AUTOMATIC LOCATION OF OPTIC DISK IN RETINAL IMAGES

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ABSTRACT

On the research work leading to automatic analysis of retinal fundus images the knowledge of optic disk location is very essential, and a new method to automatically locate optic disk is proposed in this paper. The candidate regions are first determined by clustering the brightest pixels in intensity image. Principal Component Analysis (PCA) is then applied to these candidate regions. The minimum distance between the original retinal image and its projection onto "disk space" is located as the center of optic disk. The algorithm has been tested and compared with another commonly used method and the results show that the method proposed here can automatically provide more acceptable location of the optic disk.

1. INTRODUCTION

The retinal fundus photographs are widely used in the diagnosis and treatment of various eye diseases in clinics. It is also one of the main resources for mass screening of diabetic retinopathy. Being able to automatically and quickly process a large number of fundus images can help ophthalmologists increase the productivity and efficiency in clinical environment. The optic disk is the brightest part in the normal fundus image that can be seen as a pale, round or vertically slightly oval disk. It is the entrance region of blood vessels and optic nerves to the retina and its detection is essential since it often works as a landmark and reference for the other features in the fundus image. For instance, some blood vessel tracking methods start from the optic disk [1-3]; the location of fovea is usually estimated from the location of optic disk [4] and the optic disk dimensions are also used to measure abnormal features due to glaucoma.

There are two strategies of retinal fundus image analysis. One is bottom-up processing which is applied to the detection of optic disk by many research groups. In this approach the optic disk is identified by the largest area of pixels having highest gray level in the images [1]. The method works well in normal fundus images. While processing the images with a large area of exudates, it will give the wrong location since the color and intensity of exudates are similar to optic disk. Another strategy called top-down processing is also implemented in this paper as a model-based method to locate the optic disk automatically. The proposed method combines the two strategies. First, the candidate regions are determined by the bottom-up processing. Then the PCA (Principal Component Analyses) based model approach is applied to the candidate regions to give the final location of optic disk.

2. LOCATION OF OPTIC DISK

Since the intensity of optic disk is much higher than the surrounding retinal background, a common method of optic disk localization is to find the largest cluster of pixels with the highest gray level. This algorithm is simple, fast and works well in the fundus images that the area of exudates is not large and optic disk is not obscured by the blood vessels. In order to have better success rate in all cases, a new method is proposed in this paper by using the PCA to detect the optic disk. This detection is accurate but more time consuming compared with the first method. The advantages of the two methods are combined here by first applying a simple clustering method on the intensity image to find the candidate regions where optic disk may appear and then PCA is applied only on these candidate regions to locate the optic disk.

2.1. Candidate regions determination

The pixels with the highest 1% gray levels in intensity image are selected. A clustering mechanism is used to assemble the nearby pixels into clusters. The clusters having centroids within a specified distance are combined to one cluster. If the number of the pixels in a cluster is less than 100 after combination, the cluster is abandoned. Finally all the remaining clusters are candidate regions. As the diameter of optic disk is in the range of 65~100 in the retinal image of 512×512 pixels, each candidate region is defined as a square of 120×120 pixels with the centroid of the cluster as the center. Figure 1 illustrates some examples of candidate regions determined by this

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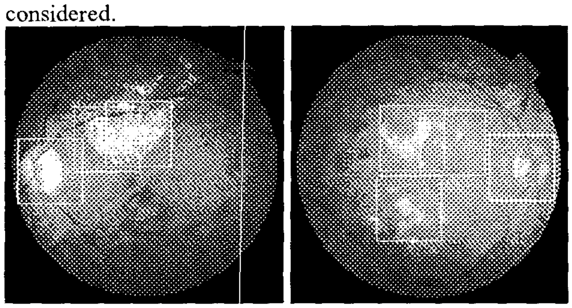
algorithm. The possibility to miss the optic disk decreases when not only the cluster with the largest area but all the clusters with individual area greater than 100 pixels are considered.



(a) (b)

Figure 1. Examples of candidate regions.

2.2. PCA method.

The information of blood vessels is considered rather than ignored in the location of optic disk. PCA based model has been widely investigated in the application of face recognition [5]. The problem of optic disk location is similar to face detection in certain respects in that both of them can be supported by knowledge-based methods. The approach includes calculating the eigenvectors from the training images, projecting the new retinal image to the space specified by the eigenvectors and calculating the distance between the retinal image and its projection. The center of optic disk is located at the point with the minimum distance.

