

Automatic Identification of Optic Disc in Retinal Fundus Images

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Abstract

The Optic Disc (OD) is a round area in the back of the eye where retinal nerve fibers collect to form the optic nerve. The OD is the entry point for the major blood vessels that supply the retina. OD attends as a revolutionary for fundus features, such as relatively constant distance between OD and macula center (Fovea). OD and Macula detection is the vital step for the automatic extraction of retinal anatomical structures for Diabetic Retinopathy (DR). Changes in OD shape and area may indicate disease processes, particularly glaucoma, and accurate identification of the disk boundary may be used to quantify changes. Besides, the distance between two center points of the OD for an individual is unique that can be used in security purpose. This paper describes a technique for identifying the boundary of the OD in fundus images of the retina, using an approach based on active contours (snakes) and mathematical morphology. For accurate boundary detection, some pre-processing of the image is essential. This pre-processing minimizes improper boundary detection due to blood vessels crossing the OD. Pre-processing techniques based on local minima detection and morphological filtering was developed. After pre-processing, the optic disk boundary was identified using an active contour. The contour was driven by a novel external image-derived field called the Gradient Vector Flow.

Keywords

Active Contours, Snakes, Segmentation, Retinal Images, Optic Disk

1. Introduction

The Optic Disc or the optic nerve head is that area of the retina where nerve fibres and blood vessels pass through the sclera. It appears in color fundus images as a bright yellowish or white region. Its shape is more or less circular, interrupted by the outgoing vessels. Sometimes the optic disc has the form of an ellipse because of a non-negligible angle between image plane and object plane. The size varies from patient to patient; its diameter lies between 40 and 60 pixels in 640×480 color photographs.

The retinal fundus images are broadly used in the diagnosis and treatment of various eye diseases in clinics. It is also one of the major resources for mass screening of diabetic retinopathy. If it is possible to automatically and quickly process a large number of fundus images it can help ophthalmologists by increasing the productivity and efficiency in clinical environment. It is the entrance region of blood vessels and optic nerves to the retina and its identification is important since it often works as a landmark and reference for the other features in the fundus image. For example, some blood vessel segmenting methods start from the optic disk [1-2, and 7]; the location of fovea is usually projected from the location of optic disk [6 and 8] and the optic disk dimensions are also used to measure abnormal features due to glaucoma.

Morphological Operators:

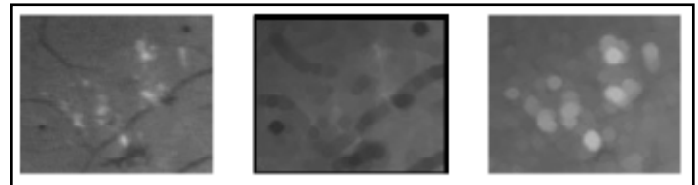
In this section we briefly define the basic morphological operators used in this paper (see [5, 9-10]).

Mathematical morphology is a nonlinear image-processing technique. The basic operators presented in this paper deal with

two-dimensional discrete images (defined on $E \subset Z^2$). Binary images are defined as subsets of E and gray scale images as functions $f: E \rightarrow T$, with $T = \{T_{\min}, \dots, T_{\max}\}$ the set of gray levels. Operators in morphology are based on the use of a “test-set” B called Structuring Element (SE). Its shape and size can be chosen according to the segmentation or filtering task.

In order to calculate the morphological erosion of a binary image A and if the structuring element centered in x fits completely into A , each point x is to be tested. If this is the case, x belongs to the eroded set εA . The dilation can be understood as an erosion of the background.

