

Automatic detection of peripapillary atrophy in retinal fundus images using statistical features



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ABSTRACT

The presence of peripapillary atrophy (PPA) is associated with two kinds of diseases, namely glaucoma and myopia. PPA is one of the characteristics of these diseases that can be observed through retinal fundus images. We propose an automatic detection method of PPA in retinal fundus images using statistical features and Backpropagation Neural Network. In this research, those images are classified into two classes: no-PPA and PPA. The features are extracted from the focal areas, which capture the areas where PPA may occur in each sector. There are three features used in this method namely, standard deviation, smoothness and third moment; they are selected using gain ratio method. The performance of the proposed method achieves the accuracy of 0.95, 0.96, and 0.96 for three different datasets. These are obtained using 155 retinal fundus images, from which training and testing data of 47 images and 108 images, respectively, are randomly selected.

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1. Introduction

Peripapillary atrophy (PPA) is the loss condition of retinal pigment epithelium and choriocapillaris [1] located on the retina. The presence of PPA is associated with two kinds of diseases, namely glaucoma [1,2] and myopia [3–5]. Moreover, PPA is one of the characteristics of these diseases that can be observed by fundus images [1,6]. Glaucoma and myopia are diseases that may cause blindness. Glaucoma is the second largest cause of blindness in the world and it is an incurable disease [7]. Myopia is a disease widely suffered by both children and adults.

PPA is an area that has a distinctive texture, visually tends to be white. It lies adjacent to the outer boundary of optic nerve head (ONH) and is described as a bright rounded area. Visually, the shape of PPA can be illustrated as a crescent moon, while in several cases the shape looks like ring because it appears around the ONH. Based on the texture, PPA is categorized into two types: mild and severe. The first row in Fig. 1 shows several examples of original fundus

images, while the second row depicts the fundus images focused on the ONH. These focused images show the difference between areas with and without PPA. For more details, Fig. 1(a) shows the fundus image with no-PPA, Fig. 1(b) mild-PPA, while Fig. 1(c) and (d) severe-PPA.

A fundus image is divided into four sectors related to the center of the ONH: inferior (I), superior (S), nasal (N), and temporal (T). Sectors I and S are located at the bottom and top, respectively. Sectors N and T are located on the right and left depending on the eye. In right eyes, sector N is located on the right side and sector T is on the opposite side, and vice versa for left eyes. The location of each sector (I–S–N–T) is shown in Fig. 2.

Based on the experience of ophthalmologists, the presence of PPA often begins at sector T. However, PPA may appear in more than one sector, and even in all sectors. Although an ophthalmologist is able to detect the presence of PPA easily, in certain cases, such as the appearance of mild-PPA or a bulk work of many fundus images, manual detection will take longer and the result of the detection may become subjective. Methods and techniques for computer aided detection of PPA are being researched.

The detection of PPA requires several steps: localization and segmentation of ONH as the preliminary steps, features extraction, and classification. Regarding localization of ONH, several researchers used thresholding based on the green channel as the common method [8–10]. Associated with segmentation of ONH, several approaches have been proposed, such as threshold-based used

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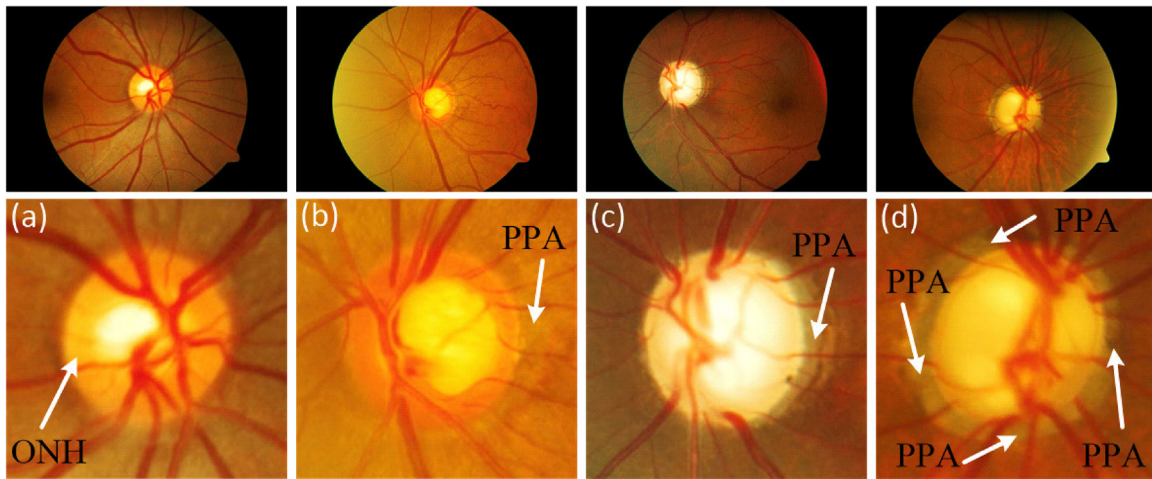


Fig. 1. Several examples of fundus images that show the presence of PPA: (a) no-PPA, (b) mild-PPA, and (c), (d) severe-PPA.

