recognition of Parkinson's disease:

- Image acquisition
- Pre-processing of the uploaded image
- Segmentation
- Features extraction from processed image
- Classification and recognition

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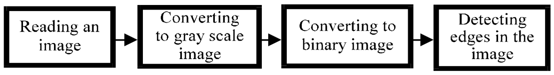

Fig. 1: Preprocessing steps

Image acquisition: The spirals drawn by the individuals are acquired and saved as bitmap image (Fig. 1).

Preprocessing of the uploaded image: Image processing deals with conversion of image to digital form to either enhance the image or extract valuable information from it. Pre-processing input image is a small area of a pixel which produces new brightness value in the output image. Thus, it improves the image data by enhancing the brightness and other image features of individual pixel image and suppressing unwanted distortions for further processing and analysis task.

The image is read first into the workspace. Then, it is converted to gray scale. Wiener filter is used for analysis of image for effective deblurring of image and reducing noise. Now, the edges are detected using canny method. Canny edge detection is a complex and multistage algorithm to detect wide range of edge in image. Canny edge detection is widely used as it gives low error rate, single edge point response and localization of edge point.

Reading an image: The image is first read into the workspace. Some irrelevant parts of the image are removed and the image region of interest is focused.

Converting to gray scale image: The image is converted to gray scale. A gray-scale image contains only two level of significant information: the foreground level which contains objects of interest and the background level against which the foreground is discriminated.

Image denoising: A statistical approach for removal of blur in images due to linear motion is the Wiener filter. The Wiener filteris a filter that produces a desired random process by Llinear Time-Invariant (LTI) filtering of an observed noisy process, assuming knownstationarysignal (non-adaptive filter) and noise spectra and additive noise. The Wiener filter minimizes the mean square error between the estimated random proces and the desired process. So, it is called minimum mean square error approach or Wiener filtering approach.

If the original image is f and reconstructed image is $\hat{f}$ then the Wiener filter minimizes the error function e which is the difference between expectation value of f and $\hat{f}$ square where f is the original degraded image and f is the restored image from the degraded image. So, f minus $\hat{f}$ square gives the square error and this wiener filtering tries to minimize the expectation value of this error. A Wiener filter minimizes the least square error:

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left(f(x, y)-\hat{f}(x, y)\right)^2 dxdy$$

$$F(u, v) = W(u, v)\, G(u, v)$$

Where:
F(u, v) = The restored image
G(u, v) = The received image
W(u, v) = The wiener filter

Restored signal is an image and the difference between restored and degraded is considered as the noise.

The Wiener filtering minimizes the overall mean square error in the process of inverse filtering and noise smoothing. The Wiener filtering is a linear estimation of the original image:

$$e^2 = E\left[f\text{-}\hat{f}\right]$$

The Wiener filtering executes an optimal tradeoff between inverse filtering and noise smoothing by removing the additive noise and inverting the blurring simultaneously.

Edge detection: An edge is an abrupt change in intensity of pixel or discontinuity in image brightness or contrast which occurs on boundary between two different regions in an image. Edges store a lot of information about underlying objects in the scene. Edge detectors are used in binary images to locate changes in brightness function using local image pre-processing methods. Processing is reduced by considering only the edge elements instead of all pixels. Edge detection is mainly used for feature extraction and detection. Important features like corner, curve and line are detected. Edge detection is based on 2 properties similarity and discontinuity. The four steps of edge detection are:

- Smoothing: to suppress as much noise as possible, without destroying the true edges
- Enhancement: to apply a filter to enhance the quality of the edges in the image (sharpening)
- Detection: to determine which edge pixels should be discarded as noise and which should be retained
- Localization: to determine the exact location of an edge. Edge thinning and linking are used

