Adaptive Neuro Fuzzy Inference System Assisted Diagnosis of Diabetic Retinopathy from Fundus Image

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ABSTRACT
In this paper, it is proposed to detect the exudates in the retinal image and to classify the severity stages caused by the exudates and non-exudates using Adaptive Neuro Fuzzy Inference System (ANFIS). The retinal image used for this project work is subjected to the preprocessing steps such as green channel extraction, median filter, histogram equalization and contrast enhancement. Then the image is subjected to morphological operation for dilation and erosion. Optic disk is eliminated by connected component technique and statistical features like exudates area, size, color, energy, skewness, kurtosis, entropy, homogeneity and texture properties are extracted. The features are now classified to identify the normal eye and affected eye. The classification is accomplished using ANFIS.

General Terms
Intelligent Classification

Keywords
Retina, Exudates, Diabetic retinopathy, Adaptive Neuro Fuzzy Inference System classification

1. INTRODUCTION
All people with diabetes mellitus are at risk – those with Type I diabetes and those with Type II diabetes. The longer a person has diabetes, the higher the risk of developing some ocular problem. Between 40 to 45 percent of diagnosed with diabetes have some stage of diabetic retinopathy. Diabetic retinopathy is oozing of exudates in the retina. Alireza Osareh et al . developed a tool to segment the retinal images using Fuzzy C-Means (FCM) clustering technique. The features are extracted and ranked using Genetic Algorithm and classified using neural network. Akara Sopharak et al. detected exudates from nonmydriatic, low contrast retinal digital images using mathematical morphology techniques. Akara Sopharak et al. proposed an automatic method for detection of exudates from the diabetic retinopathy images using fuzzy c-means clustering technique. Asha Gowda Karegowda et al. developed a Back propagation Neural network classifier to detect exudates in retinal images. The significant features are identified by Decision Tree and GA- CFS method. Doaa Youssef et al. found that Green channel have high contrast and necessary information (exudates). Canny edge detector and Hough transform was used for optic disk elimination and morphological operation for detection of blood vessel tree. A Bayesian classifier was used for classification of images into exudates and non-exudates was given by Ege et al.. Huan Wang et al. Detected exudates by using a minimum-distance discriminant classifier based on statistical pattern recognition and used local window for classification. Lili Xu et al. use a segmentation method to differentiate the contrast in larger and thin blood vessels. Adaptive local thresholding is used to produce the normalized image and to extract larger vessels. Thin vessel segments are classified using Support Vector Machine. Different stages of Diabetic retinopathy disease severity are detected by Morphological operation and Texture Analysis methods applied on retinal images. The statistical features are extracted and classified using Bayes Minimum Distant Discriminant (MDD) classifier and the classifier is compared with original and brightness enhanced image. Niemeijer et al. proposed a method to differentiate the bright lesions such as exudates, cotton wool spots and drusen from colour retinal images. Sinthanayothin C et al. developed a Recursive region growing segmentation technique which is used for the automated system of detection of diabetic retinopathy stages. Huiqi Li and Opas Chutatape have presented a method to detect exudates using region growing and edge detection techniques. He also detected optic disk using principal component analysis. Using a modified active shape model the shape of optic disk was detected. Sánchez et al. detected hard exudates by colour, statistical classification and sharpness of its edges using Kirsch operator.A fundus coordinate system is used to describe the features. Usher et al. found an adaptive intensity thresholding method for the extraction of exudates. The features extracted are size, shape, hue and intensity and are used as the input to artificial neural network. Prof B. Venkatalakshmi and V.Saravanan presented a method to detect hard exudates using color and sharp edges of lesion. Graphical user interface window created using MATLAB used in examining the abnormal fundal retinal images automatically and thus reducing the examining time of the physician. Walter et al. have presented and discussed an algorithm for detection of exudates, as well as detection of optic disk which was essential for this approach. Exudates were found using their grey level variation, and their contours were determined by means of morphological reconstruction techniques. The optic disk was detected by means of morphological filtering techniques and the watershed transformation was to find its contours. V. Vijaya Kumari, N. Suriya Narayanan developed a method for early detection of Diabetic Retinopathy. Optic disk is extracted by propagation through radii method and exudates are detected using feature extraction, template matching and enhanced MDD classifier. In the proposed work, it is planned to obtain the retinal images using fundus camera, preprocess the image and separate the extrudates in the image and classify the eye image as normal and affected eye.