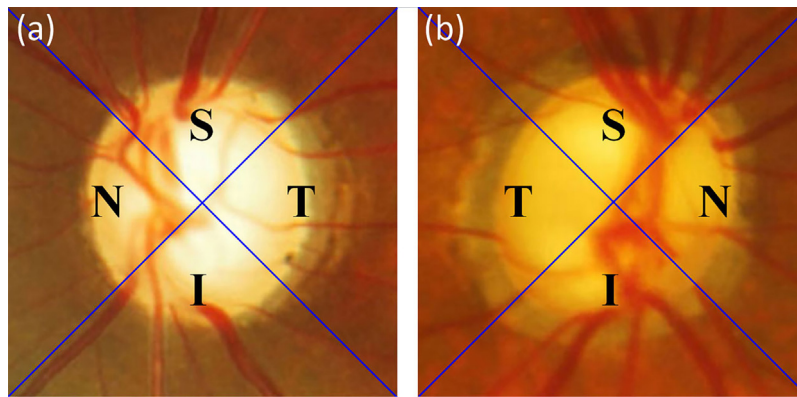


Fig. 2. The location of sectors I, S, N, and T: (a) left eye and (b) right eye.

in [11,9,12], active contour-based developed in [10,13,14], super-pixel discussed in [15,16], region growing implemented in [17,18], and the clustering method implemented in [19,20] by using FCM algorithm while in [14] by using K-Means algorithm. This process is required because ONH area is an area that is ignored or considered as background in this case.

The presence of blood vessels may lead to misclassification. In order to reduce its influence, several researchers performed blood vessel inpainting before the features extraction process. Methods that are commonly used for blood vessel inpainting include morphological operations used in [21,22], black top-hat transformation based on green channel used in [19], edge detection using Canny operation based on green channel used in [17], and thresholding based on blue channel used in [11].

Currently, there are only a few researches related to the detection of PPA. Some of these proposed methods of features extraction are based on the texture features since the area with PPA has a different texture from that with no-PPA. A combination of several techniques was proposed in [23], which consists of scanning with filter size 1×3 , thresholding and region growing that are performed based on red and blue channels to increase the difference between the areas of PPA and non-PPA. Gray level co-occurrence matrix (GLCM) is used in [24] to obtain the features by initially resizing the Region of Interest (ROI) of 600×600 -pixel images into 150×150 -pixel ones, then reducing the grayscale from 256 to 32 levels. In [25], features extraction is performed by using thresholding method in hue layer; this begins with transforming the color space of red green blue (RGB) to hue saturation value (HSV). Elimination of PPA was proposed in [26] using edge filter-

ing and constraint elliptical Hough transform to form the boundary between the areas of non-PPA and PPA.

Entropy analysis was carried out in [27] to obtain the features of PPA; this analysis was based on the blue channel to make the area of PPA clearer. On the other hand, pixel neighborhood technique of size 9×9 pixels was applied in [28] to do the same thing. Biologically inspired features were proposed in [29] to obtain three types of features, namely intensity units, colors units, and C1 units. Firstly, the intensity units are formed by dyadic Gaussian pyramid method as a hierarchy of low-pass filtered versions of the original image. The color units are formed based on the red, green, blue and black colors by dyadic Gaussian pyramids method as well. C1 units are formed using Gabor function method. The scan-line method was proposed in [21] to obtain several statistical values based on gray color images.

In several researches, the features extraction of PPA is performed gradually based on the location of the sectors (I-S-N-T) [25,26,28]. This aims to follow the workings of ophthalmologists, where they detect the presence of PPA based on its location in a particular sector.

In the last step of PPA detection, a classification process is required to determine the presence or absence of PPA on the fundus images. Several kinds of machine learning are used in this process. Support Vector Machine (SVM) is used in [27] to obtain the optimal results. Several methods, namely K-Nearest Neighbors (KNN), Linear Discriminant Classification (LDC) and SVM, were tested in [21,29]. These researchers showed that the optimal result is obtained by SVM method.

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