The significant features (eigenvectors) of optic disk are obtained by PCA method. The training images of optic disk are intensity images of the size N×N. These are acquired by cropping a square image around optic disk from the retinal image manually and resizing them to N×N. The intensity of the training images is adjusted linearly to the same output range to eliminate the illumination difference between each image. The image can also be considered as a vector of dimension N^2 where N is set to 90 according to the size of optic disk. The training set of optic disk images is denoted as vector Γ_1, Γ_2, ... Γ_M, where M is the number of training images. Training images of right eyes are flipped horizontally to get their symmetrical images that can be calculated together with the images of the left eyes. The average image of the training set is defined by

$$\Psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i \qquad (1)$$

The vector Φ_i denotes the difference between the training image and the average image.

$$\Phi_i = \Gamma_i - \Psi \qquad (2)$$

The vector u_i and λ_i are the eigenvector and corresponding eigenvalue of the covariance $N^2 \times N^2$ matrix C:

$$C = \frac{1}{M}\sum_{i=1}^{M}\Phi_i\Phi_i^T = AA^T \qquad (3)$$

where $A=[\Phi_1\ \Phi_2\ \ldots\Phi_M]$. When M is less than N^2, the eigenvectors u_i of C can be obtained by computing the eigenvectors of an M × M matrix A^TA. Assuming v_i is the eigenvector of A^TA such that

$$A^TA\, v_i=\mu_i v_i \qquad (4)$$

Av_i is the eigenvector of C, which can be seen by pre-multiplying both sides of equation (4) by A:

$$AA^TA\, v_i=\mu_i A\, v_i \qquad (5)$$

The eigenvector u_i of C can be calculated based on the eigenvector v_i of M×M matrix A^TA. The subspaces defined by the eigenvector u_i is called as "disk space" and eigenvector as "eigen disk". The eigenvector u_i is a linear combination of the original training-image vectors and arranged in descending order according to its associated eigenvalue. In the application, the M′ (M′<M) most significant eigenvectors as determined by their eigenvalues are enough to represent the training set of images as shown in figure 2. The average image of the training set and the first six "eigen disks" are shown in the figure 3 and figure 4 respectively.

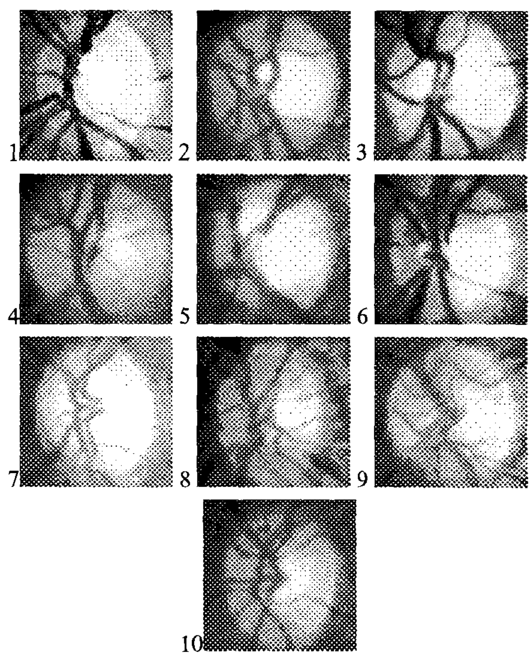


Figure 2. Training set of images. The first five images are mirror images of right eyes. The last five images are obtained from the left eyes.

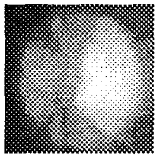


Figure 3. The average image Ψ of the training set of images.

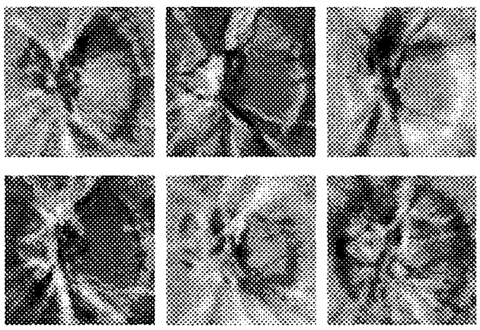


Figure 4. First six "eigen disks" obtained by applying PCA to the training set.

