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Red Lesion Detection in Fundus Images – A Survey

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Abstract

The detection of the disease in the eye known as Diabetic Retinopathy is done with the help of Fundus Photographs. These images are captured using a special type of camera called as Fundus camera which has three values namely Red, Green, and Blue respectively. Each value is quantised to 256 levels. Earlier detection of the disease plays a vital role for saving the vision of the affected person, if unnoticed might lead to blindness which is irreversible.This paper presents the analysis of various algorithms used to classify the detected lesions in the images.

Keywords: *Diabetic Retinopathy, Hemorrhages, Microaneurysm, Fundus*

1. Introduction

In today's era many health-related diseases arise due to the changes in food style and ageing too. Among them the most prevalent disease that affects starting from the middle aged to old aged people is Diabetic Retinopathy(DR). This is caused due to a high increase in Sugar levels and also when the pancreas fails to produce insulin or functioning [10].

DR is among the most leading causes for the loss of vision at the Global Level. According to the report taken in 2015 2.6 million people lost their vision because of DR, the number of infected people is about to raise to 3.2 million in 2020 [12]. Red lesions and white lesions are the earlier signs of DR and Red lesions includes Microaneurysm(MA) and Hemorrhages(HMs) whereas the white lesion consists of exudates and cotton –wool spots. Early detection can lead to laser treatment and prevent or postpone further vision loss [5].

In the previous days Diabetes was thought to be a disease that affected only the wealthy , but now it has crossed the limit in affecting both the developed and the developing countries. The spread of diabetes is associated with the disorders of DR which is becoming increasingly prevalent, with the result that the diabetic retinopathy industry has made considerable progress. This paper elucidates the detection of red lesions by means of using the recent computer savvy and Image Processing Techniques which assist the ophthalmologists to perform timely diagnosis and detect the lesions at the earliest. Application of the recent techniques would depreciate the workload of the ophthalmologists and helps in accurate diagnosis of the disease.

The symptoms of diabetic retinopathy includes:

- Eye floaters
- Blurred vision
- Loss of central vision
- Difficulty in seeing well at night
- Fluctuating vision.
- Impaired color vision.
- Dark or empty areas in your vision.

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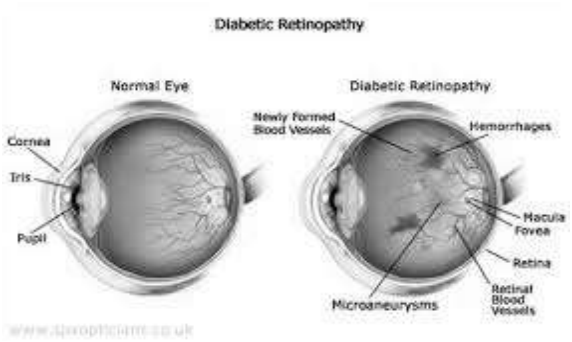

(A) (B)

Fig 1. A view of (A) Normal Eye (B) An Affected eye with DR

Diabetic Retinopathy is classified into two types namely Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). The latter type is superior than the other. NPDR bereaves the oxygen of the retina results in the growth of a fragile blood vessel, the gel-like fluid which fills the back of the eye.

Depending on the depth of the retinal layers the shape of the Hemorrhages may be small and round (dot or blot) or flame shaped. The earliest noticeable changes found in DR is the presence of Microaneurysms. These microaneurysms are widely spread and are stretched beyond their normal dimensions and appear like a tiny red balloon that is usually saccular in shape.
The diabetic retinopathy is classified into Four stages namely

1. **Mild NPDR**

In this stage the presence of microaneurysms do not affect the vision and often goes unnoticed.

2. **Moderate NPDR**

The blood vessels in this stage are swollen inorder to provide a proper nourishment to the retina. These changes caused in the retina are noticed.

3. **Severe NPDR**

At this stage a significant portion of the retina is blocked which decreases the flow of blood into the retina which leads to neovascularization.

4. **PDR**

The final stage is the advanced stage of Diabetic Retinopathy. Delicate and new capillaries that grow in this stage are typically both weak and abnormal, which can lead to leakage of blood in the eye, vision problems and potential blindness.