2. DIABETIC RETINOPATHY
The retina is a multi-layered sensory tissue that lines the back of the eye. It contains millions of photoreceptors that capture

light rays and convert them into electrical impulses. These impulses travel along the optic nerve to the brain where they are turned into images. There are two types of photoreceptors in the retina: rods and cones.

Figure 1: Eye affected by Diabetic Retinopathy

The retina contains approximately 6 million cones. The cones are contained in the macula, the portion of the retina responsible for central vision. They are most densely packed within the fovea, the very centre portion of the macula. Cones function best in bright light and allow us to appreciate colour. When the retina is been affected as a result of diabetes, this type of disease is called Diabetic Retinopathy (DR) , if not properly treated it might eventually lead to loss of vision. Ophthalmologists have come to agree that early detection and treatment is the best treatment for this disease. The retinal image affected by DR is shown (see Figure 1).DR occurrence have been generally categorize into three main form viz, Background DR, Proliferative DR, Severe DR. Retinopathy (damage to the retina) is caused by complications of diabetes, which can eventually lead to blindness. It is anocular manifestation of diabetes, a systemic disease, which affects up to 80 percent of all patients who have had diabetes for 10 years or more. Despite these intimidating statistics, research indicates that at least 90% of these new cases could be reduced if there was proper and vigilant treatment and monitoring of the eyes. The longer a person has diabetes, the higher his or her chances of developing diabetic retinopathy.

3. PROCESSING OF RETINAL IMAGES

The retinal image used for this research work is subjected to the pre-processing steps such as green channel extraction, histogram equalization and contrast enhancement. The optic disk is eliminated by connected component analysis and features like exudates area, size, color, and homogeneity and texture properties are extracted. The images for this project work are taken from publicly available data on the website **"Drive**". The images forms a dataset of 100 colour fundus images in which 32 are normal and 68 contains exudates patches with different stages of severity. Each image was captured using 24 bit per pixel at a resolution of 774 X 893 pixels in JPEG format. The retinal images in the dataset are often noisy and poorly illuminated because of unknown noise and camera settings. Also there is a wide variation of colour of retina from patient to patient. Thus the images are subjected to various preprocessing steps, which include green channel extraction, histogram equalization, median filter and contrast enhancement. The retinal images and the preprocessed images for normal, mild, moderate and severe stages of exudates are shown in below image respectively. The exudates appear bright in the green channel compared to red and blue channels in RGB image. Hence green channel is used for further processing by neglecting other two components. Histogram equalization and contrast enhancement are used to increase the contrast between the exudates and the image background. Median filter are used in addition for removing noise in the image. The median filter removes the noise like salt and pepper noise and etc. Data pre-processing describes any type of processing performed on raw data to prepare it for another processing procedure. Commonly used as a preliminary data mining practice, data pre-processing transforms the data into a format that will be more effective to feed to the next process.

3.1 Grayscale Conversion

The RGB color model is an additive colour model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green and blue. In photography and computing a gray scale or grey scale digital image is an image in which the value of each pixel is a single sample, that is, it carries only intensity information. Images of this sort, also known as black-and-white, are composed exclusively of shades of gray, varying from black at the weakest intensity to white at the strongest. Grayscale images are often the result of measuring the intensity of light at each pixel in a single band of the electromagnetic spectrum (e.g. infrared, visible light, ultraviolet, etc.), and in such cases they are monochromatic proper when only a given frequency is captured. But also they can be synthesized from a full color image; see the section about converting to grayscale. This input image is subjected to the grayscale conversion (see Figure 2)

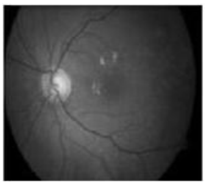

Figure 2: Gray scale converted retinal image

3.2 Green Channel Enhancement

The image is pre-processed with green channel enhancement .Using this red and blue components in the image are eliminated. The exudates appear bright in green channel compared to red and blue (see Figure 3). The exudates appear bright in the green channel compared to red and blue channels in RGB image. Hence green channel is used for further processing by neglecting other two components

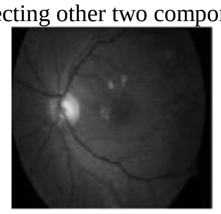

Figure 3: Green Channel Enhanced Image

3.3 Histogram Equalization

Histogram equalization is used to increase the global contrast of the images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Histogram equalization is a specific case of the more general class of histogram remapping methods. These methods seek to adjust the image to make it easier to analyze or improve visual quality. This method increases global contrast of images and hence the intensities can be better distributed on the histogram. So the hidden features of the image are more visible. Histogram provides economic hardware implementations. Histogram is the basic for a number of spatial domain processing techniques. They are simple to calculate in software. In this image technique, we are able equalize the image pixels. The histogram equalized image shows how the pixels are equally distributed (see Figure 4, 5, 6).

