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Original Research Article

A generalized method for the segmentation of exudates from pathological retinal fundus images

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ABSTRACT

Diabetic retinopathy, an asymptomatic complication of diabetes, is one of the leading causes Q3 of blindness in the world. The exudates, abnormal leaked fatty deposits on retina, are one of the most prevalent and earliest clinical signs of diabetic retinopathy. In this paper, a generalized exudates segmentation method to assist ophthalmologists for timely treatment and effective planning in the diagnosis of diabetic retinopathy is developed. The main contribution of the proposed method is the reliable segmentation of exudates using dynamic decision thresholding irrespective of associated heterogeneity, bright and faint edges. The method is robust in the sense that it selects the threshold value dynamically irrespective of the large variations in retinal fundus images from varying databases. Since no performance comparison of state of the art methods is available on common database, therefore, to make a fair comparison of the proposed method, this work has been performed on a diversified database having 1307 retinal fundus images of varying characteristics namely: location, shapes, color and sizes. The database comprises of 649 clinically acquired retinal fundus images from eye hospital and 658 retinal images from publicly available databases such as STARE, MESSIDOR, DIARETDB1 and e-Optha EX. The segmentation results are validated by performing two sets of experiments namely: lesion based evaluation criteria and image based evaluation criteria. Experimental results at lesion level show that the proposed method outperforms other existing methods with a mean sensitivity/specificity/accuracy of 88.85/96.15/93.46 on a composite database of retinal fundus images. The segmentation results for image-based evaluation with a mean sensitivity/specificity/accuracy of 94.62/98.64/96.74 respectively prove the clinical effectiveness of the method. Furthermore, the significant collective performance of these experiments on clinically as well as publicly available standard databases proves the generalization ability and the strong candidature of the proposed method in the real-time diagnosis of diabetic retinopathy.

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1. Introduction

Diabetic retinopathy, a complication of long-term diabetes, is a leading cause of blindness worldwide. According to World Diabetes Foundation, the increase in prevalence of diabetes is estimated about 438 million people by 2030 [1]. It is a chronic progressive disease, which advances from mild non-proliferative diabetic retinopathy to moderate and severe non-proliferative diabetic retinopathy [2]. Mild non-proliferative diabetic retinopathy is characterized by microaneurysms, whereas moderate and severe stages are characterized by exudates. Non-proliferative diabetic retinopathy exhibits no distinctive symptoms and generally does not interfere with vision until a proliferative stage of diabetic retinopathy is reached. Proliferative diabetic retinopathy is characterized by neovascularization causing visual impairment or blindness. In addition, the treatment at the proliferative stage becomes less effective. It is therefore important to diagnose diabetic retinopathy at an earlier asymptomatic clinical stage.

According to ophthalmologists, the severity level of diabetic retinopathy is judged primarily based on the size, number and locations of exudates. Exudates are aggregates of leaked fatty material formed from lipids and protein in the retina [3,4]. In retinal fundus images, exudates appear as bright yellow clusters of varying shapes, sizes and locations. Their size can vary from very few pixels, appearing as dot to as large as an optic disk. An increase in size and locations of exudates signifies the increase in severity level of the disease [5]. Mainly, the exudates can be classified as hard and soft exudates as shown in Fig. 1(a) and (b) respectively. Hard exudates, related to diabetic retinopathy, appear as bright yellow crystalline granules having sharper definition. Whereas, soft exudates are the expression of hypertensive retinopathy, appear as whitish gray in color having fuzzy boundaries.

The diagnosis of severity level of diabetic retinopathy requires the subjective and quantitative analysis of the variations in exudates. The boundaries of exudates are detected in retinal fundus images by expert ophthalmologists using manual evaluation procedure. However, the manual labeling and segmentation, accuracy in assessment of lesions and related parameters is highly dependent on the ability and experience of the expert. Thus, the ambiguity lies in (i) interpreting the exact boundaries due to their diverse shapes and intensities leading to confliction and (ii) the possibility of exudates of few pixels being missed. Also, the screening of each patient manually becomes tiresome and is a time-consuming process. In addition, the excessive cost of examinations and the lack of specialists prevent many patients from receiving effective treatment. Therefore, there is a need to design automated exudates detection and segmentation method to assist ophthalmologists, which would be helpful to reduce the cost associated with the expert graders and eliminate the inconsistency associated with manual labeling. Moreover, the detection of exudates is not only useful for diagnosis but also for treatment planning. The physicians determine the precise area of exudates to be exposed to laser for photocoagulation. Therefore, proper detection and segmentation of exudates is important for treatment decisions. Thus, a computer-aided detection and segmentation of exudates would offer fast and precise diagnosis of diabetic retinopathy.

2. State of the art

Table 1 presents the summary of the comparative study carried out on the detection and segmentation of exudates using retinal fundus images. Here, the accuracies of state of art methods are compared to assess their diagnostic capability in detection and segmentation of exudates with two main evaluation criteria: (i) lesion based evaluation and (ii) image based evaluation.

Lesion based evaluation: Each cluster of exudates in a retinal image is considered as an individual lesion comprising of one or more pixels. A pathological retinal image may contain number of such cluster of exudates. These exudates clusters are segmented by applying an appropriate segmentation method on retinal image database. Then, the lesion based evaluation results are measured in terms of sensitivity, specificity and accuracy by comparing the obtained segmentation results pixel by pixel with the reference ground truths marked by the expert ophthalmologists. The performance on pixel level evaluation must be as high as possible because the number of lesions as well as their location is crucial to assess the severity level of the retinal disease.

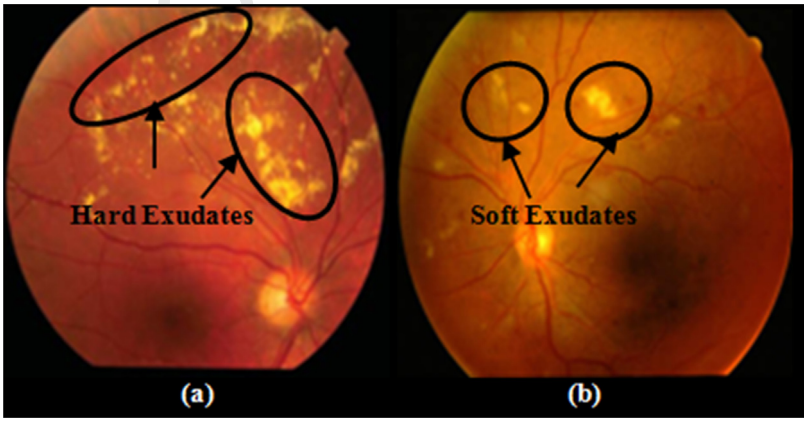

Fig. 1 – Retinal fundus images depicting (a) hard exudates and (b) soft exudates.

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