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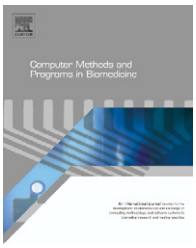

Simple methods for segmentation and measurement of diabetic retinopathy lesions in retinal fundus images

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ABSTRACT

Diabetic retinopathy (DR) is one of the most important complications of diabetes mellitus, which causes serious damages in the retina, consequently visual loss and sometimes blindness if necessary medical treatment is not applied on time. One of the difficulties in this illness is that the patient with diabetes mellitus requires a continuous screening for early detection. So far, numerous methods have been proposed by researchers to automate the detection process of DR in retinal fundus images. In this paper, we developed an alternative simple approach to detect DR. This method was built on the inverse segmentation method, which we suggested before to detect Age Related Macular Degeneration (ARMDs). Background image approach along with inverse segmentation is employed to measure and follow up the degenerations in retinal fundus images. Direct segmentation techniques generate unsatisfactory results in some cases. This is because of the fact that the texture of unhealthy areas such as DR is not homogenous. The inverse method is proposed to exploit the homogeneity of healthy areas rather than dealing with varying structure of unhealthy areas for segmenting bright lesions (hard exudates and cotton wool spots). On the other hand, the background image, dividing the retinal image into high and low intensity areas, is exploited in segmentation of hard exudates and cotton wool spots, and microaneurysms (MAs) and hemorrhages (HEMs), separately. Therefore, a complete segmentation system is developed for segmenting DR, including hard exudates, cotton wool spots, MAs, and HEMs. This application is able to measure total changes across the whole retinal image. Hence, retinal images that belong to the same patients are examined in order to monitor the trend of the illness. To make a comparison with other methods, a Naïve Bayes method is applied for segmentation of DR. The performance of the system, tested on different data sets including various qualities of retinal fundus images, is over 95% in detection of the optic disc (OD), and 90% in segmentation of the DR.

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1. Introduction

Digitized data in ophthalmology attracts more and more researchers for automatic segmentation and measurement of some important diseases such as DR and ARMD lesions. DR and other eye diseases are characterized by structural variations in retina, which are exploited in automated diagnosis systems. Since the DR is developed in diabetics in a long period of time, continuous monitoring of eyes is extremely

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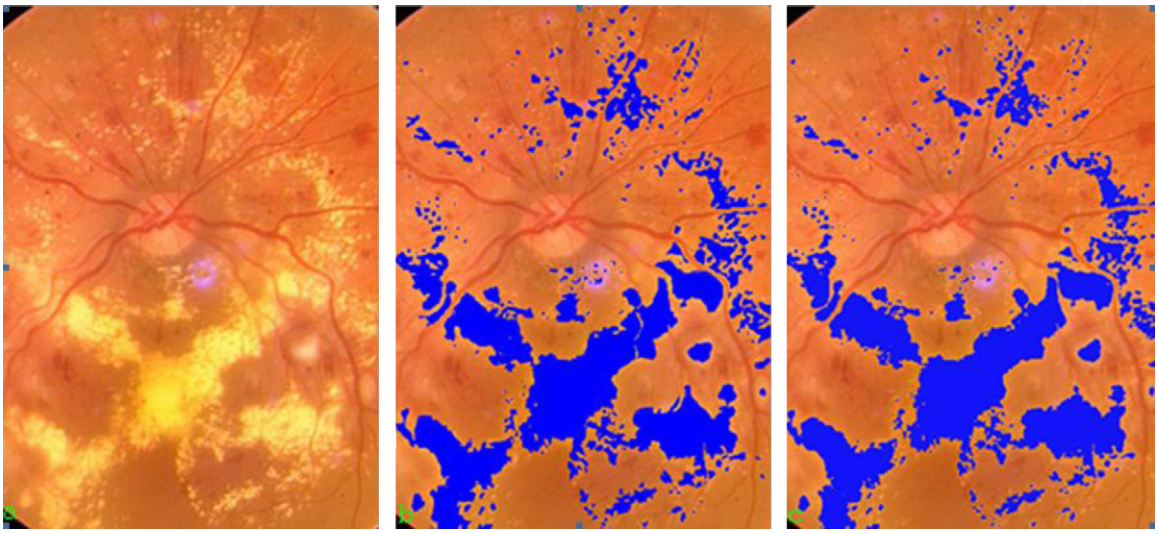

