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An Enhanced Detection of Exudates in Color Fundus Images of the Human Retina a Contribution for the Mass Screening of Diabetic Retinopathy

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Abstract: The automatic detection of exudates from the digital fundus images of the retina helps in the early diagnosis of Diabetic Retinopathy (DR) and thereby for mass screening large number of patients by medical ophthalmologists. Detection of optical disc is essential for the correct detection of exudates from the fundus images. In this paper an improved exudate detection system is proposed. The top ranking Principle Component Analysis (PCA) method is used to locate the optical disc (OD), the boundary of OD is located using Active Contour Based approach and an improved region based segmentation approach is proposed for detecting exudates.

Key words: Optical Disc · Exudates · Diabetic Retinopathy

INTRODUCTION

Retina is one among the parts of the eye where the early pathological changes can be seen. Various complications like Diabetic Retinopathy (DR), hypertension and several other eye diseases are revealed by the various anatomical structures that are inside the retina. Hence, regular screening of the retinal fundus is essential to combat eye diseases at the early stages. Diabetic Retinopathy (DR) is one among major medical problem throughout the world which leads to lindness if not treated properly at right time. Hence it is very essential for early screening of the DR.

There are two main types of DR. They are Non-Proliferative Diabetic Retinopathy and Proliferative Diabetic Retinopathy. Some of the main complications of DR are intraretinal fatty exudates, hemorrhages, microaneurysms, neovasculaization, etc. Exudates are the primary signs of DR. But screening towards the diabetic retinopathy by medical professionals is complex time consuming task. So an automatic or semi-automatic system is essential for mass screening and initial analysis of numerous fundus images from different patients.

In this paper, an automated exudate detection system is proposed by combining the principles of top ranking Principle Component Analysis method for the location of optical disc, Active Contour Approach for location of boundary of optical disc and region based segmentation approach for detecting exudates.

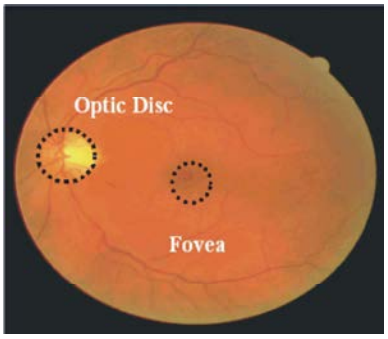

Fig. 1(a): Normal fundus image of the eye

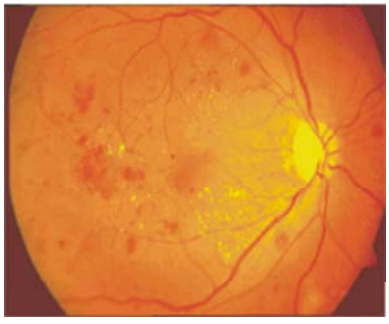
Fig. 1(b): Abnormal fundus image of the eye

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Edge detection followed by Hough transform is used to detect OD in [2]. In [3] PCA is used to locate OD and the boundary of OD is extracted by evolving a snake. In [4], a morphological processing to isolate a circular brightness region of interest, followed by Hough transform is used to locate OD. In [5], PCA modified active shape model is used in locating and detecting the shape of OD respectively. In [6] the OD's center is said to be the minimal distance between the projections of the original retinal image to its principle component.

In [7] an approach based on shade correction followed by manual thresholding is used to detect exudates. An approach based on sharpening and shade correction, which is followed by a combination of local and global threshold are used in [8]. Recursive region growing was used in grey level images in [9] for exudate detection. Segmentation using Fuzzy C- Mean clustering technique followed by the usage of neural network for classification between exudate and non-exudate patches is implemented in [10]. Watershed segmentation approach based on marker is used to detect and extract the boundaries of OD and exudates in [11].

We find most of the approaches use thresholding since it is simple, straight forward and fast but the resultant of it might not be up to the mark when measured in terms of sensitivity and predictivity. Determination of global threshold is difficult when the image has significantly changing gray levels.

The paper is organized into three sections. The first section deals with pre-processing techniques like colour image enhancement and local contrast enhancement. The second section deals with the detection of optic disc (OD) and its elimination from the preprocessed image. Finally, the third section deals with the detection of exudates.

Proposed System: The proposed system for automatic exudate detection passes through the following different stages. This system is a unique combination of relevant techniques for improved automated

- *Pre-processing of the Colour Fundus Image*
- *Detection of Optic Disc*
- *Detection of Exudates*

Preprocessing of the Color Fundus Image: The contrast of the fundus images tends to diminish as the distance of a pixel increases from the centre of the image. The objective of preprocessing was to reduce this effect and to normalize the mean intensity. The RGB color space is widely used for computer graphics or image analysis. The intensities of the three color bands were transformed to a hue-saturation- representation. This allowed the intensity to be processed without affecting the perceived relative color values of the pixels.

