Optic Disc Localization in Ocular Fundus Images

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ABSTRACT
This paper presents a novel approach to the fast localization and extraction of optic disc from fundus images of the human retina. Optic disc continues to be a major landmark for fundus image registration and is indispensible for the understanding of retinal fundus images. For the detection of optic disc, we first decompose the image into its bit planes. The lower order bit planes are found to carry important information of the location of optic disc. Then we find the exact location by means of mathematical morphology.

The algorithm has been tested on a subset of MESSIDOR[1] image database with various visual qualities. Robustness with respect to the changes of the parameters of the algorithm has been evaluated.

General Terms
Digital Image Processing, Mathematical morphology, Fundus images, Bit plane decomposition, Optic disc

Keywords: Image processing, Optic disc localization, Bit plane decomposition, Mathematical morphology

1. INTRODUCTION
Automatic localization of optic disc is indispensible in all image processing applications with fundus images. It is essential for the detection of exudates, because the optic disc has similar attributes in terms of brightness, color and contrast, and most algorithms make use of these characteristics for the detection of exudates. The detection of exudates is the key in identifying *Diabetic Retinopathy* from fundus images, which is a major cause of blindness today. Over and above that, the optic disc can be seen as a landmark or reference and it can be used for a coarse registration of retinal images in order to reduce the search space for a finer one. Furthermore, its detection is a first step in understanding ocular fundus images [5]. The diameter of the optic disc delivers a calibration of measurements that are done and it determines approximately the location of macula, the centre of vision, which is of great importance, as lesions in the macular region can affect vision immediately.

2. THE OPTIC DISC
The optic disc is the entrance of the vessels and the optic nerve into the retina. 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 [5].

[1] With permission from the providers.

BACKGROUND
The optic disc is localized by means of its high grey level variation in [2]. This works well, if there are no or only few pathologies like exudates that also appear very bright and are also well contrasted. However no method is suggested for the detection of the contours.

In [7], an area threshold is used to localize the optic disc. The contours are detected by means of the Hough transform, i.e., the gradient of the image is calculated, and the best fitting circle is determined. This approach is quite time consuming and it relies on conditions about the shape of the optic disc that are not always met. Sometimes, the optic disc is not even visible entirely in the image plane, and so the shape is far from being circular or even elliptic[5].

The approach in [8] is a Hough transform based method to detect the contours of the optic disc in infrared and argon-blue images. Obviously, some improvements have been made, but problems have been stated if the optic disc does not meet the shape conditions (e.g., if it lies on the border of the image) or if contrast is very low.

In [6], the optic disc localization problem is addressed by back tracing the vessels to their origin. This seems to be one of the most attractive ways to localize the optic disc, but it has to rely on vessel detection. It is desirable to separate segmentation tasks in order to avoid an accumulation of segmentation errors and to save computational time (the detection of the vascular tree is particularly time consuming).

The method used in [4] is morphological filtering techniques and active contours are used to find the boundary of the optic disc, while ,in [1], an area threshold is used to localize the optic disc and the watershed transformation to find its contours. However, shape irregularities due to segmentation errors, particularly in the context of outgoing vessels or in low contrast could not have been eliminated. Also in [5], a similar approach is used. But the algorithm fails when contrast is too low or the red channel is saturated.

3. LOCATING THE OPTIC DISC
3.1 Bit plane Decomposition

Separating a digital image into its bit planes is useful for analyzing the relative importance played by each bit of the image.

Instead of highlighting gray level images, highlighting the contribution made to total image appearance by specific bits is examined here. In an 8 bit gray level image, each pixel in an image is represented by 8 bits. The image is composed of 8, 1-bit planes ranging from bit plane 0 (LSB)to bit plane 7 (MSB). In terms of 8-bits, plane 0 contains all lowest order bits in the bytes comprising the pixels in the image and plane 7 contains all higher order bits. Thus bitplane decomposition of an 8 bit image yields eight binary images.

