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Automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods

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Abstract

Diabetic retinopathy is a complication of diabetes that is caused by changes in the blood vessels of the retina. The symptoms can blur or distort the patient's vision and are a main cause of blindness. Exudates are one of the primary signs of diabetic retinopathy. Detection of exudates by ophthalmologists normally requires pupil dilation using a chemical solution which takes time and affects patients. This paper investigates and proposes a set of optimally adjusted morphological operators to be used for exudate detection on diabetic retinopathy patients' non-dilated pupil and low-contrast images. These automatically detected exudates are validated by comparing with expert ophthalmologists' hand-drawn ground-truths. The results are successful and the sensitivity and specificity for our exudate detection is 80% and 99.5%, respectively.

Keywords: Diabetic retinopathy; Exudates; Retinal image; Non-dilated retinal images; Morphology

1. Introduction

Diabetes is the commonest cause of blindness in the working age group in the developed world. Patient's sight can be affected by diabetes which causes cataracts, glaucoma, and most importantly, damage to blood vessels inside the eye, a condition known as "diabetic retinopathy". Diabetic retinopathy is a critical eye disease which can be regarded as manifestation of diabetes on the retina. The screening of diabetic patients for the development of diabetic retinopathy can potentially reduce the risk of blindness in these patients by 50% [1–3].

Diabetic retinopathy is characterized by the development of retinal microaneurysms, haemorrhages and exudates. Microaneurysms are focal dilatations of retinal capillaries and appear as small round dark red dots. Haemorrhages occur when blood leaks from the retinal vessels. Exudates occur when lipid or fat leaks from abnormal blood vessel or aneurysms. The number of microaneurysms, haemorrhages and exudates increases as the degree of disease [4]. A number of techniques for microaneurysm and haemorrhage detection have been proposed. Sinthanayothin et al. [5] applied recursive region growing segmentation (RRGS) technique to segment vessels, microaneurysms and haemorrhages. The vessels were detected using a neural network. The remaining objects after vessels had been removed were labelled as microaneurysms and haemorrhages. Niemeijer et al. [6] proposed a method to detect candidate red lesions (microaneurysms and haemorrhages) using a pixel classification technique. Then the detected red lesion candidates were classified using a number of features and a k-nearest neighbour classifier. Usher et al. [7] used an RRGS, adaptive intensity thresholding and edge enhancement operator to extract the candidate red lesions. Candidate red lesions were classified using a neural network. However, in this paper we concentrate on exudate detection as a visible sign of diabetic retinopathy and a marker for the presence of coexistent retinal edema. If the exudates extend into the macular area, vision loss can occur.

Fluorescein angiogram images provide important information on pathologies. The most effective and accurate ways to

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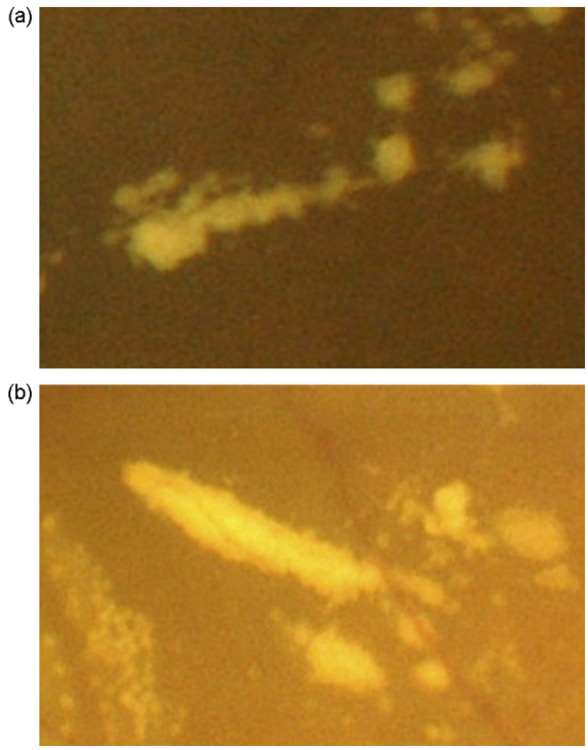

