Computers in Biology and Medicine 45 (2014) 161–171

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Detection and classification of retinal lesions for grading of diabetic retinopathy

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ARTICLE INFO

Article history:
Received 23 July 2013
Accepted 18 November 2013

Keywords:
Diabetic retinopathy
NPDR
Microaneurysms
Haemorrhage
Hard exudates
Cotton wool spots
m-Mediods
Classification

ABSTRACT

Diabetic Retinopathy (DR) is an eye abnormality in which the human retina is affected due to an increasing amount of insulin in blood. The early detection and diagnosis of DR is vital to save the vision of diabetes patients. The early signs of DR which appear on the surface of the retina are microaneurysms, haemorrhages, and exudates. In this paper, we propose a system consisting of a novel hybrid classifier for the detection of retinal lesions. The proposed system consists of preprocessing, extraction of candidate lesions, feature set formulation, and classification. In preprocessing, the system eliminates background pixels and extracts the blood vessels and optic disc from the digital retinal image. The candidate lesion detection phase extracts, using filter banks, all regions which may possibly have any type of lesion. A feature set based on different descriptors, such as shape, intensity, and statistics, is formulated for each possible candidate region: this further helps in classifying that region. This paper presents an extension of the *m*-Mediods based modeling approach, and combines it with a Gaussian Mixture Model in an ensemble to form a hybrid classifier to improve the accuracy of the classification. The proposed system is assessed using standard fundus image databases with the help of performance parameters, such as, sensitivity, specificity, accuracy, and the Receiver Operating Characteristics curves for statistical analysis.

1. Introduction

Diabetic Retinopathy (DR) is an eye abnormality caused by long term diabetes and it is one of the causes of vision impairment. DR is the most common cause of blindness before the age of 50 years [1, 2]. DR is a progressive disease but the main issue with the disease is that a patient with DR has almost no signs of vision impairment at the initial stages of the disease. The severity of DR is determined by the number and types of lesions present on the surface of the retina.

The human retina consists of different components, such as blood vessels, the fovea, the macula, and the optic disc (OD). DR is broadly divided into two stages: non-proliferative DR (NPDR) and proliferative DR (PDR). NPDR occurs when the blood vessels get damaged inside the retina and leak fluid onto the retina [3], causing the retina to become wet and swollen. In NPDR, different signs of retinopathy can exist, such as microaneurysms (MAs), haemorrhages (HMs), exudates (hard and soft) (EXs), and inter-retinal microvascular abnormalities (IRMA) [4]. PDR is an advanced stage of DR in which new abnormal blood vessels start growing in different regions of the retina and may lead to total blindness. In this paper, we mainly consider only those NPDR lesions which are MAs, HMs, or EXs.

MAs are the first sign of DR to be visible to an ophthalmologist; they occur due to leakage from tiny blood vessels of the retina. They are of smaller size, are circular in shape, and are red in color. HMs occur when the walls of MAs get ruptured. Dot haemorrhages are like bright red dots, and blot haemorrhages are larger red lesions [2]. When the leakage of blood contains lipids and proteins, it creates yellow spots on the retina known as EXs. They cause complete blindness if the accumulation of the lipid is near or on the macula. MAs and HMs are referred to as dark lesions and EXs as bright lesions [4]. The ophthalmologists normally grade NPDR into three categories: i.e., mild, moderate and severe, depending on the location and occurrence of the lesions [4]. Fig. 1 shows a healthy retina along with its main components. It also shows examples from different categories of NPDR.

There are many recent methods in the literature for the accurate detection of MAs, HMs and EXs by considering them individually and in a collective way. Ref. [6] presented a method based on successive clutter rejection in which a feature based system is formulated which passes only true MAs while rejecting false classes of clutter. For the accurate diagnosis of DR, the University of Iowa introduced the Retinopathy Online Challenge [7]. The results of the first international competition were reported

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http://dx.doi.org/10.1016/j.compbiomed.2013.11.014