In general, the higher order bit planes contain a majority of visually significant data while the lower order ones contribute to more subtle details in an image . On examining the eight bit planes of the fundus image , the lower order bit planes are found to carry significant information regarding the location of the optic disc .

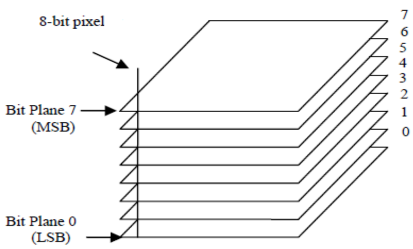

Figure 1. Bit plane Decomposition

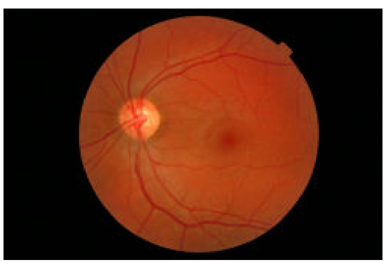

Figure 2. Original RGB Image

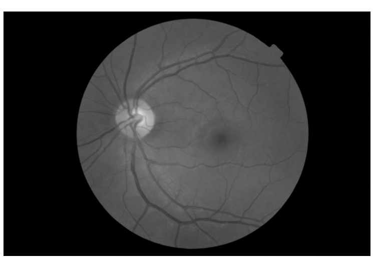

Figure 3. Grayscale Image

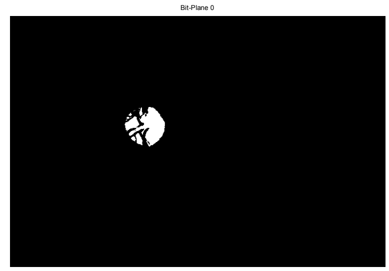

Figure 4. Bitplane 0

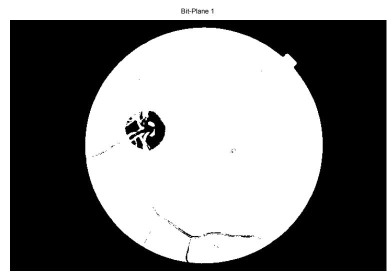

Figure 5. Bitplane 1

3.2 Mathematical morphology

Mathematical morphology deals with non-linear processes which can be applied to an image to remove details smaller than a certain reference shape called the structuring element. The most widely used morphological operations used in image processing are dilation, erosion, opening and closing. Binary images are best suited for performing morphological operations. The images obtained after bit plane decomposition are binary images, which are thus suitable for performing morphological operations. Note that bit planes 0 and 1 contain the most significant information regarding the location and shape of the optic disc .

Dilation is an operation in which the binary image is expanded from its original shape. The amount of expansion is controlled by the structuring element. The dilation process is similar to convolution, in which the structuring element is reflected and shifted from left to right and then from top to bottom. In this process, any overlapping pixels under the centre position of the structuring element are assigned with 1 or black values. If X is the reference image and B is the structuring element, the dilation of X by B is represented as

$$X \oplus \mathrm{B} = \left\{ Z \middle| \left[(\hat{B}) Z \cap X \right] \subseteq X \right\}$$

Where $\hat{B}$ is the image B rotated about the origin. When an image X is dilated by a structuring element B, the outcome element Z would be that there will be at least one element in B that intersects with an element in X

Erosion is a thinning operator that shrinks an image. The amount by which shrinking takes place is determined by the structuring element. Here, if there is a complete overlapping with the structuring element, the pixel is set white or 0. The erosion of X by B is given as

$$X \Theta \mathrm{B} = \left\{ Z \middle| \left[(\hat{B})_Z \right] \subseteq X \right\}$$

In erosion, the outcome element Z is considered only when the structuring element is a subset or equal to the binary image *X*.

