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Original Research Article

Estimation of severity level of non-proliferative diabetic retinopathy for clinical aid

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ABSTRACT

Diabetic retinopathy, a symptomless complication of diabetes, is one of the significant causes of vision impairment in the world. The early detection and diagnosis can reduce the occurrence of severe vision loss due to diabetic retinopathy. The diagnosis of diabetic retinopathy depends on the reliable detection and classification of bright and dark lesions present in retinal fundus images. Therefore, in this work, reliable segmentation of bright lesions namely exudates and cotton wool spots, and dark lesions namely micro aneurysms and hemorrhages has been performed using iterative clustering irrespective of associated heterogeneity, bright and faint edges. Afterwards, a computer-aided severity level detection method is proposed to aid ophthalmologists for appropriate treatment and effective planning in the diagnosis of diabetic retinopathy at its early stage, i.e. non-proliferative diabetic retinopathy. This work has been performed on a composite database, comprising 2942 clinically acquired retinal images from eye hospital and 2106 retinal images from open source benchmark databases namely STARE, MESSIDOR, DIARETDB1, DRIVE, HEI-MED and e-OPTHA. This composite database of overall 5048 retinal images having varying attributes such as position, dimensions, shapes and color is formed to make a reasonable comparison with state-of-the-art methods and to establish generalization capability of the proposed method. The segmentation outcomes are evaluated by performing two experiments namely: per-lesion and per-image based evaluation criteria. Experimental results on per-lesion basis show that the proposed method outperforms state-of-the-methods with an average sensitivity/specificity/accuracy of 96.41/96.57/94.96 and 95.19/96.24/96.50 for bright and dark lesions respectively on composite database. Individual per-image based class accuracies delivered by the proposed method: No DR-95.9%, MA-98.3%, HEM-98.4%, EXU-97.4% and CWS-97.9% demonstrate the clinical competence of the method. Major contribution of the proposed method is that it efficiently grades the severity level of diabetic retinopathy in spite of huge variations in retinal images of different databases. Additionally, the substantial combined performance of these experiments on clinical and open source benchmark databases supports a strong candidature of the proposed method in the diagnosis of non-proliferative diabetic retinopathy. Q3

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1. Introduction

Diabetic retinopathy, a complication of diabetes mellitus, is the leading cause of vision impairment. 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 the presence of at least one micro aneurysms (MA). Moderate non-proliferative diabetic retinopathy is identified by the presence of few hemorrhages (HEM), hard exudates (HE) and cotton wool spots (CWS), whereas these lesions are found in greater quantity in severe NPDR. Hemorrhages are of several types namely: "dot", "blot" and "flame" hemorrhages. Dot hemorrhages are tiny red structures ranging from 10 to 100 µm and are usually referred to as micro aneurysms. Blot and flame hemorrhages correspond to leakage of blood in deeper layers of retina. They appear as large dark red retinal lesions with irregular contours, leading to various shapes [3]. Exudates, accumulations of leaked fatty material formed from lipids and protein in the retina, are the bright yellow clusters of varying shapes, sizes and locations having sharper definition. Whereas, cotton wool spots, the manifestation of hypertensive retinopathy, seem to be white gray in color having fuzzy contours.

Micro aneurysms and hemorrhages are referred to as dark lesions and exudates and cotton wool spots as bright lesions as shown in Fig. 1(a)–(c) respectively [4]. Non-proliferative diabetic retinopathy exhibits no characteristic symptoms and might not affect vision until a proliferative stage of diabetic retinopathy is reached. Proliferative diabetic retinopathy, an advanced stage characterized by the growth of new blood vessels in distinct regions of retina, may lead to vision impairment. Also, non-proliferative diabetic retinopathy itself is not a sight threatening condition, but it can trigger other forms of diabetic retinopathy such as diabetic macular edema and diabetic macular ischemia. These diseases may cause rapid vision impairment at any stage of diabetic retinopathy. Also, the treatments at this stage such as laser photocoagulation, vitrectomy, anti-VEGF drugs, corticosteroids, etc. have many side effects and possible complications. It is therefore significant to diagnose non-proliferative diabetic retinopathy

not only to cease diabetic retinopathy at an initial symptomless clinical stage, but also to diagnose other retinopathies.

Experienced ophthalmologists visualize various shape, intensity and texture-based features in retinal images to judge the severity level of diabetic retinopathy. The grading of severity level of non-proliferative diabetic retinopathy requires the subjective and quantitative validation of dark and bright lesions present in retinal image. However, the manual marking and segmentation, precision in judgment of lesions and related parameters is vastly dependent on the capability and experience of the ophthalmologist. Thus, the ambiguity lies in (i) the interpretation of precise contours due to their varied shapes and intensities resulting in confliction and (ii) the likelihood of retinal lesions of few pixels being skipped. Moreover, assessment of each patient manually becomes wearisome and is a tedious process. Furthermore, the unnecessary cost of examinations and the dearth of experts avert many patients from receiving effective treatment. Therefore, it is essential to design a computer-aided severity level detection method to aid ophthalmologists, which would reduce the cost associated with specialist graders and remove the inconsistency corresponding to manual assessment. Moreover, the detection and classification of different retinal lesions is not only helpful for diagnosis but also for treatment preparation. The experts determine the exact area of lesions to be exposed to laser for treatment. So, efficient detection and classification of retinal lesions is significant for fast and precise diagnosis of non-proliferative diabetic retinopathy.

2. State of the art

The segmentation, feature extraction and classification are important aspects of any computer-aided detection method. There are various recent methods proposed in literature for the detection and classification of micro aneurysms, hemorrhages, exudates and cotton wool spots for the diagnosis of non-proliferative diabetic retinopathy. The detection and segmentation of retinal lesions are considered individually or in a collective way. The diagnostic capability of detection and segmentation of retinal lesions in state-of-the-art methods are assessed with two evaluation criteria: (i) per-lesion based evaluation and (ii) per-image based evaluation.
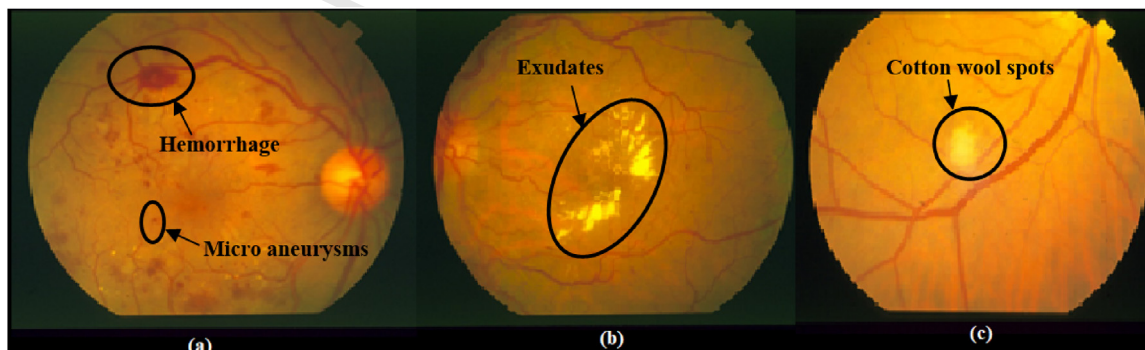

Fig. 1 – Retinal fundus images depicting (a) micro aneurysms and hemorrhages, (b) exudates and (c) cotton wool spots.