The N×N subimage Γ is obtained by cropping an N×N square with the center pixel (x, y) and its intensity adjusted linearly to the same output range of the training image. To project the subimage Γ to "disk space", the mean image Ψ should be subtracted first as equation (2): $\Phi=\Gamma-\Psi$. The subimage Γ is projected onto the "disk space" by the following transformation:

$$w_k = u_k^T(\Gamma-\Psi) \qquad k=1,2,\ldots,M' \tag{6}$$

The vector of weights $\Omega^T=[w_1, w_2, \ldots, w_{M'}]$ describes the contribution of each "eigen disk" while representing the newly input subimage by the "eigen disk". The input subimage can be reconstructed as Γ_p

$$\Gamma_p = \Psi + \sum_{i=1}^{M'} w_i u_i \tag{7}$$

The distance between the original image and its projection (reconstruction) onto the "disk space" is calculated to measure the likeness of optic disk. The point with the acceptably small distance indicates the existence of optic disk. Denoting Φ_p as the projection of Φ onto "disk space", the Euclidian distance E at pixel (x, y) is calculated as:

$$\begin{aligned} E^2 &= \|\Phi-\Phi_p\| \\ &= (\Phi-\Phi_p)^T(\Phi-\Phi_p) \\ &= \Phi^T\Phi - \Phi^T\Phi_p - \Phi_p^T\Phi + \Phi_p^T\Phi_p \\ &= \Phi^T\Phi - \Phi_p^T\Phi_p - \Phi^T\Phi_p + \Phi_p^T\Phi_p - \Phi_p^T\Phi + \Phi_p^T\Phi_p \\ &= \Phi^T\Phi - \Phi_p^T\Phi_p - (\Phi-\Phi_p)^T\Phi_p - \Phi_p^T(\Phi-\Phi_p) \end{aligned} \tag{8}$$

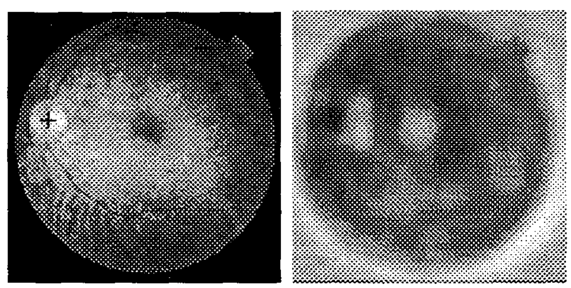
As Φ_p is the projection of Φ onto the "disk space", $\Phi_p \perp (\Phi-\Phi_p)$, which means $(\Phi-\Phi_p)^T\Phi_p$ and $\Phi_p^T(\Phi-\Phi_p)$ are both equal to zero. Φ_p can be expressed as the linear combination of eigenvectors from equation (7), that is $\Phi_p = \sum_{i=1}^{M'} w_i u_i$. Hence $\Phi_p^T\Phi_p = \sum_{i=1}^{M'} w_i^2$. The computation of Euclidian distance E in equation (8) can be simplified as

$$E^2 = \Phi^T\Phi - \sum_{i=1}^{M'} w_i^2 \tag{9}$$

The pixel with the smallest E in the retinal image is located as the center of optic disk.

3. RESULTS AND DISCUSSION

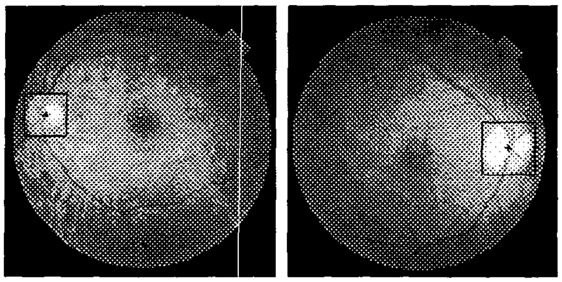
PCA method is applied to each pixel in the input retinal image. The location result and the distance map E of the input retinal image are shown in figure 5. Figure 5(a) is the original image and final location result. Figure 5(b) illustrates the distance map E. The darkest point in the figure 5(b) represents the location of optic disk.



(a) (b)

Figure 5. (a) is the optic disk location result where '+' indicates the location of optic disk. (b) is the Euclidian distance map E of the input image, where the darkest point represents the location of optic disk.