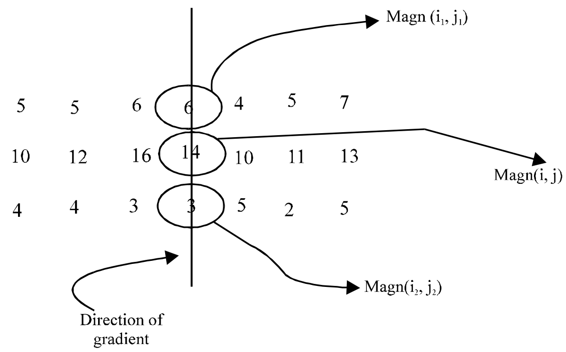

Fig. 2 : Non-maxima suppression

Different edge detection such as classical Gradient edge detection like Sobel, Prewitt, Kirsch, Robinson, Guassian based filter like canny edge detection filter, Marr Hildreth filter, Wavelet filter, fuzzy logic are used. Canny edge detection is widely used (Ding and Goshtasby, 2001). Canny has shown that the first derivative of the Gaussian closely approximates the operator that optimizes the product of signal-to-noise ratio and localization. His analysis is based on “step-edges” corrupted by “additive Gaussian noise”. It is a complex and multistage algorithm. The stages are:

- Image smoothing
- Gradient operation
- Non maxima suppression
- Hysteresis thresholding
- Connectivity analysis

Smoothingaims to suppress noise or other small fluctuations in the image. The aim of gradient operators is to indicate such locations in the image where the image function undergoes rapid changes. In non-maxima suppression, to find the edge points, we need to find the local maxima of the gradient magnitude. Broad ridges must be thinned, so that, only the magnitudes at the points of greatest local change remain. All values along the direction of the gradient that are not peak values of a ridge are suppressed (Fig. 2).

Algorithm 1:

For each pixel (x, y) do:
if magn (i, j)<magn (i_1, j_1) or magn (i, j)<magn (i_2, j_2)
else I_N(i1, j) = magn (i, j)

In hysteresis thresholding/edge linking, the output of non-maxima suppression still contains the local maxima created by noise. If we set a low threshold, some noisy maxima will be accepted too. If we set a high threshold, true maxima might be missed (the value of true maxima will fluctuate above and below the threshold, fragmenting the edge). A more effective scheme is to use two thresholds-a low threshold t_l and a high threshold t_h.

Algorithm 2:

1. Produce two threshold images I_1(i, j) and I_2(i, j)
(note: since I_2(i, j) was formed with a hidh threshold it will contain fewer false edges but there might be gaps in the contours)
2. Link the edges in I_2(i, j) into contours
   2.1. Look in I_1(i, j) when a gap is found
   2.2. By examining the 8 neighbors in I_1(i, j), gather edge points from I_1(i, j) until the gap has been bridged to an edge in I_2(i, j)

The algorithm performs edge linking as a by-product of dobule thersholdng!! (Fig. 3).

Algorithm 3:

- Compute f_x and f_y:

$$f_x = \frac{\partial}{\partial x}(f*G) = f*\frac{\partial}{\partial x}G = f*G_x$$

$$f_y = \frac{\partial}{\partial y}(f*G) = f*\frac{\partial}{\partial y}G = f*G_y$$

G (x, y) is the Gaussian function

G_x (x, y) is the derivate of G (x, y) with respect to $x: G_x(x, y) = \frac{-x}{\sigma^2}G(x, y)$

G_y (x, y) is the derivate of G (x, y) with respect to $y: G_y(x, y) = \frac{-y}{\sigma^2}G(x, y)$

- Compute the gradient magnitude:

$$magn(i, j) = \sqrt{f_x^2 + f_y^2}$$

- Apply non-maximum suppression
- Apply hystresis thresholding/edge linking

Segmentation: Fuzzy C-means is used to perform image segmentation. Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. Fuzzy image processing has three main stages: image fuzzification, modification of membership values and image defuzzification.

