Bio-medical imaging: Localization of main structures in retinal fundus images

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Abstract. Retinal fundus images have three main structures, the optic disk, fovea and blood vessels. By examining fundus images, an ophthalmologist can diagnose various clinical disorders of the eye and the body, typically indicated by changes in the diameter, area, branching angles and tortuosity of the three main retinal structures. Knowledge of the optic disk position is an important diagnostic index for many diseases related to the retina. In this paper, localization of optic disc is discussed. Optic disk detection is based on morphological operations and smoothing filters. Blood vessels are extracted using the green component of a colour retinal image with the help of a median filter. Maximum intensity values are validated with blood vessels to localize the optic disk location. The proposed method has shown significant improvements in results.

Introduction

Early diagnosis of retinal diseases can prevent vision loss in large populations. Currently, Diabetic retinopathy, glaucoma and age-related macular degeneration are the main diseases which can lead to blindness if not treated earlier. To detect changes in retina, image processing techniques are being developed to facilitate and share the burden of ophthalmologists in screening programs.

Many automatic methods have been developed for the localization of retinal structures (pl. see Figure 1) during the last decade because manual localization is a very time-consuming and tedious job which requires high levels of concentration, a lot of training. It takes time for an ophthalmologist to become proficiently skilled. In normal retinal fundus images, the Optic Disk (OD) is a circular shaped bright yellow structure. Blood vessels enter the eye through the OD. Location of the OD and its diameter is also important because its examination discloses information about certain diseases of the eye. Its diameter is used as a reference for detecting the macula region in the retinal image. Many methods have been proposed to find the OD location including general shape based approaches like the Hough

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transform [1], template matching [2], blood vessels convergence [3], variance of intensity [4], modified active contour [5] and so on.

Figure 1. Retinal structures: Optic Disk, blood vessels and Fovea/Macula

In this paper, an OD localization method is proposed based on two facts, firstly that the OD is located at the convergence of the main blood vessels and secondly it is the brightest part of the image. The method first segments the fundus-image to identify the main blood vessels and then uses the resultant blood vessel map to efficiently identify the brightest region and with it the OD centre.

Methodology

In retinal images the OD is the bright yellow part which lies on the widest (main) blood vessel. Steps involved in the proposed method are shown in Figure 2.

A colour fundus retinal-image is used as the input to the method, which automatically outputs the location of the OD as the result. Each colour image is processed using the raw Red, Green and Blue (i.e. RGB) colour space. It is observed that in the Green component the blood vessels are very prominent as compared to the other two components whereas in OD is clearer in the Red colour channel. So in order to find the main blood vessels the Green component is extracted to form a vessel map, this map is then smoothed using a median filter, this produces a final diffused vessel map. The vessel map is used to mask the original image, isolating the actual blood vessels to produce an actual blood vessel map. This actual blood vessel map is then used to validate the coordinates of the point selected as the location of maximum intensity. To find the location of maximum intensity the green component is first smoothed with a small median filter, large enough to usefully reduce image noise, but small enough to retain fine edge information. Typically the smoothed image will have many pixels with the same intensity, so in order to locate the OD, a median of these maximum intensity points is calculated along the x and y axes and the closest integer coordinate is selected as the
candidate centre point for the OD. The candidate point is then validated against the actual blood vessel map if the validation fails then the next best candidate point is considered. This process continues till the exact localizing point in OD is obtained. It is important to note that if this search could not find any point with the described criteria then first encountered point is considered the localization point.

![Optic disk detection steps](image)

Most of the times, program outputs a valid point whereas on a few pathological images program fails to find the actual location in the OD because in these image vessels image is not complete which diverts to incorrect localization. In future, a better vessel image extractor will be incorporate to overcome this problem.

**Results and Discussion**

In this paper, experiments on to publically available retinal databases are reported. DRIVE[6], the mostly commonly used database in this research domain, contains 40 colour images of the retina. These images are captured by a Canon CR5 3CCD camera with a 45 degree field of view (FOV), with 565×584 pixels and an 8 bit depth per RGB colour component. The database is divided into two sets, a test set and a training set with 20 images each. Four images with pathologies are included in the test set.

The DIARETDB1 [7] database contains 89 colour retinal fundus images. Eight four images have at least mild non-proliferative signs of diabetic retinopathy, and 5 are normal images with no signs of the...
diabetic retinopathy according to all experts who took part in an evaluation of the dataset. All images are captured with a 50 degree FOV using a digital fundus camera with varying settings. This dataset is referred to as "calibration level 1 fundus images". The OD is manually segmented by experts to evaluate the efficiency of algorithmic results. If the detected point is within the manually segmented image of the OD then it is considered a correct localization of the OD. Experimental results on the mentioned databases are given in Table 1. In the DRIVE database, the OD is localized in all the images successfully. In DIARETDB1 database, seven out of 89 images are not correctly localized by the proposed method. The proposed method used both intensity and blood vessels in consideration when finding the OD location. The algorithm performs excellent on DRIVE database because it does not contain severely pathological images which are present in DIARETDB1.

| Database     | No of images | Success Rate |
|--------------|--------------|--------------|
| DRIVE        | 40           | 100%         |
| DIARETDB1    | 89           | 92.13%       |

Results are compared with other methods in Table 2.

| METHOD                  | DRIVE | DIARETDB1 |
|-------------------------|-------|-----------|
| Sopharak et al. [8]     | 95    | 59.55     |
| Walter et al. [9]       | 77.5  | 92.13     |
| Stapor et al. [10]      | 85.5  | 78.65     |
| Seo et al. [11]         | 95    | 80.89     |
| Lupascu et al. [12]     | 95    | 86.51     |
| Kande et al. [13]       | 95    | 88.76     |
| Pereira et al. [14]     | 100   | 93.25     |
| Malek et al. [15]       | 100   | 89.00     |
| Proposed method         | 100   | 92.13     |

*Results of other methods are obtain from the literature.*
Retinal fundus images are a main source of diagnosis for retinal diseases. The main structures present in the retinal images are blood vessels, macula/fovea and the optic disk. Knowledge of the OD position is an important diagnostic index for many diseases. In this research work, a method is proposed to localize the OD from the retinal images based on maximum intensity locations and blood vessels. Experiments are performed on two databases which are publicly available. Proposed method shows promising results. As future work, we will include segmentation and boundary information of the OD and improve the methods by considering other properties related to the OD.

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