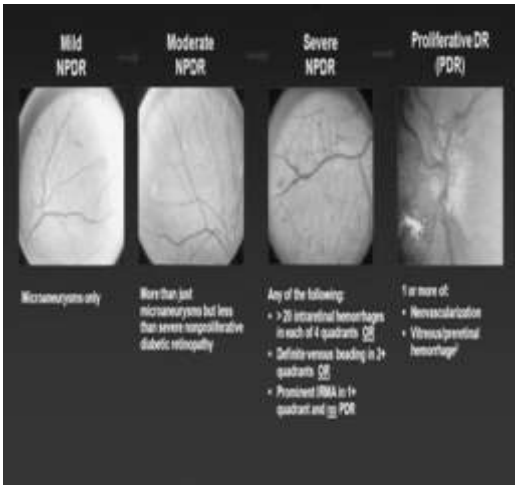

Fig 2. Stages of Diabetic Retinopathy

With regard to the detection of red lesion, most of the researches have been done by following the three main steps: preprocessing, candidate lesion extraction, and supervised classification of candidate lesions into lesion or non-lesion classes. Modifications are made often to improve the contrast between red lesions and the background of the retina, so as to find out the new features which could be used for classification, or developing hybrid classifiers for outstanding results. Hence it is necessary to identify the candidates because of the presence of dark lesions as the early signs of the disease. This paper summarizes several frequently used algorithms used for classifying the dark lesion. The fundus images are taken into account for pre-processing in which removal of noise and enhancement of the image is done. The preprocessed image undergoes Feature extraction phase where a stepwise morphological method is applied for removing the features. Finally in the Classification step respective classifiers are applied to classify the images.

2. Related works

Many studies have been made till date in fundus images for the automation and early detection of red lesions. In [9] microaneurysm is extracted by following a stepwise morphological method. GMM (Gaussian Mixture Model) Classifier is applied for classifying the sharpness of DR into severe, mild, moderate and NoDR. The paper [3] detected the candidate lesion using the Gaussian Shaped Curve and Matched Filter detection. In the work proposed by the author in paper [6] the extraction of the retinal vasculature and detection of candidate filtering for the detection of MAs and HMs was performed by applying Matched Filtering.Mayaet.al[7] in their work recognized the HEM and MAs by using Matched Filtering , Laplacian of Gaussian and Mutual Information Maximization which is time consuming .

M. U. Akram et.al [1**],** detected all the possible NPDR retinal lesions by using a novel hybrid classifier by following the steps such as preprocessing , extraction of candidates lesions, feature set formulation and classification by combining an extension of the m-mediods based on the modeling approach along with a Gaussian Mixture Model. The accuracy of the classification is improved with the help of the Hybrid Classifier which is formed by combining the GMM in an ensemble. It is the HC which assigns weights to different classification probabilities in order to improve the overall accuracy.

The proposed work in [2] a novel method for automatic detection of red lesions in digital fundus images is introduced. A new feature called elliptical variance is included during the classification phase in order to reduce the occurrence of false positives significantly. The algorithms (ASG) Automatic Seed Generation is used to extract the candidate lesions. Contrast Enhancement is done by applying GLG (Gray Level Grouping). Shade Correction is performed using the Median Filtering which is applied on the Green Channel of the input image. MTH (Morphological Top Hat) method is ignored and the lesions are localized by ASG. In classification step the hybrid classifier named "Spatio Temporal Feature Map"(STFM) Classifier is being applied to classify the images. With the help of image processing and Machine Learning techniques an automated method for detection of red lesions is proposed by the author in paper[5].The summarization of different methods proposed for the preprocessing phase in the detection of dark lesions present in the digital color fundus photographs has been done in the research paper[8]. False detection is the major problem faced in detecting the red lesions with the presence of blood vessels in the retina. To overcome the problem a new filter named Frangi Filter is introduced by the author in [10] to detect the HMs and MAs respectively. The author of paper [4] proposed a novel and automated Lesion detection Scheme. The proposed system contains the four steps namely Vessel Extraction, Pre-processing, candidate lesion detection, post-processing. Since most of the lesions appear in variables sizes with irregular shapes etc. it becomes tedious to detect the presence of the various types of lesions. Various algorithms are applied to detect the lesions. Curvlet Edge Based Enhancement seperates the dark lesions from the background. The optimally designed Wide Baseband Filter is used to enhance the contrast between the bright Lesions and background . In order to enhance the dark lesions Curvlet Transform is applied. With the help of the Band Pass Filter (BPF) the dark and bright lesions are enhanced together. The post processing step combined with the different Processing techniques along with MF and

LoG filter when applied smartly yields an efficient way to detect different lesions irrespective of their features. When Morphology based Post processing is applied it eliminates the occurrence of the falsely detected candidate pixels.