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(a) Original (b) Erosion (c) Dilation

Fig. 1: Erosion and Dilation With a Circular SE of a Retinal Image

The gray level dilation/erosion substitutes the value $f(x)$ by the maximum/minimum of f for all the pixels contained in the translated SE_{B_x} .

$$[\varepsilon^B(f)](x) = \min_{b \in B} f(x+b)$$

$$[\delta^B(f)](x) = \max_{b \in B} f(x+b)$$

Morphological openings γ^B and closings ϕ^B are the consecutive application of erosion and dilation:

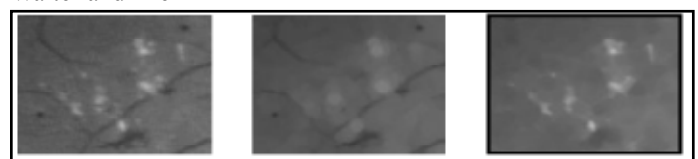
$$\gamma^B(\cdot) = \varepsilon^B \delta^B(\cdot)$$

$$\phi^B(\cdot) = \varepsilon^B \delta^B(\cdot)$$

with $B^* =$ transpose of structuring element.

In order to realize the behavior of gray scale openings and closings, it is useful to consider the image f as a topographic surface i.e. Pixels with low gray-levels correspond to valleys; pixels with high gray-levels correspond to mountains. A morphological opening removes all bright features that can't contain the structuring element; “it raises the elevations.” A morphological closing removes all dark features that can't contain the structuring element; “it fills the depressions in the surface.” The morphological opening and closing of a retinal image are shown in following fig. 1.

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(a). Original (b). Opening (c) Closing

Fig. 2: Opening and Closing of a Retinal Image With a Structuring Element

III. Algorithm Based on Morphological Operators

After comparing several color spaces, it is found that the contours of the optic disc to appear most continuous and less disturbed by the outgoing vessels in the red channel f_r for the RGB color space. As the red channel has a very small dynamic range and as the optic disc belongs to the brightest parts of the color image, it is more reliable to work on the luminance channel f_r to the HSL color space to localize the optic disc and on f_r to find its contours.

As the approximate size of the optic disc is known and also parts of it belong to the brightest parts of the image f_r a simple area threshold has been applied to obtain a binary image b that contains some parts of the optic disc as well as bright appearing pathologies like exudates. Exudates are not very big, and they are far from reaching the size of the optic disc. Hence, the biggest particle of the image b coincides with one part of the optic disc. Its centroid c that can be calculated as the maximum of the discrete distance function of the biggest particle of b can be considered as an approximation for the locus of the optic disc.

In a first step we filter the image f_r in order to eliminate large gray level variations within the papillary region. First we "fill" the vessels, applying a simple closing with a circular structuring element. In order to remove large picks morphological opening has been used. As this filter alters the shape of the papillary region considerably, the image has been reconstructed.

In order to detect the contours of the optic disc the classical watershed transformation [11] has been applied to the gradient of the filtered image with c as internal marker and a circle among c with radius bigger than the diameter of the papilla as external marker.

IV. Result

The algorithm has been tested on 100 color fundus images of size 640×480 containing various pathologies. In all images, the optic disc has been localized with the proposed technique. The diameters of optic disc for different images vary from 45 to 65 pixels. The segmented optic disc from a given fundus image is shown in fig. 3. Fig. 3(a) shows the converted gray level image from an input RGB fundus image, fig. 3(b) provides the input image in red channel as in this channel the optic disc becomes brighter comparing to the other macula region, fig. 3(c) shows the optic disc after segmentation using basic morphological techniques. In the image shown in fig. 3(c), some gaps around the contour have been found because of the vessels generated from the optic disc. Fig. 3(d) provides us the final segmented optic disc after filling up those gaps.



(a). Input Gray Image (b). Image in Red Channel
(c). Segmented OD (d). OD After Filling up the Vessel Gaps
Fig. 3: Result of Segmented Optic Disc (OD) for a Given Fundus Image

V. Conclusion

A computer assisted automated process to detect the optic disc from the retinal fundus images is described in whole paper. It is the more simple process compare to the other techniques already established. These would be used in a screening clinic to identify at-risk patients. Images are collected from various ophthalmologists from different medical institute. This method has been developed to separate the normal from the abnormal images; this has been done with reasonable success. Future work is directed in two directions: accumulating further data and developing more robust and accurate methods of processing this highly variable data.

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