HSI model is applied to enhance an image, since it can be converted back to RGB for visual display. HSI model is best suited because the intensity component is decoupled from the color information of the image [12]. Then applying a contrast-limited adaptive histogram equalization (CLAHE) operator to the intensity component and converting the result to RGB for display will not affect the color content of the image (Fig. 3).

However, the technique of local contrast enhancement not only adjusts the contrast of the image but also increases the noise. Hence, a 2D Gaussian smoothing filter or median is applied in order to reduce the noise before the local contrast enhancement process.

Detection of Optic Disc: The brightest part of the normal retinal fundus image is the Optic Disc (OD). It is usually seen as a pale, round or slightly oval structure. OD is the

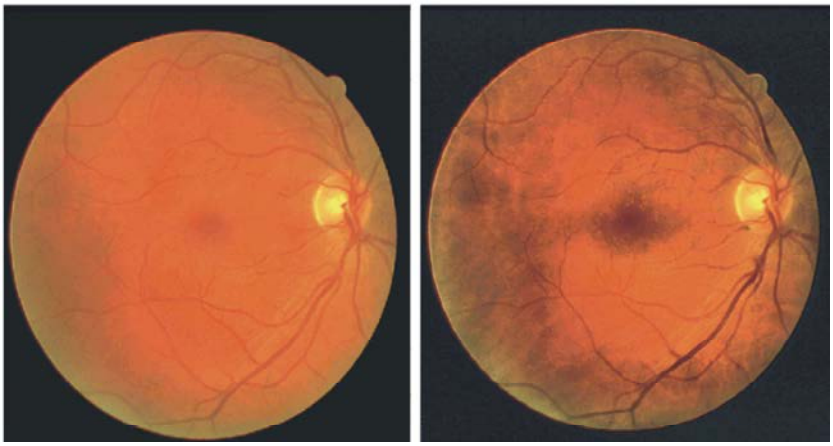

Fig. 3: Original image and after pre-processing

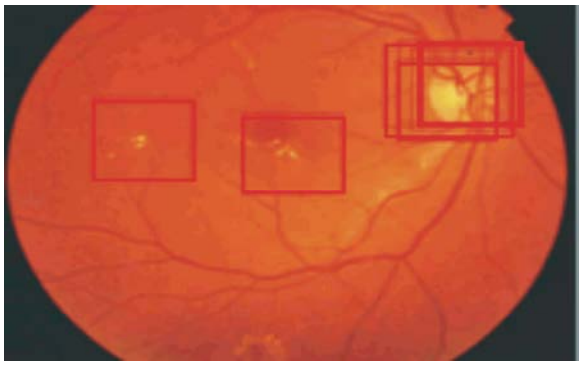

Fig. 4: Red squares are selected candidate regions

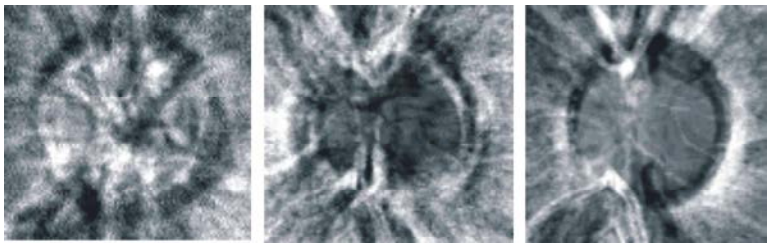

Fig. 5: Eigen discs obtained on applying PCA on the training set images

spot on the retina where the optical nerve leaves the eye. Detection of optical disc is an essential part in the exudate detection process since its color, contrast, brightness, etc are similar to the exudates. It's easy to locate the macula and track the blood vessels on locating the OD.

The localization of OD consists of two steps namely *Candidate Region Extraction* followed by *Principle Component Analysis (PCA)*.

Candidate Region Extraction: The pixels with highest 5% intensity level and along with hue value in the yellow range are chosen for candidate region identification. Clustering mechanism is applied to group pixels and a threshold limit is used to finely refine the items. Finally the remaining clusters are the candidate regions. We define a square of 100 x 100 in each candidate region with its cluster's centroid as center. The red squares in Fig: 4 show the various selected candidate regions [16].

Principle Component Analysis: The procedure for the implementation of PCA for OD localization is in line with [6]. The PCA method is used to identify the OD from amongst the candidate regions which have been obtained after the candidate region extraction process in the previous section. This approach includes the calculation of the eigen vectors of the covariance matrix of the training images and construction of a "disc space" specified by the eigen vectors (eigen discs). The eigen discs are shown below

The candidate image patches that are obtained by Candidate Region Extraction process in the previous section are then projected onto the disc spaces and their distances between the retinal image and their projection are calculated respectively [17]. The candidate with the minimum difference is identified to be the Optic Disc amongst the candidates and the centre of Optic Disc is located at the point with the minimum distance (Fig:6).

