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An Adaptive Algorithm for Detection of Exudates Based on Localized Properties of Fundus Images

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ABSTRACT

This article presents an algorithm to detect exudates, which can be considered as one of the many abnormalities, to identify diabetic retinopathy from fundus images. The algorithm is invariant to illumination and works well on poor contrast images with high reflection noise. The artefacts are correctly rejected despite their colour, intensity and contrast being almost similar to that of exudates. Optic disc is localized and segmented using average filter of specially determined size which is an important step in the rejection of false positives. Exudates are located by generating candidate regions using variance and median filters followed by morphological reconstruction. The strategic selection of local properties to decide the threshold, makes this approach novel and adaptive, that is highly accurate for detection of exudates. The proposed method was tested on two publicly available labelled databases (DIARETDB1 and MESSIDOR) and a database from a local hospital and achieved a sensitivity of 96.765% and a positive predictive value of 93.514%.

KEYWORDS

Diabetic Retinopathy, Exudates, Image Processing, Mathematical morphology, Retinal Images

INTRODUCTION

Diabetic Retinopathy is an ocular manifestation of diabetes, which causes retinal damage and eventually leads to blindness. It is characterized by retinal micro vascular dysfunction (Joussen, Paulaki, Le, 2004) and it has been found to affect almost 80 percent of people who have had diabetes for more than a decade (Kertes, Johnson, 2007). Diabetic retinopathy is a major cause of blindness (Abramoff, 2008) and constitutes around 5% of the vision loss cases around the globe due to retinopathy (Salomao, Mitsuhiro, Belfort, 2009). It has been estimated that in the next 10-15 years, almost all patients with type-I and two-third of those with type-II diabetes will suffer from retinopathy (Klein, Klein, Moss, Davis, Demets, 1984). There are limited early warning signs of diabetic retinopathy. Specialized ophthalmologists can diagnosis this condition through fundus photography, a task that is both time-consuming and expensive. One popular and inexpensive treatment of DR is laser surgery. However, the number of people affected by diabetic retinopathy is still increasing significantly each year and is the leading cause of blindness for people between the ages of 20 and 64 (Engelgau, 2014). An early detection of DR is crucial so that ophthalmologists can provide laser treatment to patients (Jelinek, 2005). Computer-aided image processing offers a fast and accurate alternative to the complex and

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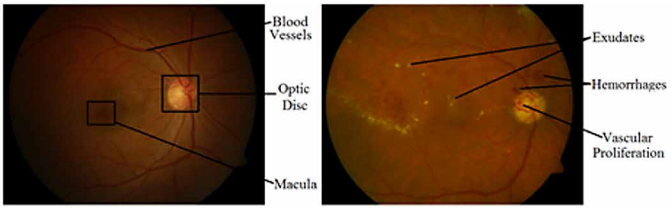
Figure 1. Fundus Image (a) Normal Image and its features (b) Fundus image with Exudates, hemorrhages and retinal vascular proliferations



slow procedures of manual diabetic retinopathy detection. It also provides a diagnostic tool for mass screening.

The first stage of the DR is called Non-Proliferative Diabetic Retinopathy, where the patient normally has unaffected vision. If there is reduced vision, the back of the eye can be examined by fluorescent angiography. Blocked retinal blood vessels can be clearly seen and this is called retinal ischemia. Under such condition, the release of proteins from the blocked and damaged vessels can occur and is termed as exudates (Lee, Lee, Wang, Klein, 2005). If these exudates are found in the macular region of the fundus, then it can be a major cause of blindness (Ghafour, Allan, Foulds, 1983). The second stage is Proliferative Diabetic Retinopathy where abnormal new blood vessels form at the back of the eye. These can burst and bleed, resulting in blurred vision.

A fundus image is a photographic view of the interior surface of the eye. A normal fundus image of the eye contains elements such as the optic disc, macula and retinal blood vessels, as seen in Figure 1 (Figure 1(a)). The bright spot where the retinal vessels converge is called the optic disc. The dark region towards the temporal side of the optic disc is the macula. Sensitivity of human vision at the macula is maximal and the presence of abnormalities near the region causes a deterioration of vision. The elements of the ophthalmoscopic view of diabetic retinopathy are hemorrhages, macular pigment anomalies, exudates and vascular proliferations as shown in Figure 1(b). This work addresses the detection of exudates from retinal fundus images. Exudates are described as small, sharply demarcated yellowish waxy patches. These are often termed as 'hard' exudates or 'waxy' exudates because of their appearance. Severe hypertension retinopathy patients also show signs of another kind of exudates, the so called 'cotton wool' exudates or soft exudates. Such exudates can be found in diabetic patients, but they are most commonly found in cases where arterial hypertension has complicated diabetes mellitus (Esmann, Lundbaek & Madsen, 2009).

Past research indicates that exudates detection can be broadly divided into four categories: intensity-based thresholding techniques, morphological image processing techniques, classification techniques and region-growing techniques. Thresholding based techniques focus on the analysis of grey levels; however, the difficulty lies in choosing a threshold that adapts for every image since the illumination varies from image to image. Sanchez et al (Sanchez, Garcia, Mayo, Lopez, Horneo, 2009) proposed an algorithm that dynamically threshold images to separate the exudates from the background using mixture models. Grisan et al (Grisan, Ruggeri, 2007) proposed an algorithm based on thresholding and an evaluation of the spatial density of pixels. Mathematical morphology-based techniques use gray-scale morphological operators to remove unwanted structures so as to detect the exudates effectively. Walter et al (Walter, Klein, Massin, Erginay,2002) used morphological filtering and reconstruction techniques to detect exudates. Similarly, Welfer et al (Welfer, Scharcanski, Marinho, 2010) depend on mathematical morphology to detect exudates in color images. Region growing based techniques use illumination homogeneity and spatial contiguity to segment retinal images. Sinthayanayothin et al (Sinthayanayothin, 2002) used a recursive region growing segmentation algorithm to detect exudates. Similarly, Li et al (Li, Chutatape, 2004) proposed an algorithm which combines region growing and edge detection to achieve the same. Classification based techniques