The remaining sections in the paper is structured as follows. In section III several classification approaches are summarized. Section IV dicusses the comparison results of the discussed approaches in section II. At the end , Section V contains the conclusion.

3. Classification Techniques for Fundus Images

After preprocessing the images and extracting the relevant features from the fundus images it is a need to classify the images so as to know the performance of the proposed methods. Based on the classifications the severity of DR is categorized into four stages considering the count of microaneurysms listed in Table 1

TABLE 1: VARIOUS STAGES OF DIABETIC RETINOPATHY

List of Stages	Microaneurysms count	Severity Level of DR
Stage 0	0	No DR
Stage 1	1-5	Mild
Stage 2	5-15	Moderate
Stage 3	>15	Severe

The classification approaches are as follows

A. Gaussian Mixture Model Classifier (GMM)

The GMM classifier is used for automatic classification and segmentation of the images. In this method the selected features in [9] are put in to calculate the severity in DR with respect to the count of the microaneurysm. If the count is higher then there is a chance of losing vision and if it is mild then proper medication has to be taken inorder to avoid reaching the severity level.

B. Support Vector Machine (SVM)

The Support Vector Machine is a statistical learning method based on Structural Risk Minimization (SRM). The extracted features in [6] are given to train the classifier. The vector vessels local entropy thresholding for proper selection of threshold. The classifier thus catergorizes the input image object into lesion and non-lesion respectively. The paper[5] Machine Learning algorithms which needs a set of features for detection of false positives. The features are obtained from having a region of interest and with the help of those regions Gray-Level Co-occurrence Matrix (GLCM) is created. Using the training data set machine learning model is created which is in turn used to remove the false positives from the red lesion candidates. In the proposed work [10] the features extracted from the training dataset were used to train a Support Vector Machines (SVM) classifier with RadialBasisFunction(RBF) kernel. For each lesion, a single classifier was trained so as to predict the presence or absence of the lesion in the test image. The proposed method outperformed the state of-the-art works in detecting MAs with an area under ROC curve (AUC) equal to 0.97. For Hs, the AUC was same as the state-of-the-art(0.87) so further improvement has to be made . The proposed work in paper [3] classified the candidate red lesions from other dark lesions by using SVM.

C. K Nearest Neighbours

The kNN classifier is the simplest classification algorithm. It yields highly competitive results. It can also be used for regression problems.

D. Spatio Temporal Feature Map classifier(STFM)

The paper[1] used a hybrid classifier STFM to classify the input image and reduced the false positives.

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4. Comparative Results

The following table 2 lists the performance of classifiers in detection of fundus images.

Table 2: Performance of Classifiers

Author Name	Sensitivity	Specificity	Accuracy
Lokuarachchi et.al [5]	92.05	98.68	-
Kande et.al [3]	96.22	99.53	-
M.U.Akram et.al [1]	97.83	98.36	98.12
S.Balasubramaniam et.al [2]	-	83.57	-
Mane et.al. ,[6]	96.42	100	96.62

5. Conclusion

In this paper various methods for detecting the red lesions are summarized. The performance of the classifiers are judged based on Sensitivity, Specificity and Accuracy. They are expressed as follows

$$\textbf{Sensitivity} = TP/(TP+FN)$$

$$\textbf{Specificity} = TN/(TN+FP)$$

$$\textbf{Accuracy} = TN+TP/(TN+TP+FN+FP)$$

where TP denotes the correctly classified retinal lesion region, the lesion free regions which is detected as retinal lesion is denoted as FP, TN is the lesion free regions that is classified correctly, FN denotes the wrongly classified non- lesion regions. From the readings in table2 it is clear that the Gaussian Mixture Model a Hybrid Classifier yields outstanding results in detecting the red lesions in fundus images.

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