Figure 4: Histogram equalized retinal image

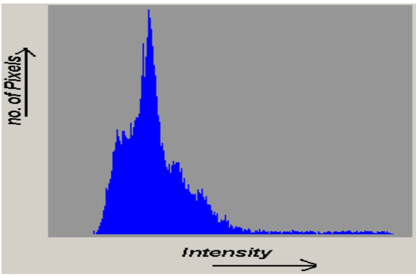

Figure 5. Histogram of the original image

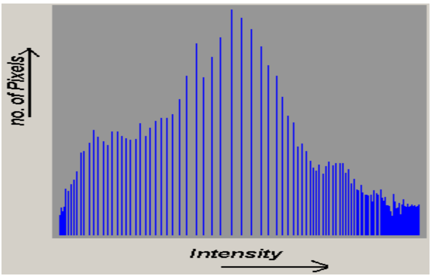

Figure 6. Histogram of the equalized Image

3.4 Contrast Enhancement

The contrast enhancement is used to increase the contrast between the exudates and the background. (see Figure 7).

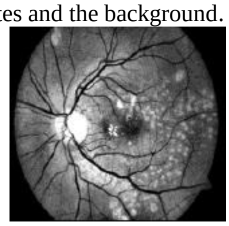

Figure 7: Retinal image after contrast Enhancement

4. EXUDATES SEGMENTATION

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighborhood, you can construct a morphological operation that is sensitive to specific shapes in the input image. The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries (see Figure 8).

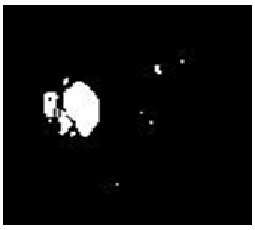

Figure 8: Retinal image after dilation and erosion

4.1 Optic Disc Elimination

The morphologically operated image has only exudates and optic disk. The optic disk occupied maximum area in the image and hence it is eliminated by connected component analysis. The optic disk eliminated image for normal, mild, moderate and severe stages of Diabetic Retinopathy

- The optic disk occupies the maximum area in the image
- Now it is eliminated using connected component analysis
- This is done using connected component analysis

Connected-component labeling is used in computer vision to detect connected regions in binary digital images, although color images and data with higher dimensionality can also be processed. When integrated into an image recognition system or human-computer interaction interface, connected component labeling can operate on a variety of information. Blob extraction is generally performed on the resulting binary image from a thresholding step. Blobs may be counted, filtered, and tracked. Blob extraction is related to but distinct from blob detection. A graph, containing vertices and connecting edges, is constructed from relevant input data. The vertices contain information required by the comparison heuristic, while the edges indicate connected 'neighbors'. An algorithm traverses the graph, labeling the vertices based on the connectivity and relative values of their neighbors. Connectivity is determined by the medium; image graphs, for example, can be 4-connected or 8-connected. This image shown in figure 9 shows the exudates of the eye and optic disk has been removed by connected component (see Figure 9).

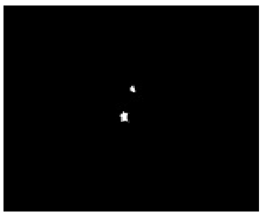

Figure 9: Image with exudates

5. FEATURE EXTRACTION

In image processing, feature extraction is a special form of dimensionality reduction. Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately. Morphological features like exudates area, exudates perimeter and the statistical feature; the standard deviation are used in this work. Table 1 lists the sample of the features used for the classification.

