

Detection of Exudates in Retinal Images Using Fuzzy Techniques

S. Mohanapriya, M. PonniBala and S. Vijayachitra

Department of Electronics and Instrumentation Engineering, Kongu Engineering College,
Perundurai-638052, Tamilnadu, India

Abstract: Diabetic Retinopathy is a major cause for blindness, identified early by the formation of exudates in the retina. The conventional method followed by ophthalmologists is the regular supervision of the retina. As this method takes time and energy of the ophthalmologists, a new feature based classification for the detection of exudates in color fundus image is proposed in this study. This method reduces the professionals work to examine on every fundus image rather than only on abnormal image. The exudates are separated from the fundus image by thresholding and removal of optic disk using morphological operation and connected component analysis. The features are extracted from processed image and fuzzy technique is used for classification of images as exudates and non-exudates.

Keywords: Connected component, exudates, fundus image, morphological operation

INTRODUCTION

Diabetic Retinopathy (DR) is the eye related disease caused by the diabetes. DR is the most common sight threatening disease when untreated leads to vision loss and in many cases it cannot be reversed (Rema and Pradeepa, 2007). There are two types of DR: Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). In the first case, the damaged blood vessels leak extra fluid and small amount of blood into the eye. This condition leads to the formation of exudates in the retina. As the disease progresses the amount of exudates also increases. In the second case, the blood vessels in the retina closes and prevents blood flow in the eye. This condition leads to the emerge of new blood vessels in order to supply blood to the blocked area and this condition is called as neovascularization (Sivakumar *et al.*, 2003).

Figure 1 shows the normal retinal image and Fig. 2 shows the retinal image with exudates. Exudates are manifested as spatially random yellowish or whitish patches of varying sizes, shapes and locations. These are the visible sign of DR and a major cause of visual loss in Non-Proliferative forms of DR.

In this study, the retinal images are classified as exudates and non-exudates using statistical features extracted from the images. The detection of exudates in retinal images was investigated by many researchers.

The global and local thresholding values are used to segment exudate lesions (Phillips *et al.*, 1993). Before thresholding, the images were preprocessed to eliminate photographic non-uniformities and the contrast of the exudates was then enhanced. Ege *et al.* (2000) located

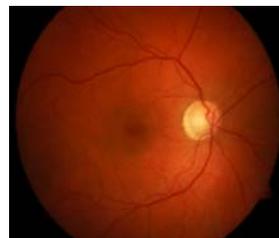


Fig. 1: Normal retinal image



Fig. 2: Retinal image with exudates

exudates using template matching, region growing and thresholding techniques. A Bayesian classifier was then used for classification of images into exudates and non-exudates.

Sinthanayothin (1999) applied a recursive region growing technique using selected threshold values in gray-level images. In this study, the processed retinal image includes only exudates and no other bright lesions were considered.

The statistical features are extracted and classified using Bayes Minimum Distant Discriminant (MDD) classifier by Wang *et al.* (2000). The classifier is

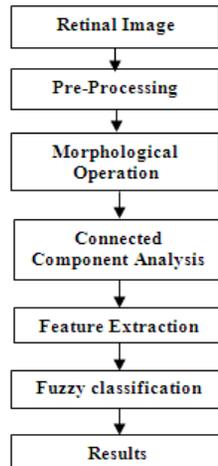


Fig. 3: Flowchart of the proposed methodology

compared with original and brightness enhanced image. The brightness enhanced image gives 100% accuracy where as 66% for normal image. Walter *et al.* (2002) detects exudates as well as optic disc in retinal images. Optic disk is removed by morphological filtering and watershed transformation and for exudates detection morphological operation and thresholding technique is used. Choosing of correct parameters like window size and thresholding is stated as crucial part in this study.

Osareh *et al.* (2009) segmented images using Fuzzy C-Means (FCM) clustering technique. The features are extracted and ranked using Genetic Algorithm and classified using neural network. Youssef *et al.* (2010) proposed green channel have high contrast and necessary information (exudates). Canny edge detector and Hough transform is used for optic disk elimination and morphological operation for detection of blood vessel tree in this study.

From the above study, the following observations are made. Green channel of the retinal image has useful information (exudates). Brightness of the image should be enhanced for better accuracy. And connected component analysis is a new approach for exudates detection.