Opening operation is done by first performing erosion, followed by dilation. Opening smoothens the inside of object contours, breaks narrow strips and eliminate thin portions of the image. It is mathematically represented as

$$X \circ \mathrm{B} = (X \Theta B) \oplus B$$

Closing operation does the opposite of opening. It is dilation followed by erosion. Closing fills small gaps and holes in a single pixel object. The closing process is represented by

$$X \bullet \mathrm{B} = (X \oplus B) \Theta B$$

Closing operation protects coarse structures, closes small gaps and rounds off concave corners.

Morphological operations are widely used in the detection of boundaries in a binary image. For an image X , the following can be applied to obtain a boundary image

$$Y = X - (X \Theta B)$$

$$Y = (X \oplus B) - X$$

or

$$Y = (X \oplus B) - (X \Theta B)$$

Where, the operator '$\oplus$' denotes dilation , '$\ominus$' denotes erosion and '$-$ ' indicates the set theoretical subtraction.

4. THE METHODOLOGY

We first converted the RGB image obtained from the fundus camera to an equivalent grayscale image using the Matlab function '*rgb2gray'*. Now bit plane decomposition is performed on the gray scale image to decompose it into its bit planes. The lower order bit planes are preserved for further processing and the higher order ones are discarded. Figure 4 and Figure 5 shows bit plane 0 and bit plane 1 respectively of a representative image. Bit plane 0 is now dilated by a disc structuring element to obtain a clear white region corresponding to the optic disc as shown in Figure 6.

A suitably processed bit plane 1 can be used to compensate for errors, if any, in the previous operation. The most severe errors in this stage are found to be at the optic nerve head for certain images. Also deformities can be seen corresponding to the interface of the vasculature with the optic disc boundary.

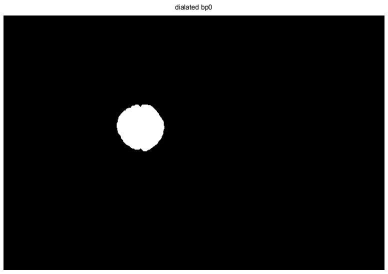

Figure 6. Dilated Bit plane 0

The matlab function '*bwperim*' is made use of for obtaining the outline of the Optic Disc. This outline is subsequently dilated by a disc shaped structuring element to obtain an image as shown in Figure 7

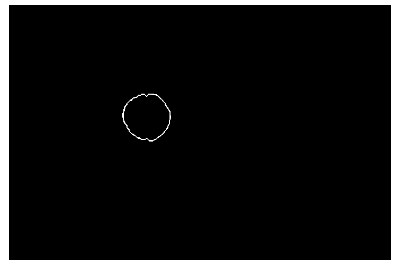

Figure 7. Dilated Outline

At this stage, the dilated outline can be superimposed on the original fundus image to obtain a clearly marked view of the Optic Disc. The result is as shown in Figure 8

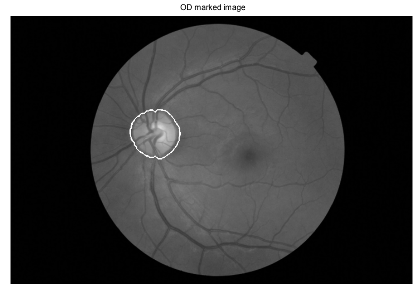

Figure 8. Localized Optic Disc

The algorithm is implemented in Matlab version 7.6 (R2008a) and is found to be reasonably fast than the existing computationally intensive methods.

5. RESULTS AND DISCUSSION

The algorithm has been evaluated on more than 50 images of the MESSIDOR[1] image database with various visual qualities. The database has been established to facilitate studies on computer-assisted diagnoses of diabetic retinopathy. The algorithm is found to be superior to the existing algorithms in terms of computational time and accuracy. It has high value in clinical practice for automatic screening of early diabetic retinopathy. Our algorithm successfully identifies 43 optic discs out of 50 images (including training and testing sets) meaning an average accuracy of 86%. We also tested the algorithm on images with serious anomalies like *macular edema* and of different retinopathy grades. Our algorithm demonstrates its strong ability to differentiate the true optic disc from bright lesions. This technique works pretty well even if the input image is a low-contrast one.

6. ACKNOWLEDGMENTS

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