Detection of Blood Vessels and Hard Exudates using Curvelet in Fundus Images

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Abstract— In this paper an algorithm is proposed for the identification of hard exudates in fundus images. The method is based on segmenting all objects that have contrast with the background including the exudates. The exudates could then be extracted after extracting the blood vessel based on curvelet transform operations and optic disc is detected and masked. The regions representing the blood vessel and the optic disc are removed to get the regions of exudates. The exudates are obtained by morphological reconstruction. This method is shown to be promising as we can detect the very small areas of exudates.

Key words: Exudates, Optic Disc, Fundus Image, Blood Vessel

I. INTRODUCTION

The diabetic retinopathy is a complication of diabetes, causing abnormalities in the retina, and in the worst case, blindness. Typically there are no salient symptoms in the early stages of diabetes, but the number and severity predominantly increase during the time. Diabetic retinopathy is characterised by changes in the retina that include blood vessel diameter changes, microaneurysms, lipid and protein deposits referred to as hard exudates and cotton wool spots depending on the appearance, haemorrhages and new vessel growth [1,2]. The amount of exudates, microaneurysms and haemorrhages increases as the degree of disease [3]. The appearance of exudates is the earliest and most prevalent symptom of diabetic retinopathy.

Exudates are formed by the leakage of proteins and lipids from the bloodstream into the retina via damaged blood vessels [4]. In retinal images, hard exudates appear as bright yellow lesions with varying sizes, shapes, and locations. They also have a considerable contrast with respect to the background. The optic disk, bright circular region from where the blood vessels emanate, is the only area in the fundus images having the same brightness and colour range like the exudates. Figure 1 illustrates the appearance of the exudates and the optic disc in the colored fundus images. So, detection of exudates could accurately be done by extracting the bright yellow regions after elimination the optic disc area from the image.

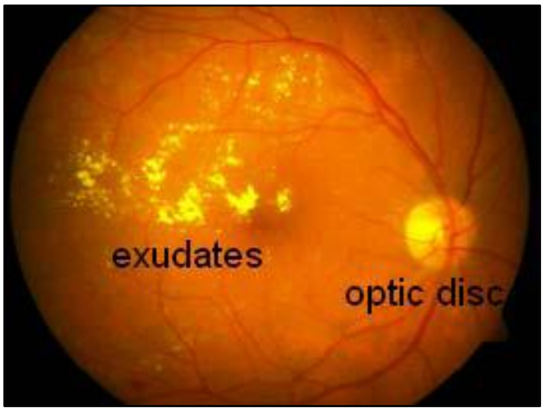


Fig. 1: Image showing exudates and optic disc

A large number of methods for automatic exudate detection have been proposed already. C. Sinthanayothin et al. [5] proposed an automated system of detection of diabetic retinopathy using recursive region growing segmentation (RRGS). A. Osarah et al. [6, 7] use fuzzy c-means (FCM) clustering to segment color retinal images, then a neural network and support vector machines (SVMs) are used to separate exudate and non-exudate areas. Morphological reconstruction techniques to detect the contours of exudates are proposed by T. Walter et al. [8]. D. Usher et al. [9] use a combination of RRGS and adaptive intensity thresholding to detect candidate exudate regions and a neural network is used to classify exudates and non-exudates. X. Zhang and O.Chutatape [10] use local contrast enhancement and FCM to segment candidate bright lesion areas. In one of the previous works automatic detection of optic disc and exudates was done [11].

In this present work, a method for detection of exudates in fundus photographs is proposed. The method is based on detecting areas of higher intensities, yellow color and high contrast by eliminating the blood vessels and optic disc.

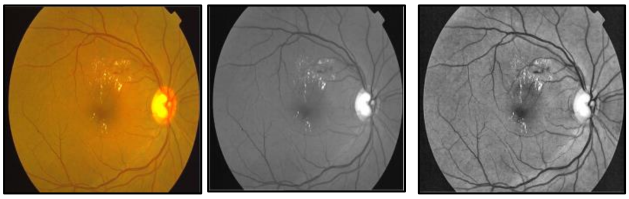
This paper is organized as follows. Section 2 introduces extraction of blood vessels using curvelet transform. Section 3 introduces optic disc extraction Section 4 describes the detection of exudates. . The experimental results are shown in Section 5.

II. DETECTION OF BLOOD VESSELS

An efficient method for extraction of blood vessels in retinal images is used to improve the detection of low contrast and narrow vessels. The proposed algorithm is composed of the following steps: contrast enhancement, curvelet-based edge extraction, and filtering.

A. Contrast Enhancement

Generally, retinal images are to be pre-processed to correct the non-uniform illumination. The low contrast of the images and the presence of noise are among these problems. The green component always has the highest contrast and contains the information that can be extracted from the fundus images. Because of that, we used the green component to extract the exudates. The contrast enhancement is applied to the green component.



