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Automated detection and segmentation of drusen in retinal fundus images☆

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ABSTRACT

The druse, an abnormal yellow/white deposit on retina, is a dominant characteristic of age-related macular degeneration (AMD) which is a retinal disorder associated with age. The early detection of drusen is useful for ophthalmologists to diagnose the patients that suffer from AMD. An automated method has been proposed in this work to detect and segment drusen using retinal fundus images by (i) gradient based segmentation to find true edges of drusen, (ii) connected component labeling to remove suspicious pixels from drusen region and (iii) edge linking to connect all labeled pixels into a meaningful boundary. The proposed method outperforms other existing methods in detection of drusen with an accuracy/sensitivity/specificity of 96.17/89.81/99.00 on two publicly available retinal image databases. In order to grade the severity of AMD, the detected drusen by the proposed method are further quantified into small, intermediate and large with an accuracy of 88.46, 98.55, and 88.37%, respectively.

1. Introduction

Age-related macular degeneration is a chronic irreversible medical condition characterized by drusen. Worldwide, AMD is the third most leading cause of irreversible vision loss in persons over the age of 50 [1]. If it is not detected and treated in time, it may cause total blindness. There are mainly two types of AMD: dry and wet. Most of the people, around 90%, with macular degeneration are affected by dry AMD, which causes lack of functioning of visual cells due to the presence of drusen on retina [2, 3]. An increase in number of drusen is a prominent symptom of dry AMD and used as a marker to detect the risk of AMD [4]. Therefore, a new methodology for more accurate detection of drusen has been proposed in the presented work.

Drusen are fatty deposits that appear as yellowish, cloudy bright blobs in retinal fundus images. They exhibit no specific size or shape [2, 5]. The modification in the size of individual drusen and their confluence indicates the development of macular degeneration disease. The severity level of macular degeneration is judged on the basis of the size of drusen and visibility of its boundaries in Wisconsin AMD grading system. The literature survey reveals that drusen can be classified as hard or soft [6] as shown in Fig. 1(a) and (b), respectively. Soft drusen are further classified as distinguishable and indistinguishable [4– 6]. Hard drusen appear smaller in size with sharper definition as compared to soft drusen that have fuzzy boundaries. Therefore, the accurate identification of boundary of drusen is a challenging task.

Drusen and their boundaries can be detected in retinal fundus images by trained clinicians with manual evaluation procedures [4] whereas biomedical researchers use automatic/semiautomatic methods to detect them. The automatic/semiautomatic

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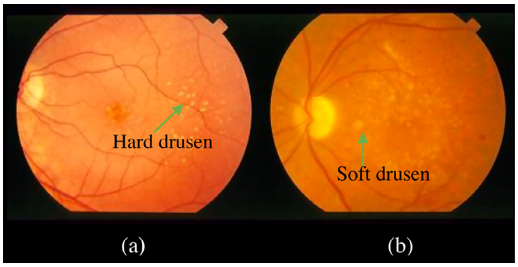

Fig. 1. Types of drusen, (a) hard drusen; (b) soft drusen.

methods proposed by several researchers to detect drusen are briefly summarized in Table 1. Mora et al. proposed drusen modeling and a gradient based segmentation approach to detect drusen [10]. They validated their method with twenty-two images and achieved a sensitivity of 68%. Bhuiyan et al. developed a drusen detection method using local intensity distribution, adaptive intensity thresholding and edge information [15]. They validated their method with twelve images and achieved a sensitivity of 74.94%. Grinsven et al. proposed a machine learning based method for AMD diagnosis. They achieved a sensitivity of 85% [16]. Prasath and Ramya proposed a method for drusen detection and validated with the dataset of forty images showing achieved results with only one performance measure. [19]. Kumari and Mittal validated their drusen detection method with thirty six images showing 95% sensitivity [20]. In a nutshell, the major limitations of existing works on drusen detection are the validation of methods on limited dataset with moderate performances in terms of sensitivity/accuracy, inaccurate drusen detection and insufficient information regarding quantification of drusen. Therefore, in the present work, a new method for drusen detection is proposed by (i) finding true edges of drusen using gradient based segmentation, (ii) removing suspicious pixels from drusen regions using connected component labeling and (iii) connecting detected edge pixels into a meaningful boundary using edge linking. The major highlights of the method are its validation on larger datasets resulting in comparatively higher sensitivity/accuracy than other methods, accurate detection of drusen boundaries with 99% specificity and categorization of detected drusen on the basis of size, area and number of drusen present in an image, contributing in early diagnosis of AMD especially through telemedicine for the people in rural areas.

The method comprises of three phases: in the first phase bright regions are enhanced followed by the noise removal in the retinal fundus images; in the second phase, regions of drusen are detected by suppressing the spurious regions; in the third phase boundary of drusen is detected by the edge linking procedure. In the last, the performance of proposed method is evaluated by (i) statistical measures and (ii) quantification of drusen to grade severity of AMD.

The rest of the paper is organized as follows: experiment materials for this paper are introduced, the proposed method are described in details and statistical measures to evaluate the proposed method are presented in Section 2, experimental results are showed, described and compared with other algorithms in Section 3, while conclusion is drawn in Section 4.

2. Materials and method

Materials:

The retinal fundus images for the present study have been taken from open-source benchmark databases that are available online. The databases used in the study are (i) Structured Analysis of Retina (STARE) [21] and (ii) Automated Retinal Image Analysis (ARIA) [22]. The STARE database comprises of 400 images and they have been acquired using Topcon fundus camera at 35 degree field of view with resolution of 700×605 pixels. The ARIA database comprises of 450 images and they have been acquired using Carl Zeiss Meditec fundus camera at 50 degree field of view with resolution of 768×576 pixels. The images containing drusen were sorted out from these databases. Thus a total of 48 images comprising of 37 images from STARE database and 11 images from ARIA database have been used in the present work.

Method:

The proposed method as shown in Fig. 2 consists of three phases, namely (i) retinal image preprocessing, (ii) drusen candidate edge detection and (iii) boundary extraction of drusen. The steps followed in these three phases of method are explained in this section. The performance evaluation parameters and grading criterion of AMD are also explained in the later stage of this section.

2.1. Retinal image preprocessing

The retinal fundus images contain artifacts that occur during retinal image acquisition process. Retinal image preprocessing is necessary to remove these artifacts in order to improve quality of an image for easy detection of drusen. There are several factors responsible for the presence of artifacts in the image. One of them is non-uniform illumination which is responsible for the presence of intensity homogeneities and the shading artifacts in an image. Also, camera dependent factors like pixel noise and compression artifacts further degrade the image. The noise in the image may get amplified during contrast enhancement and impart a visible graininess to the image. This is highly undesirable especially in cases where the lesion characteristics are comparable to those of the artifacts produced due to noise amplification. Hence, retinal image preprocessing is essential to