Table 1: Results of extracted feature values of normal and abnormal images

Images	Exudates Area	Exudates Perimeter	Standard Deviation	Cluster Prominence
1Normal	0	0	12.6636	37.1786
2 Normal	0	0	12.4484	39.2548
3 Normal	0	0	14.7885	56.4474
4 Normal	4	4.8484	13.8476	43.9339
5 Mild	79	63.0122	16.8181	67.8963
6 Mild	1567	574.6589	17.9293	69.6419
7 Medium	1640	683.5706	19.3183	94.3429
8 Medium	3286	1238.2	19.9039	96.8846
9 Severe	5243	1668.5	22.6175	118.5877
10 Severe	7836	1597	20.5315	117.1396

6. CLASSIFICATION

The features extracted from the retinal images are classified using ANFIS. Input to the ANFIS is the morphological features like exudate area and the exudate perimeter and the statistical data includes the standard deviation. The output of the ANFIS is 0 for the normal retinal images and 1, 2 and 3 for Background retinopathy, pre-proliferative retinopathy and proliferative retinopathy respectively. Epoch is set to be $1e^{-4}$. Out of the 100 samples, there are 32 Normal data, 13 images of Background DR, 10 images of Pre-proliferative and 45 images of Proliferative eye disease. 75% data in each group is selected for training and the remaining 25% data is used for testing and validation. Gbell membership function is used in the input side and Takagi Sugeno Constant membership function is used in the output side. Hybrid optimization is used for the training and 300 epoches were selected for the training. Figure 10 shows the architecture of the ANFIS used for detecting the diabetic retinopathy. Figure 11 and 12 show the rule viewer and surface viewer used to show the results of the trained output.

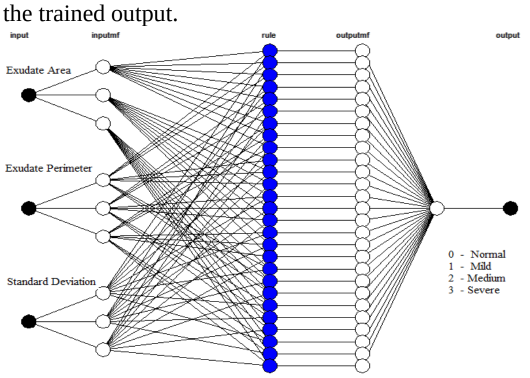

Figure 10: Architecture for the ANFIS based retinal diabetes detection

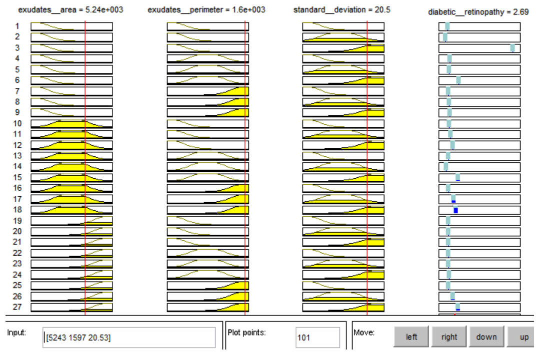

Figure 11: Rule viewer for the detection of the diabetic retinopathy

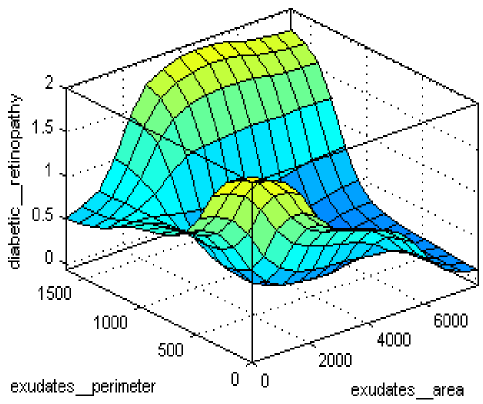

Figure 12: Surface viewer to diagnose diabetic retinopathy from the morphological and statistical retinal image data

7. CONCLUSION

This research work presents the use of state of art algorithms for the processing of fundus images, with particular attention to the aspects related to diabetic retinopathy. The retinal image is preprocessed by green channel extraction, histogram equalization and contrast enhancement. The optic disk is eliminated by connected component analysis and features like exudates area, size, color, and homogeneity and texture properties are extracted. 100 data is collected and preprocessed. Morphological and statistical features are extracted and classified using ANFIS. Normal data, background DR and pre-proliferative data was identified with 100% accuracy, the proliferative data alone was identified with 97% accuracy.

8. REFERENCES

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