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EXTRACTION OF DIFFERENT FEATURES TO DETECT DIABETIC RETINOPATHY FROM RETINAL FUNDUS IMAGE: A REVIEW

RajalaxamiSahoo*

Abstract

Usually because of less secretion of insulin from the pancreas, the body is incapable of holding the process probably which directly identifies diabetes that is a chronic end organ disease. Diabetes can affect the whole circulatory system even including the retina. In case of Diabetic Retinopathy, retina is damaged because of fluid leaks from blood vessels into the retina. According to ophthalmologists, some basic features are there to recognise diabetic retinopathy such as blood vessel area, exudates, haemorrhages, microaneurysms and texture. In this paper some reviewed algorithms and implemented methods are included for extraction of these features from digital fundus image. Furthermore some classifications efficiency of different DR that use these features to classify individual fundus images are discussed. According to analysed fundus images, most reported systems are highly optimized for which generalization of individual result is difficult. This review shows that classification result is getting closure to classification capabilities of human ophthalmologists.

Keywords:

Diabetic Retinopathy;
Exudates;
Bloodvesselarea;
Haemorrhages;
Microaneurysms.

* Mphil Computer Science,SambalpurUniversity,Odisha.

1. INTRODUCTION

The treatment for DR can be carried out in the very first stage of disease. So detection through regular screening is very important. Here digital image capturing technology enables us to employ state-of-the-art image processing techniques which can detect the abnormalities in retinal images. Features such as blood vessel areas,exudates,haemorrhages,microanerusyms and texture are used for automatic detection of DR.

Knowledge about structure/ shape and location of optic disc, fovea, macula and vessels is very important in retinal fundus image analysis. Optic disc features are similar to exudates, and hence it is required to erase the optic disc area from the image before the classification of exudates. Also, finding the location of optic disc is important for segmentation of other retinal features such as fovea and macula. Identification of fovea is used for identifying the risk associated with DR such as DME. Vessel narrowing, complete occlusions or new vessel development introduces changes in morphological structure of the retina vessel distribution/ blood flow. Segmentation of vessels is necessary for locating structures of retina like fovea and optic disc.