The FCM algorithm is one of the most widely used fuzzy clustering algorithms (Suganya and Shanthi, 2012). The FCM algorithm attempts to partition a finite collection of elements X = {,, ...,} into a collection of C fuzzy clusters with respect to some given criterion. The algorithm is based on minimization of the following objective function:

$$J(U, V) = \sum_{i=1}^{n}\sum_{j=1}^{c}(\mu_{ij})^m \|x_i - v_j\|^2$$

Where:

m(the fuzziness exponent)	=	Any real number >1
N	=	The number of data
C	=	The number of clusters
μ_{ij}	=	The degree of membership of x_i in the cluster j
x_i	=	The ith of d-dimensional measured data
v_j	=	The d-dimension center of the cluster and ‖*‖ any norm expressing the similarity between any measured data and the center

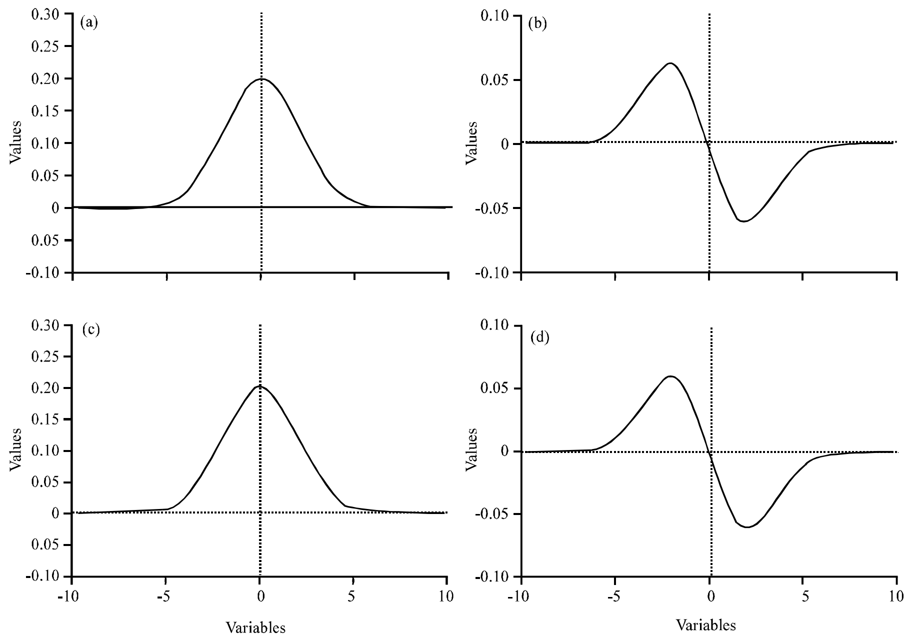

Fig. 3: Canny edge detection steps: a) Gaussan g(x) with mean 0 and SD 2; b) First deriva five of Gaussan with mean 0 and SD 2; c) Gaussan g(x) with mean 0 and SD 2 and d) First deriva five of Gaussan with mean 0 and SD 2

This gives best result for overlapped data set and comparatively better than K-means algorithm.

Feature extraction: A statistical method of examining texture that considers the spatial relationship of pixels is the Gray-Level Co-occurrence Matrix (GLCM) also known as the gray-level spatial dependence matrix. The GLCM functions characterize the texture of an image by calculating how often pairs of pixel with specific values and in a specified spatial relationship occur in an image, creating a GLCM and then extracting statistical measures from this matrix. Contrast, correlation, energy, homegenity is calculated. GLCM is a very effective technique for texture computation of an image (Luhach *et al*., 2015).

Classification: The Adaptive Network-based Fuzzy Inference Systems (ANFIS) is a Fuzzy Inference System (FIS) implemented in the framework of an adaptive fuzzy neural network. Explicit knowledge representation of an FIS is combined with artificial neural networks to provide the best features of both. ANFIS is a function approximator program used to solve problems related to parameter identification. This parameter identification is done through a hybrid learning rule combining the back-propagation gradient descent and a least-squares method.

ANFIS is basically a graphical network representation of Sugeno-type fuzzy systems endowed with the neural learning capabilities. The network is comprised of nodes with specific functions collected in layers. ANFIS is able to construct a network realization of if/then rules. Consider a Sugeno type of fuzzy system having the rule base:

- If x is A_1 and y is B_1, then $f_1 = c_{11}x+c_{12}y+c_{10}$
- If x is A_2 and y is B_2, then $f_2 = c_{21}x+c_{22}y+c_{20}$