METHODOLOGY

The objective of this project study is to classify the retinal image into exudates and non-exudates (normal). The retinal image is subjected to the preprocessing steps and is morphologically operated by a disk shape structuring element. The optic disk is eliminated by connected component analysis and features like exudates area, exudates perimeter, compactness, size, color, homogeneity and texture properties are extracted. From the extracted features the images are classified using

fuzzy classifier. The flowchart of the proposed method is shown in Fig. 3.

Image acquisition: A dataset of manually labeled images is taken for our method. This dataset consists of 65 images taken from a screening program for DR in Lotus Eye Care Hospital, Coimbatore. The images were acquired using Cannon non-mydratic ZEISS camera. Each image is 24 bit per pixel at a resolution of 774x893 in JPEG format. Of the 65 images in the dataset, 45 are of patients with abnormal (contains exudates) and the rest of the images are normal.

Pre-processing: Pre-processing is the initial step in all the case of image related diagnosis system. In case of Diabetic Retinopathy, the retinal images in the dataset are often noisy and poorly illuminated because of unknown noise and camera settings. Also the color of retina has wide variation from patient to patient. Thus to remove noise and undesired region the images are subjected to preprocessing steps, which include green channel extraction, histogram equalization and contrast enhancement.

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.

Optic disk elimination: The enhanced retinal image is converted to binary image by applying proper thresholding value. This binary image is subjected to morphological operations opening and closing (Gonzalez and Woods, 2002). Closing operation is defined as dilation followed by erosion and opening is the reverse of closing operation. Dilation is an operation that grows or thickens objects in a binary image. Erosion shrinks or thins the objects in the binary image. The process of thickening and thinning is controlled by a shape called structuring element. As the optic disk and exudates are circular in shape, a disk shape structuring element is used in this study.

The mathematical equations governing morphological operations are:

$$\begin{aligned}
 &[\gamma^{(sB)}(f)]\delta^{(sB)}[e^{(sB)}(f)] \dots\dots \text{Opening} \\
 &[\Phi^{(sB)}(f)]e^{(sB)}[\delta^{(sB)}(f)] \dots\dots \text{Closing} \\
 &[e^{(sB)}(f)](x) = \min_{b \in sB} f(x+b) \dots\dots \text{Erosion} \\
 &[\delta^{(sB)}(f)](x) = \max_{b \in sB} f(x+b) \dots\dots \text{Dilation}
 \end{aligned}$$

where, f is a gray level image and sB is structuring element B of size s (Soille, 2003).

Because of the similar attributes of exudates and optic disk, the morphologically operated image has both

exudates and optic disk. The optic disk is removed by connected component analysis.

Connected component analysis is an image segmentation technique in which image pixels are grouped into components based on pixel connectivity (i.e., each connected component have similar pixel intensity values or in some way connected with each other).

It is defined as a region R (subset of S) is said to be connected under c (s) if for all $s, r \in R$ there exists a sequence of M pixels, s_1, \dots, s_M such that:

$$s_1 \in c(s), s_2 \in c(s_1), \dots, s_M \in c(s_{M-1}), r \in c(s_M)$$

i.e., there is a connected path from s to r .

Since the optic disk occupies maximum area in the image, by using connected component properties the maximum area is eliminated.

Feature extraction: The processed image after the removal of maximum area (optic disk) has only exudates. This image is used for feature extraction. The statistical features like exudates area, exudates perimeter, number of exudates patches, compactness, entropy, correlation, energy, contrast, homogeneity, standard deviation, mean, skewness and kurtosis are extracted from the image. From this features, the most effective features are used for fuzzy classification.