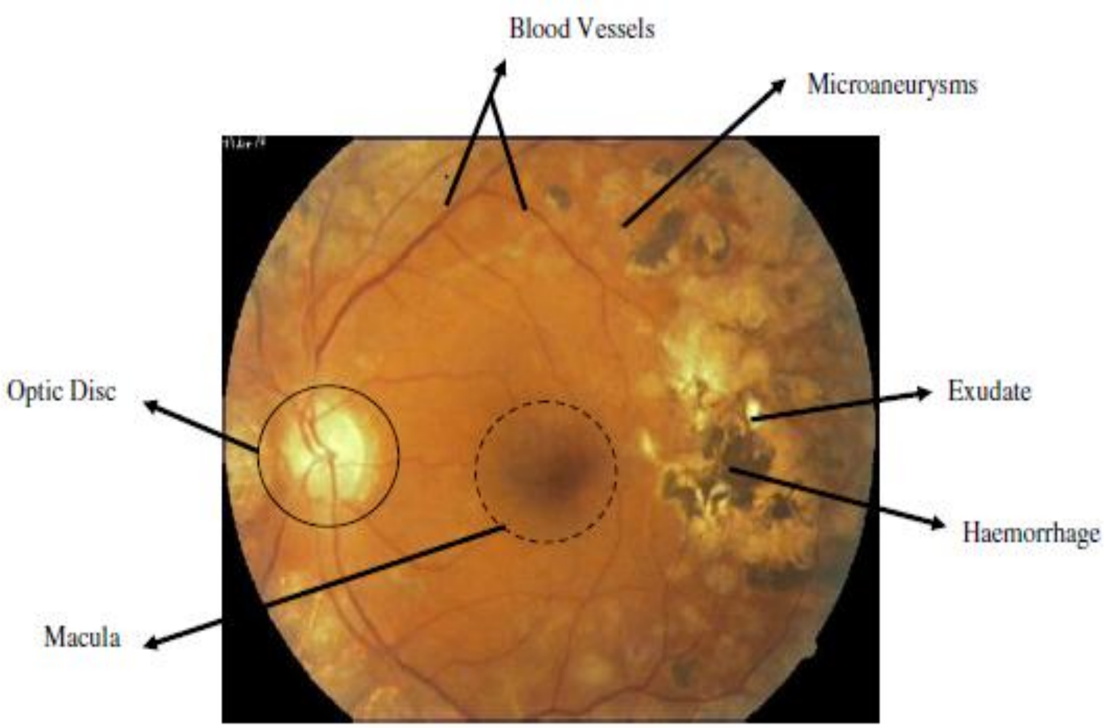

Fig. 1: Different features in Diabetic Retinopathy image

1.1 OVERVIEW ON DIABETIC RETINOPATHY

Diabetic retinopathy:

Due to increase of glucose level in blood capillaries damage,which causes DR and nourish the retina also.For this damage the capillaries leak blood and fluid in the retina. The above discussed features such as blood vessel areas,exudates,haemorrhages,microanerusyms and texture are the effects of this leakage. DR can be broadly classified into two types PDR and NPDR (Non Proliferative Diabetic Retinopathy). These phases can be described according to the presence of specific DR features.

Some sub-classes of these phases are as follows:

1. Mild NDPR:

Minimum one microanerusysm should be present with or without retinal haemorrhages, hard exudates or cotton wool spots. such mild signs of diabetic retinopathy found in approximately 40% of diabetic people.

2. Moderate NPDR:

In such class a number of microanerusyms and retinal haemorrhages are absent. Also a less no of cotton wool spots of venous beading seen 16% of such patients will develop PDR within 1yr.

3. Severe NPDR:

This can be characterized by one of these following characteristics:

* Number of haemorrhages and microanerusyms in all quadrants of retina.

*Venous beading in 2 or more quadrants.

*At least one quadrant may contain intraretinal micro vascular abnormalities.

There are 50% of chance of severe NPDR can convert to PDR in 1yr.

4. PDR:

It is the advance stage where signal sent by the retina for nourishment, trigger the growth of new vessels. These vessel walls are very thin and fragile which leads to a high risk of leaking blood. These leaked blood contaminates the vitreous gel which can cause severe vision loss even blindness. about 3% of people can experiencethis severe vision loss.

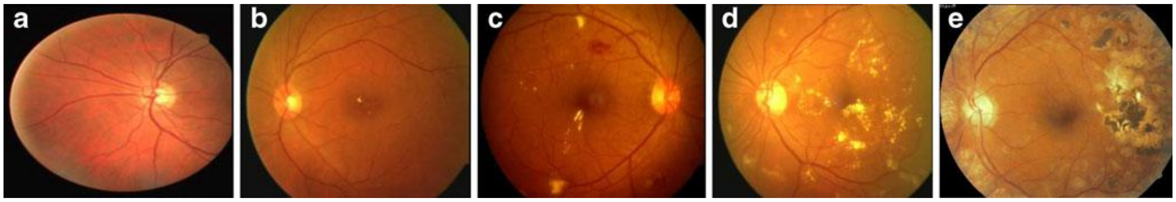

Fig. 2 Typical fundus images: (a) normal (b) mild DR (c) moderate DR (d) severe DR (e) prolific DR

2. Research Method

2.1. Feature extraction Methods:

Blood vessels, exudates, haemorrhages, microanerusyms and maculopathy detection techniques are described below. These detection techniques are used to automate DR.