The OD region is enhanced using Lab color morphology [3]. The OD's boundary can be found out by fitting a snake [13] around the approximate centre of the detected OD. The snake in general is a parametric curve $X(s)=(x(s,y(s))$ where $0 \le s \ge l$. The snake moves under an evolution equation that pushes it towards configurations that minimize internal and external energies. This energy function can be defined as:

$$E_{snake} = \int_0^1 \frac{1}{2}\left(\alpha \left|X'(s)\right|^2 + \beta \left|X''(s)\right|^2 \right) + E_{ext}(X(s))ds \quad (1)$$

where X(s) is a parametric curve and the coefficients α and β control the snake's tension and rigidity. The E_{ext} (X(s)) is the external energy and can be replaced by an edge map, for example

$$E_{ext} = \left| \nabla\left[G_\sigma(x,y) * I(x,y)\right] \right|^2 \quad (2)$$

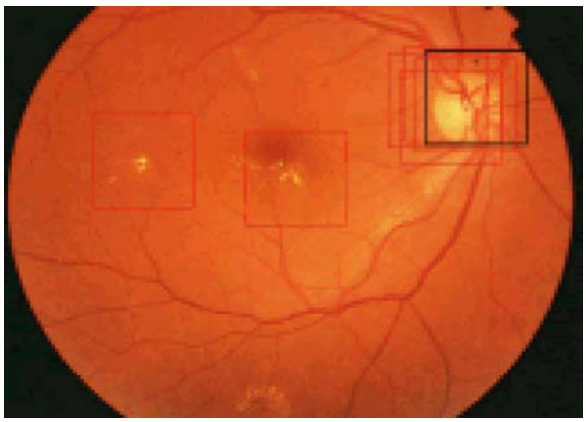

Fig. 6: Black square is the localized OD

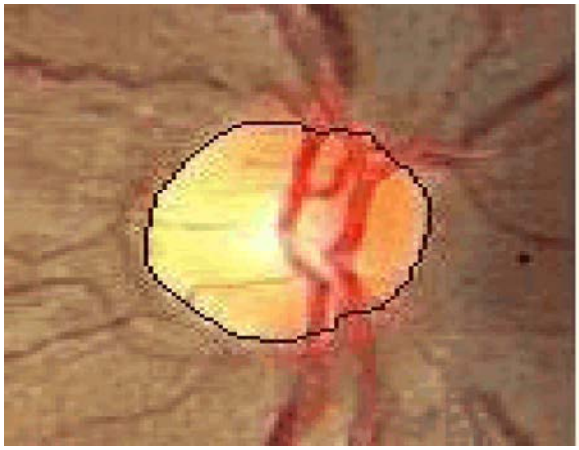

Fig. 7: Boundary of OD

where I is the image and G is a Gaussian smoothing filter with standard deviation σ, & ▽ and * are the gradient and convolution operators respectively.

The result of OD extracted image is given below.

The estimated location of optic disk is masked with a circular disk of color equal to the average intensity of the image as shown in Fig: 7b.

Detection of Exudates: In case of DR, due to the abnormal permeable blood vessels, serum lipoproteins leaks through them, especially across the microaneurysms and other surrounding capillaries [1]. Hard exudates are usually seen as yellowish intra retinal deposits. They have sharp margins and can be seen as individual streaks or in some circulate pattern around microaneurysms. In the Mass Screening of the DR, detection of exudates contributes to a significant level.

The exudates appear in more contrast in green channel component [1] than any other. So to detect exudates in our proposed system, green component of the image is used. The use of global threshold is fast, but it might lead to undesirable results. The bright optic disk has similar features as exudates and it is often identified incorrectly as an exudate; so it is essential to eliminate it before exudate detection.

The exudate detection phase of the proposed system consists of the three phases namely *An Integrated Thresholding Approach, Rough Segmentation* and *Final Integration Phase*.

An Integrated Thresholding Approach: The image is initially considered as a whole segment and is segmented into a quadrant if not homogenous and then each new segment is partitioned into a quadrant successively until it does not meet out the homogeneity. In histogram based thresholding approach, global thresholding (T) is performed throughout the image with a variable threshold value (α) depending on each individual sub image can be represented by G_1 as equation 3.

$$G_1 = \sum_{l \in k} T_{\alpha l}(P_l) \tag{3}$$

where k is the number of subimages.