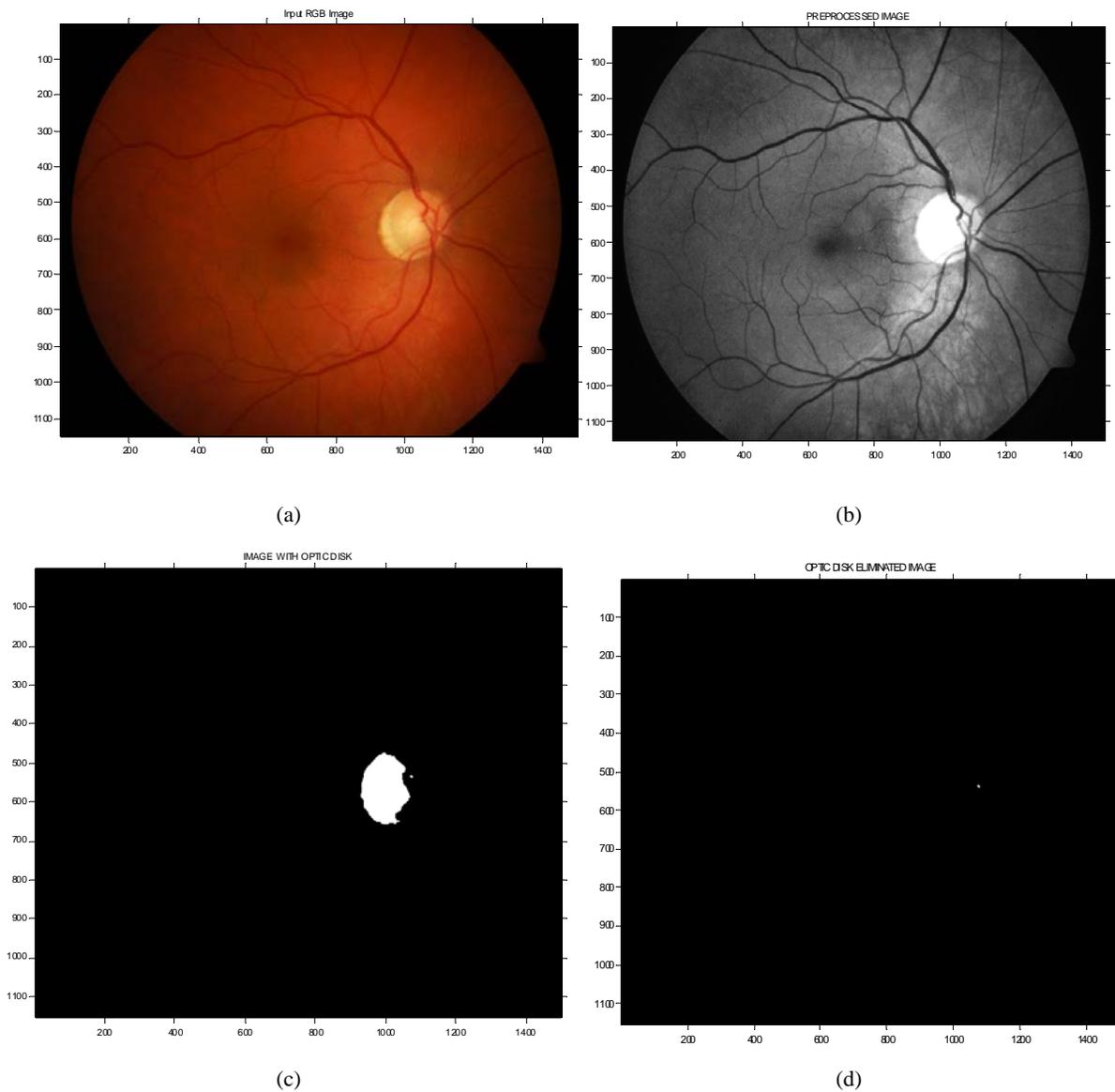


Fig. 4: Steps involved in exudates detection for normal image, (a) Original image, (b) preprocessed image, (c) image with optic disk, (d) optic disk removed using connected component analysis