2.1.1. Blood Vessels Detection:

1. Retinal fundus image gives a clear idea of the blood vessels in the retina. Using the green component of the RGB fundus image, blood vessels was obtained to a no of image processing algorithms techniques [1]. **Chaudhuri et al.**Using 2D Matched filters, blood vessels were detected. Gaussian shaped curve provides the cross-section of blood vessel of grey-level. This technique used to detect the piecewise linear segments of blood vessels after the vessel approximations [2].

2. **Hoover et al.** With the help of Fuzzy c-means classifier vessels points can be found in cross-section. The blood vessels outline edges can be detected by using this novel method to segment blood vessels which concatenate the local vessel attributes of the network structure [3].

3. **Englmeier et al.** To identify the retinal vascular network which is captured by digital camera, the blood vessel tracker algorithm was developed. The optic disk, bright lesions such as cotton wool spots and dark lesions like haemorrhages can be detected by this tracker algorithm. Arteries and veins perform an accuracy of 78.4% and 66.5% respectively by his algorithm [4].

4. **Vimala et al.** For identification of blood vessels from normalized color images, Kirsch's method is used then it is gone through enhancement using Kirsch's template and spatial averaging filtration then histogram equalization and binarization is performed on that images. This method proposed with sensitivity more than 91% and specificity of 90.5% [5].

5. **Yogesh et al.** A pre-processing operation was performed on retinal fundus image to describe simple vessel segmentation technique. Here histogram equalization used for enhancement, morphological opening used for thickening the retinal vessel and 2D-median filter was used for removing noise and extracting the blood vessels of retina [6].

6. **Chanjira et al.** For identifying the multilayer perceptron neural net of blood vessels, inputs were derived from a principal component analysis PCA of the image. The image can be analysed for diabetic retinopathy by sight threatening such as vascular changes or fovea exudation [7].

2.1.2. Exudates Detection:

Exudates are collection of lipid and protein in the retina. On the retina they are seen as bright, reflective, white or cream colored lesions. It can cause of increase vessel permeability which is a risk for retinal edema. Though they close to macula centre, they are considered as sight threatening lesions.

These are seen mostly with microaneurysms which themselves cause of leakage that causes a circular ring of exudates with several microaneurysms at this centre.

1. **Osareh et al.** gave results for exudates classification on fundus image. Different learning algorithms such as neural networks and support vector machine are evaluated by this method. Here neural network based approach performed better result than SVM(Support Vector Machine). It also controlled specificity and sensitivity of the method. The neural network approach gave accuracy of 93.4%,sensitivity of 93% and specificity 94% [8].

2. **Walter et al.** Exudates with high gray level variation and the morphological reconstruction techniques determined their contours. Using morphological filtering techniques and the watershed transformation, optic disc was detected. The result showed a mean sensitivity of 92.8%and mean predictive value of 92.4% [9].

3. **Sopharak et al.** This paper investigated and proposed a set of optimally adjusted morphological operators to detect exudates on diabetic retinopathy patient's non-dilated pupil and low contrast images. The automatically detected exudates by this method was validated with expert ophthalmologist’s hand-drawn ground truth data. This system acquired a sensitivity of 80% and specificity of 99.5% respectively [10].

2.1.3. Microaneurysms detection:

microaneursysm is a major feature to detect diabetic retinopathy because these structures constitutes the earliest recognizable elements to detect diabetic.

1. **Jelinek et al.** DR was identified based on the presence of microaneurysms. This method achieved a sensitivity of 97% and specificity of 88%. The automated retinopathy detector acquired 85% sensitivity and 90% specificity respectively. These sensitivity and specificity was determined by comparison with optometric and ophthalmologic assessment. The microaneurysms detector has lower sensitivity compared to optometrists [11].

2. **Walter et al.** First step of this method included image enhancement, shade correction and image normalization of the green channel whether second step included detecting the candidate in which all possibility of microaneurysms were detected. This method achieved a sensitivity of 88.5%. Based on diameter closing and kernel density estimation for automatic classifications, microaneurysm was detected [9].

