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Review

Algorithms for red lesion detection in Diabetic Retinopathy: A review

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ABSTRACT

Diabetic Retinopathy (DR) is an outcome of prolonged diabetes which directly or indirectly affect the human vision. DR is asymptomatic in its early stages and the late diagnosis lead to undeviating loss of vision. The computer aided diagnosis with the assistance of medical images helps in timely and accurate treatment. Microaneurysms (MA) mark the onset of DR, thus a vital point in screening of this disease. This review discuses various state of the art methods available till date for automated computer aided analysis of microaneurysms and haemorrhages. The paper also highlights qualitative and quantitative comparison of the existing literature with limitations for analysis of microaneurysms and haemorrhages. It is an attempt to systematize the available algorithms for an easy gathering and guidance to researchers working in this domain for future research.

1. Introduction

Diabetes is a chronic disease which is the outcome of insufficient insulin production or its ineffective utilization in the human body. Uncontrolled and prolonged diabetes eventually brings several complications and disorders along with it. The most common amongst it, is the effect on retina of the eye which leads to Diabetic Retinopathy. Diabetic Retinopathy directly or indirectly affect the human vision and may also lead to irreparable loss. The pathogenesis of DR is ornately explained in the research study by Eshaq et al. [1]. DR is asymptomatic in its early stages, and the late diagnosis leads to undeviating loss of vision.

Thus, the screening of Diabetic Retinopathy with the help of recent computer vision and image processing techniques helps in timely diagnosis and could assist ophthalmologist in its early treatment. Moreover, use of conventional methods during bulk screening programs is time-consuming, demand efforts and could be prone to error. The use of recent medical image processing algorithms could lessen the workload of ophthalmologists and results in an accurate diagnosis. Thus, it has been focused and developing research area in the past three decades for the screening of different stages of DR.

DR is primarily divided into two stages viz. proliferative DR (PDR) and non-proliferative DR (NPDR). The pathologies involved in NPDR are microaneurysms (MA), dot and blot haemorrhages (HEM), exudates, cotton wool spots whereas PDR can lead to retinal detachment called as Neovascularisation (Fig. 1) [70]. MA are the prime indicators during the onset of Diabetic Retinopathy. These are tiny red dots and occur as a result of the focal dilations caused within thin vessels. These microaneurysms rupture and lead to haemorrhages. These haemorrhages usually occur in the close vicinity of blood vessels. As MA and HEM mark the beginning of disease, the detection of these lesions is crucial for automated screening of DR. Thus, the paper reviews the existing literature available in automated screening of MA and HEM. The paper also discusses about the publicly available datasets, quantitative comparison, challenges and future research directions in computer aided screening of MA.

The objectives of this paper are:

(1) The detailed review of the existing literature for the detection of microaneurysms and haemorrhages in the screening of DR with the help of image processing techniques.
(2) To enable a quantitative comparison, qualitative findings in the available methods and identify the existing gaps.
(3) To find out the potential research areas and needed development to fill the gaps in the screening algorithms.

Several approaches have been extended as a review to the existing algorithms in computer aided screening of Diabetic Retinopathy [2,3]. There has been an extensive investigation and research carried out for the extraction of MA and HEM from the retinal images.

2. Database

There are various publicly available retinal datasets for carrying out research and scientific evaluations. The ultimate aim of all the available datasets is to provide an unambiguous platform to researchers to