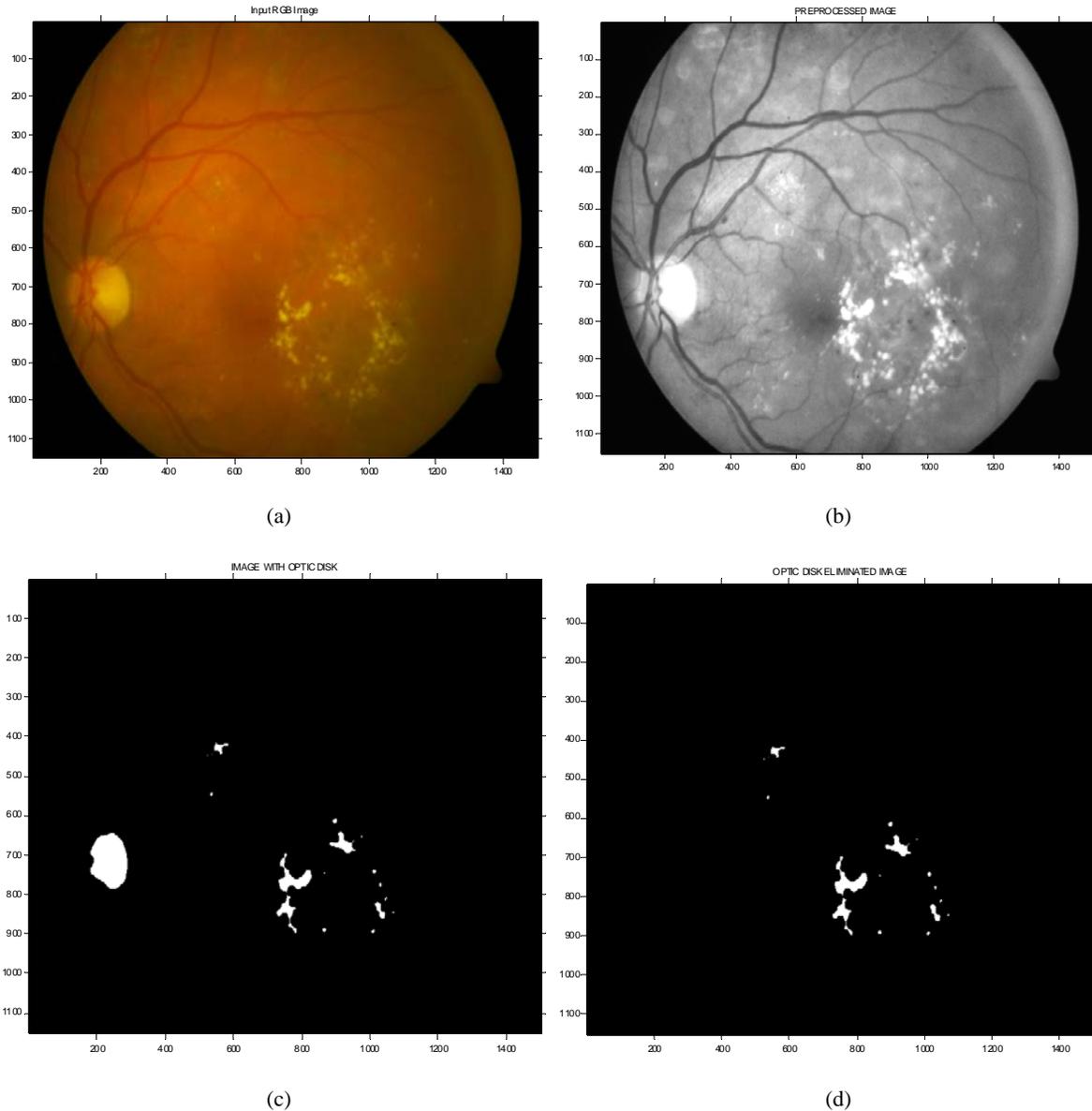


Fig. 5: Steps involved in exudates detection for abnormal image, (a) Original image, (b) preprocessed image, (c) image with optic disk and exudates, (d) optic disk removed using connected component analysis

Classification: To classify the images, a rule based Fuzzy Inference System (FIS) is used. The extracted features are given to the classifier. The classifier classifies the images into exudates and non-exudates automatically.

SIMULATION RESULTS AND DISCUSSION

The retinal image dataset is subjected to various processing steps and features are extracted. Figure 4 and 5 shows the image processing steps involved in normal and abnormal images, respectively. From the processed

image various features like exudates area, exudates perimeter, number of exudate patches, compactness, entropy, correlation, energy, contrast, homogeneity, standard deviation, mean, skewness and kurtosis are extracted.

Exudates area, number of exudates patches standard deviation and entropy are taken as features for fuzzy system.

Table 1 shows the input and output values for 6 images (3 normal and 3 abnormal) used in this study. The output of the classifier depends on the given feature input

Table 1: Input and output values for fuzzy inference system

Features	Area	Ex. pats	S.D	Entropy	Output
Image 1	0	0.0000	4.9072	2.0277	0.233
Image 2	0	0.0000	4.8743	2.6907	0.233
Image 3	0	0.0000	4.7651	2.8003	0.269
Image 4	3267	763.8549	7.9563	3.8071	0.690
Image 5	2007	511.6884	8.1087	3.7680	0.747
Image 6	6735	1980.0000	9.9138	4.3561	0.798

Output: 0-0.5 Normal, 0.5-1 Abnormal

values. Totally 28 rules are framed for 4 input and 1 output FIS system.

CONCLUSION

The main idea of this project is to reduce professionals work for classifying retinal images as exudates and non-exudates using Fuzzy classifier. The retinal image is subjected to various processing and features are extracted for the image. From the calculated feature values, a retinal image can be classified automatically under which category the image falls on (i.e., either exudates or non-exudates).

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