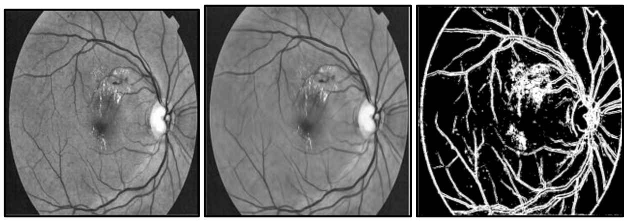
(a) (b) (c)
Fig. 2: Result of Enhancement
(a) Original Image (b) Green Component (c) Enhanced Image

B. Segmentation

Curvelet transform is a geometric multi-scale transform developed by Candès *et al* [12]. It decomposes the image into a series of high-pass and low-pass band which are the same as wavelet transform. The wavelet transform extracts directional details that capture horizontal, vertical and diagonal activity. However, curvelet transform captures the structural activity along radial 'wedges' in the frequency domain and so it has very high directional sensitivity and anisotropy. The digital implementation of this transform is based on fast discrete curvelet transform (FDCT) which uses the unequally-spaced fast Fourier transforms (USFFT).
Curvelets have several important features:

1) Curvelets are well-localized in frequency and orientation since they supported on specific wedges of the frequency domain.
2) Curvelets are also well-localized in the time domain. Since curvelets are constructed by tiling of the frequency plane.
3) Curvelet have infinite number of moments and also 'directional' moments. When a Curvelet is aligned with an edge of the image, then the modulus of its coefficient will be significant. In the case the Curvelet is essentially intersecting an edge, but not aligned with the edge, then the size of the coefficient depends on the local angle between the direction of the Curvelet function and the edge.

Then blood vessels are extracted in curvelet transform domain by removing high frequency component of image and remaining low frequency as features and, finally unwanted pixels are removed from the image using spatial filtering in the end of algorithm. Spatial Filtering is also known as neighbourhood processing. Neighbourhood processing is defined as a centre point and perform an operation (or apply a filter) to only those pixels in predetermined neighbourhood of that centre point. The result of the operation is one value, which becomes the value at the centre point's location in the modified image. Each point in the image is processed with its neighbours. Spatial Filtering of the segmented image is done with the mask defined in different orientations. This is followed by thresholding, results in the extracted blood vessels. The threshold can be varied to fine tune the output.



(a) (b) (c)
Fig. 3: Result of Segmentation
(a) Enhanced Image (b) Curvelet Transformed Image (c) Extracted Blood vessel

III. Optic Disc Detection

The optic disc is the brightest object in the healthy retinal fundus and several algorithms have been described to locate its centre and boundary. Optic disc detection must take into account the discontinuities along the boundary where blood vessels cross, as well as dramatic hue changes within the optic disc boundary, with the most extreme being due to intra-disc haemorrhage.

Grayscale image instead of the green channel is used as it is more efficient in the detection. First the maximum value for each of the columns of the image is determined before locating the largest value. The coordinates (row and column) of all brightest point(s) are then determined and the median is taken if there is more than one point.

After locating the optical disk, a mask needs to be created. A simple square mask created using loops. The mask is created in the equation for drawing circle using h and k as the coordinates (row and column) and R as the Radius.

$$R^2 = (x - h)^2 + (y - k)^2$$

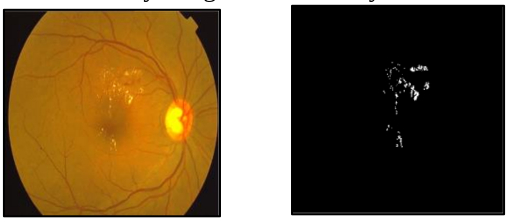
(a) (b)
Figure 4 Optic Disc detection
(a) Original image (b)Optic disc detected image

IV. Detection of Exudates

The fundus image is first pre-processed to standardize its size and the intensity of the gray scale image is then adjusted. Various features extracted are:

- Area and perimeter of the structures present in the image.
- Mean- average intensity.
- Standard deviation- average contrast.
- Relative Smoothness.
- Uniformity.

Morphological operations are applied to remove the blood vessels. The location of optic disc is detected and a mask is created to cover it as discussed before. The dilate function expands the exudates area while erode function removes the blood vessels. The image is then converted to mark the exudates region before converted back to binary with a threshold value to filter out the exudates. Non-exudates are extracted from the gray scale image and are represented as binary image after intensity inversion.



(a) (b)
Fig. 5: Detection of Exudates
(a) Original Image (b) Detected Exudates

V. RESULTS

The proposed method is tried on 20 fundus images. The result shows that the segmentation technique of the optic disc has to be improved.

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