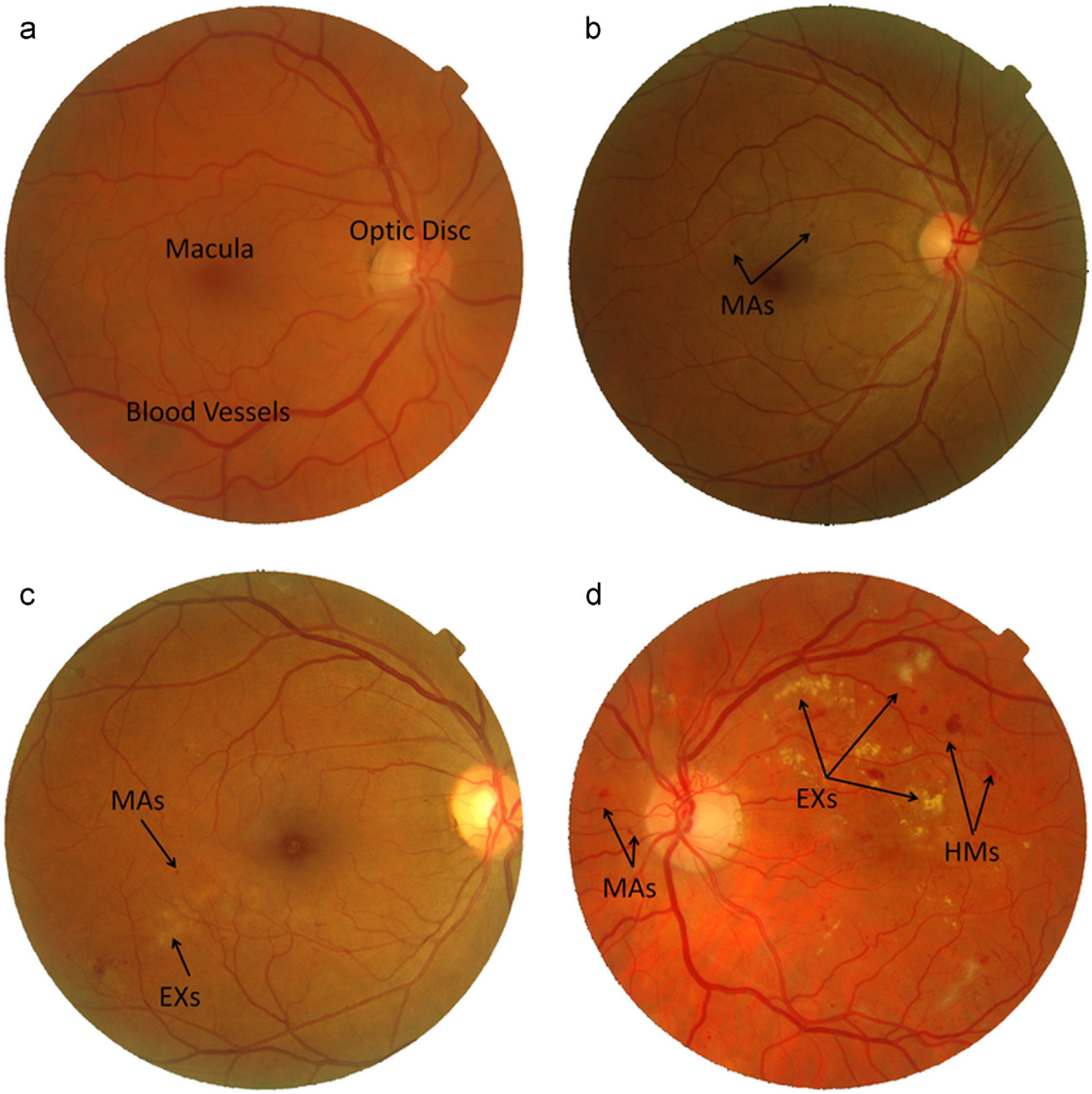

Fig. 1. Human retina and NPDR stages: (a) normal retina along with main components, (b) mild NPDR, (c) moderate NPDR, and (d) severe NPDR.

in [8]. Wavelet transform based matching using a Gaussian template is proposed in [9]. The technique was tested on 120 fundus images. Some automated diagnostic systems for DR considered haemorrhage and microaneurysm (HMA) as a common class [10] and used a moat operator for the detection. They have used only 30 fundus images for the classification of HMA and EXs. A similar study was done in [11] by using retinal images from 1273 patients. Hatanaka et al. [12] carried out the detection of HMs using the hue, saturation and value (HSV) model and the Mahalanobis distance, and tested the algorithm on 125 fundus images.

A multilayer neural network classifier was used to classify the segmented EXs in [13]. They used color, shape, size, and texture as the features and applied a genetic algorithm to choose a suitable subset of those features. The reported sensitivity and specificity are 96% and 94.6%, respectively. A generic contextual information based computer aided system was described in [14]. They described the spatial relation between the lesions and the identified exudates in two dimensional retinal images. A hybrid fuzzy neural network based classifier is used in [15] for dark and bright lesion detection. In [17], candidate regions for EXs were extracted using morphological closing of the luminance channel, local standard variation, and the watershed transform. Acharya et al. [18] proposed a system for the detection of NPDR and PDR by feeding higher order spectra based features to SVM. Their system graded the retinal images into different stages of NPDR with an average accuracy of 82%. Another system for automated detection of MAs, HMs, and EXs was presented in [19]. The proposed method achieved 82.6% and 88.3% accuracies for HMA and EXs, respectively.

This paper describes a system for the detection and classification of different types of NPDR lesions. The proposed technique extracts potential candidates for different signs of NPDR, i.e., MAs, HMs, and EXs. It then formulates a features set for each lesion depending on their properties. The true lesions are selected and classified using a hybrid classifier which is a weighted combination of multivariate *m*-Mediods and a Gaussian Mixture Model (GMM). The system uses the classification results. Then, based on the types, number, and location of the lesions, it grades the input retinal image into different categories of NPDR. The novelty of the proposed system lies in modeling of *m*-Mediods based classifier for grading NPDR.

This paper contains eight sections. Section 2 gives an overview of the complete proposed system and its different phases. Sections 3–5, respectively, present in detail the proposed techniques for preprocessing, detection of candidate lesions, and descriptions of all the features which we extract for all candidate lesions.