2.1.4. Haemorrhages Detection:

Haemorrhages isa advance degree of Diabetic Retinopathy. They cause for loss of oxygen in retina which is also known as ischemia. The increased ischemia increase the retinal vessel become more damaged and leaky which leads to exudation of fluid, lipid and proteins.

1. **Larsen et al.** This paper used image-processing algorithms for detection of both haemorrhages andmicroaneurysms. This algorithm achieved a sensitivity of 96.7% , specificity of 71.4% and accuracy of 79% respectively [12].

2.1.5. Texture :

Texture is a measure of properties like smoothness, coarness and regularity of pixels in an image [13]. Texture can be defined as a mutual relationship among intensity values of neighbouring pixels repeated over an area larger than the size of the relationship[14].These intensity values of the pixel measures the entropy, contrast and co-relation based on the grey level co-occurrence matrix. Conventional texture recognition can be classified into three classes as structural, statistical and spectral from which by using statistical approach texture can be characterized as smooth, coarse, grainy and so on. Diabetic Retinopathy stages can also b detected by using these different texture parameters.

2.2. Classification Methods:

1. **Samuel et al.** An automated diagnosis of NPDR can be performed on the basis of three lesions such as haemorrhages and microaneurysms, hard exudates and cotton wool spots. This computer aided system could become a useful clinical aid to physicians and for screening, diagnosing, used as a tool to classify NPDR. This method was able to achieve an accuracy rate of81.7% for finding out the NPDR stage correctly [15].

2. **Singalavanija et al.** Mostly the screening mechanism to identify Diabetic Retinopathy were based upon the basic features like exudates, haemorrhages and microaneurysms. For differentiate DR and normal subject correctly, the sensitivity and specificity of that software was 74.8% and 82.7% respectively [16].

3. **Kahai et al.** proposed a decision support system for the early detection of Diabetic Retinopathy. To detect microaneurysms Bayes optimality criteria was used. This method had the

ability to achieve a sensitivity of 100% and specificity of 67% for the detection of early stage of DR [17].

4. **Wong et al.** By using both area and perimeter of the RGB components of the blood vessel normal,mild,moderate,severe and prolific DR stages were autometically classified and they together with a feedforward to neural network. The system average classification efficiency was 84% and they achieved sensitivity and specificity about 90% and 100% respectively [18].

5. **Nicolai et al**. designed an automated lesion system which identified 90.1% of patients having Diabetic Retinopathy, when it was applied in a screening population comprising of patients with untreated DR. This automated system demonstrated 93.1% of sensitivity and 71.6% of specificity respectively [19].

Table 1: Different methods defined to detect Diabetic Retinopathy

Sl.No	**Method**	**Principle**	**Advantages**	**Disadvantages**	**References**
1	Green component of RGB and 2D Median filter	Blood vessels was detected and using Gaussian shaped curve cross-section of blood vessels defined.	Retains the computational simplicity of the enhancement / thresholding type of edge operators.	It incorporates the advantages of using model based edge detectors due to large size of the convolutional kernel.	Chaudhuri et al. [2]
2	Fuzzy c-means classifier	Vessels outline edges can be detectedwhich concatenate the local vessel attributesof the network structure	This method reduces the false positive rate by a factor of 15 times	This approach not captured in evaluation is the property of connectedness	Hoover et al. [3]

3	Blood vessel tracker algorithm	optic disk,bright lesions such as cotton wool spots and dark lesions like haemorrhages can be detected	The first that integrates a reliable tracking technique with bifurcations and crossing identification		Englmeier et al. [4]
4	Kirsch's method is used	Kirsch's template and spatial averaging filtration then histogram equalization and binarization	This method proposed with sensitivity more than 91% and specificity of 90.5%.	Advancement of proposed algorithm can give a better result.	Vimala et al. [5]
5	Removing noise and extracting the blood vessels of retina.	histogram equalization for enhancement, morphological for thickening the retinal vessel and 2D-median filter for removing noise	This algorithm achieved 100% of true positive rate and 0% false positive rate.	It only performs overall area of blood vessel instead of infected area.	Yogesh et al**.** [6]
6	principal component analysis (PCA)	identified the multilayer perceptron neural net of blood vessels	Principal component analysis used to exclude features those are least influential in the		Chanjira et al. [7]