Let, the membership functions of fuzzy sets A_i, B_i, i = 1, 2, Be, $\mu_{A_i}\mu_{B_i}$. In evaluating the rules, choose product for T-norm (logical and). Evaluaing the rule premises results in:

$$w_i = \mu_{A_i}(x)\mu_{B_i}(y), i = 1, 2$$

Evaluating the implication and the rule consequences gives:

$$f(x, y) = \frac{w_1(x, y)f_1(x, y)+w_2(x, y)f_2(x, y)}{w_1(x, y)+(x, y)}$$

Or leaving the arguments out:

$$f = \frac{w_1 f_1+w_2 f_2}{w_1+w_2}$$

This can be separated to phases by first defining:

$$\bar{w}_i = \frac{w_i}{w_1 + w_2}$$

Then f can be written as:

$$f = \bar{w}_1 f_2 + \bar{w}_2 f_2$$

All computations can be presented in a diagram form. ANFIS normally has 5 layers of neurons of which neurons in the same layer are of the same function family (Fig. 4).

Implementation

Snapshots: Snapshots are discussed from Fig. 5-15.

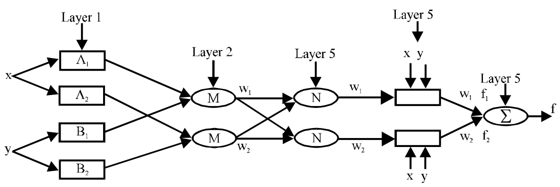

Fig. 4: ANFIS classification

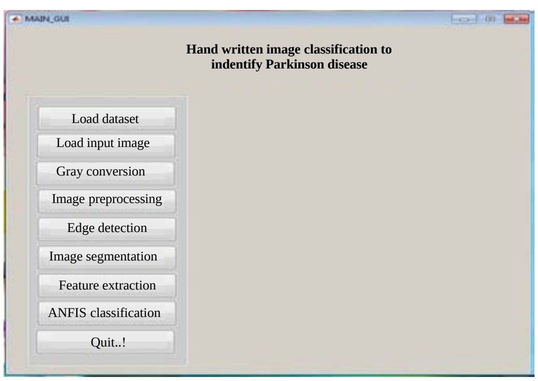

Fig. 5: GUI screen

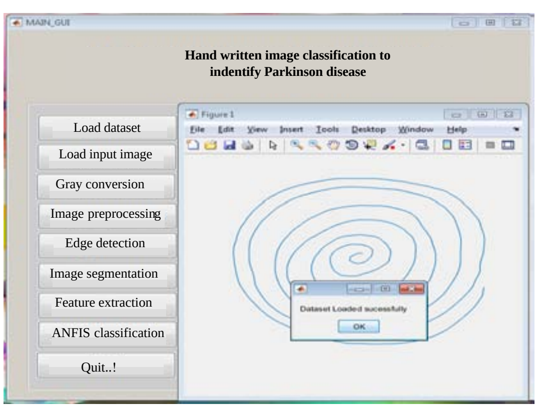

Fig. 6: GUI screen after loading the dataset

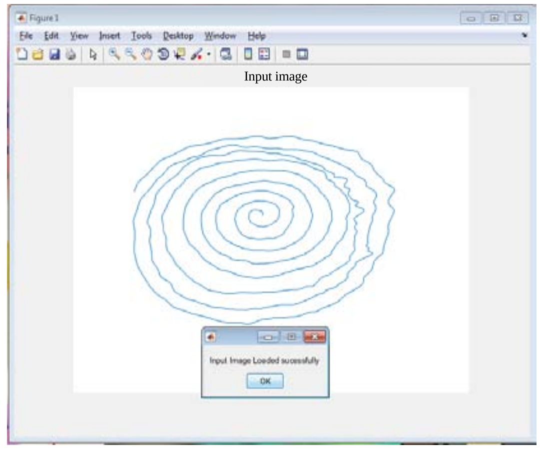

Fig. 7: Input image selected

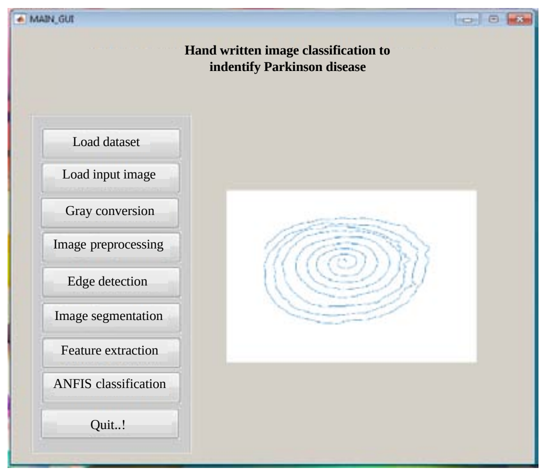

Fig. 8: GUI screen with input image

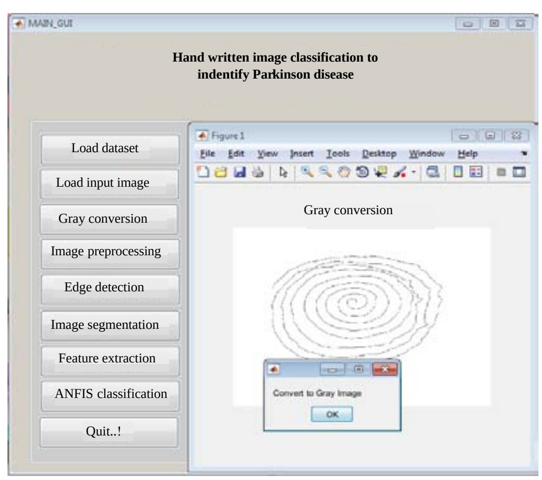

Fig. 9: GUI screen after gray conversion

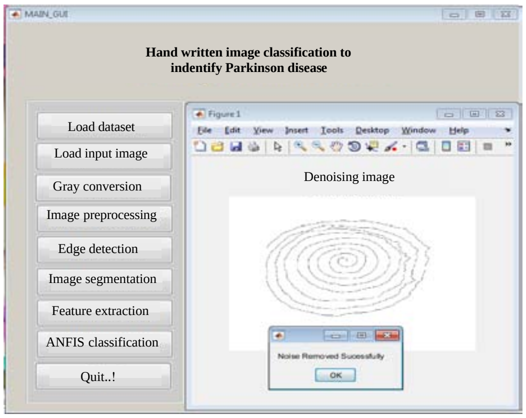

Fig. 10: GUI screen after image preprocessing