Fig. 1. (a) and (b) Retinal image containing exudates.

observe and diagnose diabetic macular edema are to investigate a fluorescein angiography. In practical terms, the decision whether to laser treat the retina does not depend significantly on the images from fluorescein angiography, it is mostly done without this investigation. The fluorescein angiograms are not suitable for an automatic screening system because there are side-effects associated with giving a patient fluorescein. The use of colour fundus images is more suitable for an automatic screening system. An automatic exudate detection system would be useful in order to detect and treat diabetic retinopathy in an early stage.

From visual inspection, exudates appear differently in a yellowish or white colour with varying sizes, shape and locations. They are often seen in either individual streaks or clusters or in large circinate structures surrounding clusters of microaneurysms. At the same time, some of them are seen in varying sizes, shape and locations as shown in Fig. 1(a) and (b).

Many techniques have been employed to the exudate detection. Gardner et al. [8] proposed an automatic detection of diabetic retinopathy using an artificial neural network. The exudates are identified from grey level images. The fundus image was analyzed using a back propagation neural network. The technique did not work well on low contrast images.

The thresholding and RRGS technique were widely used. Sinthanayothin et al. [5] reported the result of an automated detection of diabetic retinopathy on digital fundus images by RRGS algorithm where the performance was measured on 10×10 patches rather on the whole image. Usher et al. [7] detected the candidate exudates region by using a combination of RRGS and adaptive intensity thresholding. The candidate regions were extracted and used as input to a neural network. Poor quality images affected the separation result of bright and dark lesions using thresholding and exudate feature extraction using RRGS algorithm. Zheng et al. [9] detected exudates using thresholding and a region growing algorithm. The fundus photographs were taken with a non-mydriatic fundus camera and were then scanned by a flat-bed scanner.

Colour normalization and local contrast enhancement followed by fuzzy C-means clustering and neural networks were used by Osareh et al. [10]. The system works well only on Luv colour space but in the case of non-uniform illumination the detection accuracy is low. Mitra et al. [11] applied naïve Bayes classifier for diagnosis of diseases from retinal image. A system can provide a good decision support to ophthalmologist.

Much work has been performed for exudate detection based on variety of techniques. Most techniques mentioned earlier worked on dilated pupils in which the exudates and other retinal features are clearly visible. Based on experimental work reported in previous work, good quality images with larger fields are required. The retinal image of the patient must be clear enough to show retinal detail. Low quality images (non-uniform illumination, low contrast, blur or faint image) do not perform well even when enhancement processes were included. The examination time and effect on the patient could be reduced if the system can succeed on non-dilated pupils. Furthermore, many techniques required intensive computing power for training and classification.

This paper proposes an exudate detection techniques based on mathematical morphology on retinal images of non-dilated pupils that are low quality images. We based our work on this technique because it is very fast and requires lower computing power. So that the final system can be used even on a very poor computer system, such as those that may be available in rural area in developing countries where both expert ophthalmologists and high performance computers are rarely available. In addition, the location of exudates based on macular position is important information for an ophthalmologist [12,13]. They show the severity of disease, where exudates that appear closer to the macular indicate an increased severity of disease. A grid circle centred on the macular was added to provide improved diagnosis to the ophthalmologist.

2. Methods

All digital retinal images were taken from patients with non-dilated pupils using a KOWA-7 non-mydriatic retinal camera with a 45° field of view and taken at Thammasat University Hospital. The images were stored in JPEG image format files (.jpg) with lowest compression rates. The image size is 752×500 pixels at 24 bits per pixel. The overall procedure of exudate detection is demonstrated in Fig. 2.

2.1. Preprocessing

The red, green and blue (RGB) space of the original image was transformed to Hue, saturation and intensity (HSI) space because HSI colour space is more appropriate since it allows the intensity component to be separated from the other two