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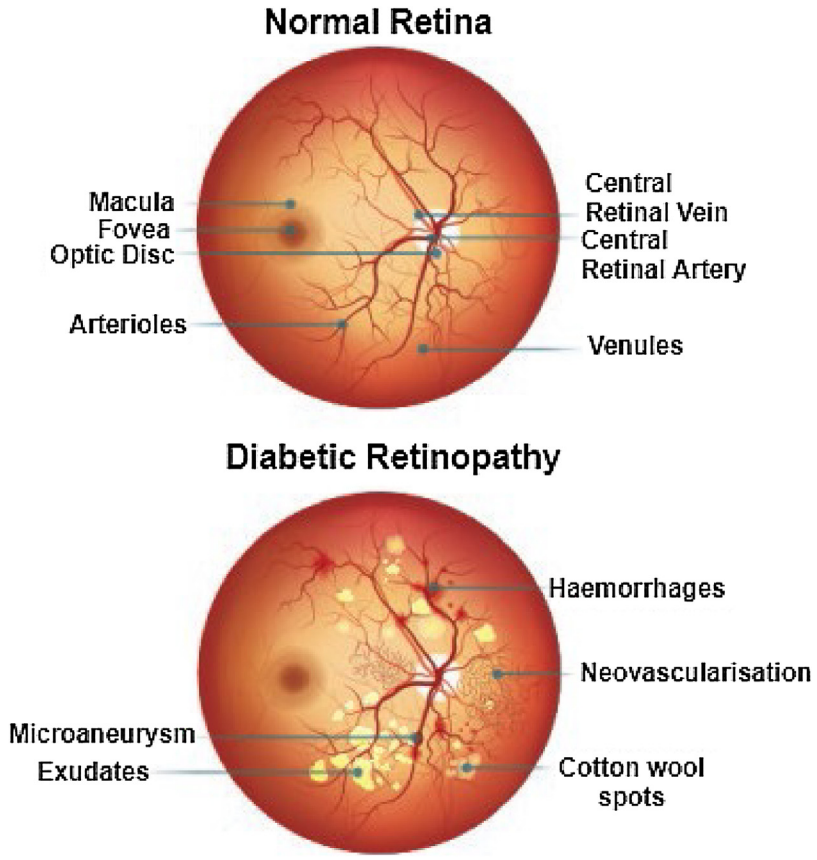

Fig. 1. Normal retina and retina with Diabetic Retinopathy.
Source: Singapore Eye Research Institute

Table 1
Normal and abnormal images in databases.

Dataset	No. of images	
	Normal	Abnormal
ROC	10	90
DIARETDB0	20	110
DIARETDB1	5	84
e-Ophtha-MA	223	148
MESSIDOR	546	654

validate their algorithms. These databases are acquired considering the practical environment and the methods run on similar kind of environment helps to make an easy comparison and thus justified inference. The commonly used datasets for MA detection are as follows:

ROC: ROC database is a set of 100 retinal images selected from a huge dataset (150,000 images) gathered during a DR screening programme [4]. The images with three different resolutions are available in the database. The dataset was randomly divided into training and test set, each containing 50 images. The details of the image specification and database are illustrated in [5]. ROC (Retinopathy Online Challenge) [5] is also an unique MA detection competition which makes the dataset and evaluation methodology available on the same platform.

DIARETDB: It is a publicly available database split into two groups, DIARETDB0 [6] and DIARETDB1 [7]. This database has been formed with a motive to unambiguously identify a testing protocol that can be a benchmark in the screening of DR. The comparison of different methods could be made under the same set of data.

MESSIDOR: MESSIDOR is a database of 1200 images and provides the retinopathy grade and risk of macular edema for each image [8]. The annotated ground truth is not available for the database.

e-Ophtha: e-Ophtha is a database of retinal images particularly designed for scientific research in DR [9]. The database consist two subsets of retinal images i.e. e-ophtha-MA (MicroAneurysms), and e-ophtha-EX (EXudates).

Table 1 depicts the number of normal and abnormal images in various databases.

3. Performance metric

Three extensively used performance metrics, namely Sensitivity (Se), Specificity (Sp) and Accuracy (Acc) are used for the validation of the algorithm. They are stated as follows:

$$\mathrm{Se} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} \tag{1}$$

$$\mathrm{Sp} = \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FP}} \tag{2}$$

$$\mathrm{Acc} = \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN}} \tag{3}$$

where TP = rightly classified lesion, FP = non-lesion misclassified as lesion, TN = rightly classified non-lesion regions, FN = true lesion misclassified as non-lesion.

The algorithm is statistically analysed with the help of Receiver Operating Characteristic (ROC) curve. It plots Sensitivity against False Positive Rate (1-Specificity). Free-response ROC (FROC) [10] is a curve that plots the sensitivity against the average number of false positive detection per image (FPI). FROC curve is summarised in a single number for a smoother comparison between the different algorithms. The single number is the average per lesion sensitivity at the FPI values ϵ [1/8, 1/4, 1/2, 1, 2, 4, 8], also known as competition metric (CPM).