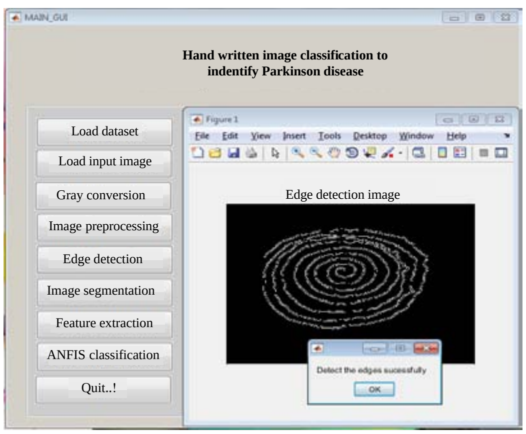

Fig. 11: GUI screen after edge detection

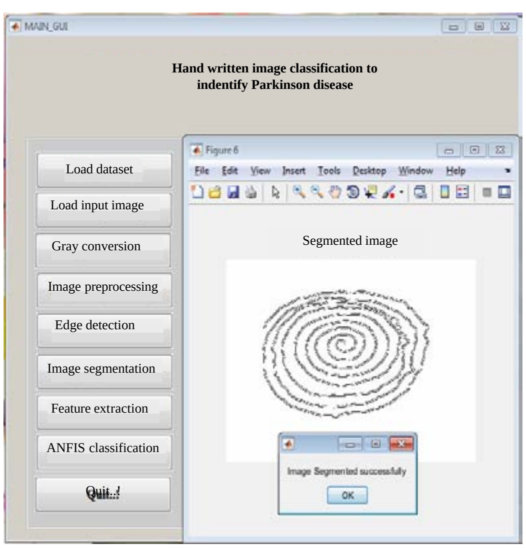

Fig. 12: GUI screen after image segmentation

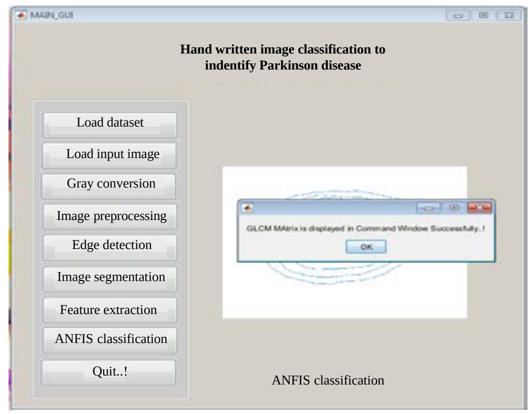

Fig. 13: GUI screen after feature extraction

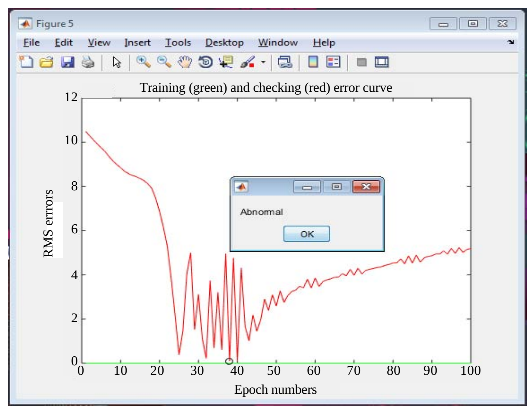

Fig. 14: GUI screen classifying image as abnormal

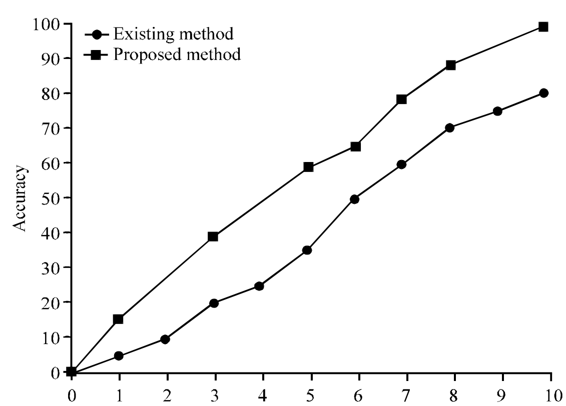

Fig. 15: Accuracy of proposed and existing method

RESULTS AND DISCUSSION

The spirals traced by the patients are acquired and stored as bitmap image. It is then converted to gray scale using rgb2gray command. Weiner 2 command is applied to the resultant image to reduce noise and improve the quality of image. Finally, canny edge detection is applied to identify the corner, curve and lines. The output from the above step is segmented using fuzzy C-means. In the resultant image, important features like contrast, correlation, homogeneity, energy and variance are extracted using the gray level co-occurrence matrix. Apart form these features, aspect ratio, stroke frequency, mean and standard deviation is calculated. These features extracted are finally fed into ANFIS system and classified as normal and abnormal patient.

The same steps are done using support vector machine algorithm. The image is acquired, preprocessed which includes gray conversion and reduction of noise using weiner filter. Now, the edges are detected using canny edge detection. To this resultant image, fuzzy c-means is applied to segment the image and the above said features are extracted using GLCM. Now, support vector machine algorithm is applied to classify as normal and abnormal patient.

A classification accuracy of 99% is achieved using ANFIS classification. The same dataset with SVM method yields only 80%. Hence, this algorithm can be used effectively.

CONCLUSION

A novel approach for Parkinson detection has been presented which shows accurate results for the database used in this system. Spiral images are finally classified as normal or abnormal patient suffering from Parkinson disease. This new method proposed for the identification of Parkinson disease is implemented using GLCM and ANFIS classification. The result compares well with the existing SVM method. The algorithm proposed is precise and reliable in diagnosis and the outcome prediction is accurate. Hence, this would serve the physicians as an aid to identify persons with neurological problems.

The abnormalities due to neurological diseases result in their inability to control their hand movements. This analysis of handwriting can be used as a reliable and effective tool for identification of Parkinson disease.

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