Fig. 1 – (a) An original image, and (b) manual and (c) automatic segmentation results of the image.

important to diagnose the early symptoms and take necessary precautions for an effective treatment [1–3]. The early treatment may avoid or reduce blindness. On the other hand, standard grading system is used in assessing images manually, which requires ophthalmologist or professionally trained graders to analyze large number of retinal fundus images [4,5]. An original image (a), its manual (b) and automatic segmentation results (c) are given in Fig. 1. Manual segmentation and measurement of the diseases as in the figure are quite difficult, and user may easily make mistakes during the operation [2,3,6]. Quality of segmentation also changes depending on quality of image, and ability and experience of user. The manual process can take up to an hour for two eyes. Therefore, a fully automated system segmenting the diseases in retinal images could definitely reduce the workload of clinicians. The image may be segmented and measured by the system first and then checked by a medical professional if further analysis is necessary upon the automatic classification of image as abnormal. It should also be perceived that these kinds of automated systems cannot fully be trusted in detection of illness or locating a specific region such as OD or macula. That is why a medical professional performs a last check on detected abnormality on images. To give an example, considering all the optic disc detection methods developed so far, none of those methods can 100% guarantee detecting the optic disc or finding the exact location of OD in any conditions without any restriction such as image conditions and quality, structure of degenerations, and the way the image is taken. Apart from automated system, highly experienced physicians can even make mistakes in detecting the OD in problematic or low quality retinal images.

Recent investigations have shown that the pathological diseases such as DR can be measured from retinal fundus images [5,7–12]. Quantifying the problems in images will enable the evaluation of the course of retinal diseases. Consequently, there is a strong demand for automated diagnosis and measurement processes [4,10,13–16]. However, segmenting, measuring and monitoring the development of degenerations such as hard exudates, cotton wool spots, MAs, and HEMs related with DR, are quite difficult because of irregular pattern of degenerations [17–19]. In other words, one common problem, encountered during segmentation of lesions, is the non-uniformity of the DR. Currently a number of semi-automated methods are used for segmentation and detection of DR [8,20–22]. Five previous methods are examined in retinopathy in [13]. In the first method, using a three class Gaussian mixture model, a group of MA candidates are segmented by thresholding fitted model. Logistic regression is used to generate likelihood for the places that may be MA. Second method presented in the paper employs feature extraction to determine the candidate places and Bayesian classifier to assign likelihood to each one to be MAs. The third method uses template matching in the wavelet domain and the fourth method uses multi scale Bayesian correlation filtering approach to find MA candidates. MA detection method based on double ring filter is used in the last method presented in [13]. Another study employs neural network classifier in order to detect hard exudates in retinal images. This study employs an algorithm which includes a neural network classifier for this task. Three classifiers were investigated: multilayer perceptron, radial basis function and support vector machine (SVM) are used in this study [23]. To detect the hard exudates, a group of features was extracted from image regions, and the subset which was best discriminated between exudates and retinal background was selected by means of logistic regression after applying normalization on the image and segmenting the candidate regions. Lastly, noisy regions are eliminated by applying post-processing on the image [17]. Another study first employs image enhancement, shade correction and image normalization as preprocessing methods on the image. The study then applies diameter closing and an automatic threshold scheme for detection of candidate regions for MA. Then, the candidate regions are classified as MA and non-MA by using feature extraction method [14]. A template matching technique using optimal wavelet transformation for detecting MAs in retinal images is employed in [24].

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