Rough Segmentation: The *Rough Segmentation* aims to classify non-exudate objects and exclude them. Most of the retinal images contain regions of light reflections with brightness similar or more than exudates do have. These reflections don't possess sharp boundaries but exudates have sharp margin [18]. The image looks like that the exudate clusters are closely distributed. In this case a morphological operator (§) is applied to the preprocessed image G_p with a structuring element s_1. The output image is denoted as G_2.

$$G_2 = \S^{s1}(G_p) \tag{4}$$

The local variance G_3 of the image can be calculated as

$$G_3 = \frac{1}{N-1} \sum_{i \in w(x)} (G_2(i) - \mu(x))^2 \tag{5}$$

where x is a set of all pixels in a sub-window w(x), N is the number of pixels in w(x), μ(x) is the mean value of G2(i) and i □ w(x). To ensure that the candidate regions include majority of the neighboring pixels, we dilate the segmented image with the structuring element $\S_2$. Then to suppress structures that are lighter than their surrounding and connected to the image border, a morphological clear border operator (*C*) is applied. The Rough exudate detection result is denoted by G_4.

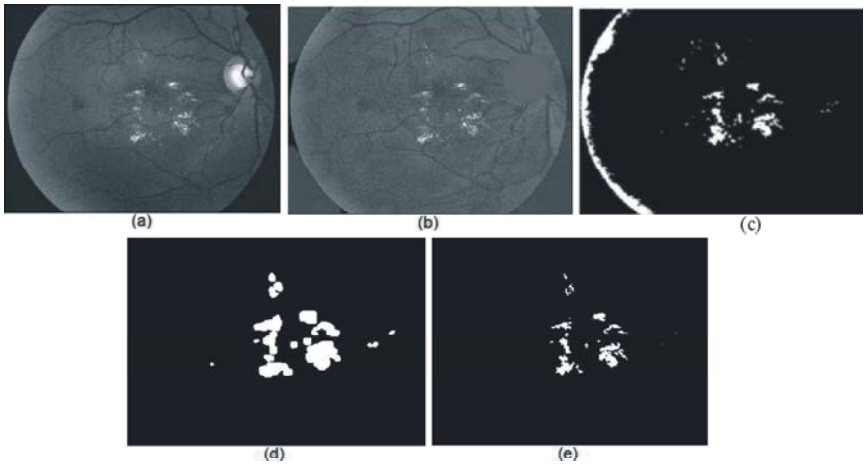

Fig. 7: (a) Green Component (b) OD masked image (c) Adaptive thresholded image (d) Image after Rough Segmentation (e) Final Integrated Image.

$$G_4 = (C)(D^{\S 2}[T_\alpha](G_3)) \quad (6)$$

where T is a thresholding operator with automatic level (α).

Final Integration Phase: In the *Final Integration Phase*, we combine the adaptive thresholding and Rough segmentation to enhance the resultant image. The final exudate detected image (G_5) is obtained by performing intersection operation between G_1 and G_4.

$$G_5 = G_1 \cap G_4 \quad (7)$$

RESULTS AND DISCUSSION

The assessment of the quality of pathology detection is not an easy task; human graders are not perfect. Hence, if a human grader does not agree with the algorithm, this can be due to an error of the human grader or due to an error of the algorithm.

The proposed automated exudate detection system is tested on DRIVE database [14]. The images in this database were acquired using a Canon CR5 non-mydriatic 3CCD camera with a 45 degree field of view (FOV). These images contain both normal (healthy) and abnormal retinas. The proposed system is implemented on 34 normal images from the Drive database with resolution of 565×584. It is also implemented on 50 abnormal images from DIARETDB0 [15] database and their corresponding clinician roughly marked images.

Performance of the proposed system is assessed quantitatively by comparing the results with clinician hand labeled data. Four types of pixels are considered in the method evaluation: true positive (TP), false positive (FP), false negative (FN) and true negative (TN). These quantities are computed with each individual image to measure: Sensitivity=TP/(TP+FN), Specificity =TN/(TN+FP) and Accuracy = (TP+TN)/(TP+FP+TN+FN).

CONCLUSION

The system to enhance the exudate detection in color fundus images has been proposed in this paper. PCA is used to localize the OD; An active contour model to extract the OD's boundary; and a combination of An Integrated Thresholding Approach & Rough Segmentation is used for detecting exudates.

The results obtained so far are promising and demonstrates the applicability of the proposed automated exudate system in contributing towards the overall goal of developing a system for mass screening of DR and thereby saving a lot of time for the medical professionals and patients. Further tests have to be carried out on the proposed system with more suitable clinical data. Such tests could contribute for further improvements, thus resulting in more robust and accurate detection that eventually could be adapted for clinical purposes.

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