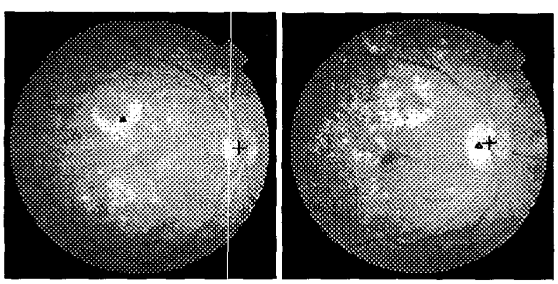
The computation is quite time consuming if the distance of all the pixels in the image is calculated as figure 5(b). In this paper only the distance of pixels belonging to the candidate regions are computed. According to the position of the candidate region, the "disk space" of left eye or right eye is used in the calculation. The "disk space" of the right eye is the horizontal symmetry of the "disk space" of the left eye shown in figure 4. PCA method with different scale (0.8~1.1) is applied to each pixel in the candidate regions of the input retinal image. The pixel with the minimum distance E in all the candidate regions and among all the scales is located as the center of optic disk. The approximate size of the optic disk in the testing image can also be gained according to the scale factor with which the minimum distance is obtained. More than forty retinal images obtained from the clinic have been tested by the proposed algorithm. Some location results of optic disk by PCA method are illustrated in Figure 6. The primary experimental result shows that the proposed algorithm is successful in the tested images and can give the sufficiently accurate location of optic disk.



(a) (b)

Figure 6. Location of the optic disk in the retinal fundus images. (a) is a retinal image of the left eye, diameter of optic disk: 80, while (b) is a retinal image of the right eye, diameter of optic disk: 100.

Compared with the location of optic disk as the centroid of the largest cluster of brightest pixels [1], the proposed algorithm achieves more accurate result. The method of centroid of largest cluster gives the wrong location of optic disk when processing the retinal image with large area of exudates, while PCA method can obtain the correct location. Illustration can be seen in figure 7(a). The location of optic disk by centroid of largest cluster in some other images deviates to the bright side of optic disk, which can be shown in figure 7(b). The proposed method improves the precision of the automatic location of optic disk in the color retinal image.



(a) (b)

Figure 7. Comparison of the location of optic disk by PCA method with centroid of the largest cluster. '+' indicates the location of optic disk by PCA method and 'Δ' presents the location by the centroid of the largest cluster of the brightest pixels.

4. CONCLUSION

A new method is proposed in this paper to detect the optic disk automatically and correctly in the color retinal images. The candidate regions are defined by clustering the brightest pixels in retinal image. PCA method with different scaling factors is applied to the candidate regions to find the minimum distance between the original input image and its projection onto the "disk space". The center of optic disk is located at the point with the minimum distance in the candidate regions among all the scaling factors. The approximate size of optic disk can also be obtained during the processing. The comparison between the proposed method and other method was also performed. The experimental results demonstrate that the proposed algorithm is more robust especially with the presence of large area of light lesions.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] S. Tamura, Y. Okamoto and K. Yanashima, "Zero-crossing Interval Correction in Tracking Eye-fundus Blood Vessels", *Pattern Recognition*, Vol. 21, No.3, pp.227-233, 1988.

[2] O. Chutatape, Z. Liu and S. M. Krishnan, "Retinal Blood Vessel Detection and Tracking by Matched Gaussian and Kalman Filters", *Proceedings of 20th Annual International Conference-IEEE/EMBS*, pp.3144-3148, Hong Kong, Oct.29-Nov.1, 1998.

[3] G. Zahlmann, B. Kochner, I. Ugi, D. Schuhmann, B. Liesenfeld, A. Wegner, M. Obermaier and M. Mertz, "Hybrid Fuzzy Image Processing for Situation Assessment", *IEEE Engineering in Medicine and Biology*, pp.76-83, January/February 2000.

[4] C. Sinthanayothin, J. F. Boyce, H. L. Cook, T. H. Williamson, "Automated Location of the Optic Disk, Fovea, and Retinal Blood Vessels from Digital Colour Fundus Images", *British Journal of Ophthalmology*, Vol. 83(8), pp.902-910, August 1999.

[5] M. Turk and A. Pentland: Eigenfaces for recognition. *Journal of Cognitive Neuroscience*, Vol.3, No.1, pp.70-86, 1991.