			classification.		
7	Neural networks and support vector machine are evaluated	Gave results for exudates classification on retinal fundus image	Obtained good class separability between EX and non-EX classes	Flexibility variance between NN and SVM	Osareh et al.[8]
8	Morphological filtering techniques and the watershed transformation detection	Exudates with high grey level variation and optic disc was detected.	This is achieved by diameter closing and an automatic threshold scheme.	Evaluation of this algorithm on larger populations is still required	Walter et al. [9]
9	Optimally adjusted morphological operators	detect exudates on diabetic retinopathy patient's non-dilated pupil and low contrast images	The proposed techniques work effectively even on a poor computing system.	The algorithm depends on other tasks, namely, the detection of the optic disc, and vessel removal.	Sopharak et al. [10]
10	Automated retinopathy detector	DR was identified based on the presence of microaneurysm s.	Cost-effective, and provide a history of changes in the retinal fundus image.	Has a lower sensitivity compared to the optometrists.	Jelinek et al. [11]
11	Based on diameter closing and kernel density estimation for	detecting the candidate in which all possibility of microaneurysm	An algorithm used for the detection of both hemorrhages	The moderate number of FP should not increase too much the burden of	Walter et al. [9]

	automatic classifications	s were detected.	and exudates.	image grading.	
12	Image-processing algorithm	Detection of both haemorrhages andmicroaneurysms.	Single fundus lesions can be achieved with a performance comparable to that of experienced ophthalmologists.		Larsen et al. [12]

Table 2: Comparison of different classification methods

Sl. No	**Authors**	**Method**	**Accuracy of Classification**	**Sensitivity**	**Specificity**
1.	Samuel et al. 2005 [80]	Automated diagnosis of NPDR	81.7%	Not Reported	Not Reported
2.	Singalavanija et al. 2006 [81]	Exudates, haemorrhages and microaneurysms	Not Reported	74.8%	82.7%
3.	Kahai et al. 2006 [36]	Decision support system	Not Reported	100%	67%
4.	Wong et al. 2008 [75]	Area of blood vessel	84%	90%	100%
5.	Nicolai et al. 2003 [51]	Automated lesion system	Not Reported	93.1%	71.6%

3. Discussion:

The diabetes leads to the formation of microaneurysms and subsequently it leads to exudates as well as haemorrhages. A vision loss or even blindness can happen by severing these features. To avoid such complications, need to detect DR very early stage. In such processes microaneurysm can only be detected accurately because it is difficult to detect exudates which are in the form of tiny spots in the retina. Detection of haemorrhages is very challenging because the texture of haemorrhages and macula are almost same. So for this differentiation we need a robust algorithm to detect these features.

Previously authors classified into two classes using two or three features of fundus image. Then subsequently more features are included to increase the efficiency of classification. A good designed classification increase the automatic detection rate.

4. Conclusion:

In case of Diabetic Retinopathy, the retina is getting damaged by leaking fluids from blood vessels. Usually Diabetic Retinopathy can be detected depending upon features like blood vessel areas, haemorrhages, microaneurysms, exudates and texture. In this paper we have discussed many methods for extraction of these features to detect stages of DR. Ophthalmologists are using ophthalmoscope to visualise the blood vessels for detecting DR. Digital imaging screening tools are now availing to provide high quality permanent records to the retinal appearance, which can be further processed, monitored and reviewed by the ophthalmologists. The regular screeningfor DR of patients with diabetes is important resulting the appropriate treatment of the patient which is less expensive also. So here the reviewed algorithms and classifiers are close to achieve the result of clinical practice to detect DR.

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