Grading of Diabetic RetinopathyUsing Retinal Color Fundus Images by an Efficient MATLAB Application

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ABSTRACT

Diabetic retinopathy is the most common diabetic eye disease and a leading cause of blindness. Regular screening for early disease detection has been a highly labor and resource intensive task. Hence automatic detection of these diseases through computational techniques would be a great remedy.In this paper, a novel method for automatic detection of both microaneurysmsandhemorrhages in color fundus images is described.The main contribution is a new set of shape features, these features represent the evolution of the shape during image flooding and allow to discriminate between lesions and vessel segments called Dynamic Shape Features. Based on the values of the feature vectors, each patient segment is categorized as Normal,Medium and severe using random forest (RF) Classifier. The proposed MATLAB app. is validated on per-image basis using four different publicly available databanks.On the Messidor database, when detecting images with diabetic retinopathy, the proposed method achieves an area under the ROC curve of 0.899, comparable to the score of human experts, and it outperforms state-of the-art approaches.

Keywords— Color fundus images, Classifier lesion detection, diabetic retinopathy, fundus IMAGING, Random Forest, retina, screening.

I.INTRODUCTION

DR is one of the complications of diabetes, which causes impairment of sight by damaging the blood vessels in the retina. It is the common cause of vision loss [1].Many studies show that one out of three diabetic person presents signs of DR [2] and 10 out of 100 DR patients should be referred to a doctor (Dr.) since their complications are very severe [3][4].

Based on latest reports by 2030 there is an epidemic rise of 4.4% in the global prevalence of diabetes [5].Patient's sight can be affected by diabetes which causes impairment of sight by damaging the blood vessels in the retina, the condition known as "diabetic retinopathy".

In order to extend the quality of patient's life, there is a need of an efficient automatic computational system that assists the ophthalmologist to detect cases with DR, andgrade these cases to reduce their burden. As the number of specialist is limited, the analysis of retinal images is really a very challenging task for the image processing community [6].

DR causes several kinds of lesions in the retina. A computer-aided screening and grading system relies on the automatic detection of lesions. Fundus images with DR exhibit red lesions, such as microaneurysms (MA) and hemorrhages (HE), and bright lesions, such as exudates and cottonwool spots. In this paper, we will focus only on MA and HE which are among the very first manifestations of DR.

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Even though MAs are among the first signs of DR, HEs are also highly valuable for DR screening and useful for grading. In fact, retinal HEs are the result of MAs starting to leak into the retinal layers, indicating a more severe level of DR. According to the most common DR severity scale [7], their presence and number indicate either a moderate or a severe nonproliferative DR. HEs come in different types, such as ”dot”, ”blot” and ”flame” [8]. Dot HEs and MAs are difficult to distinguish from one another on fundus images, thus dot HEs are usually referred to as MAs. A flame HE corresponds to blood leaking into the nerve fiber layer A blot HE corresponds to blood leaking deeper in the retinal layer. It appears larger than a dot HE, and its borders are irregular, leading to various shapes.Fig. 1 shows examples of these lesions types.

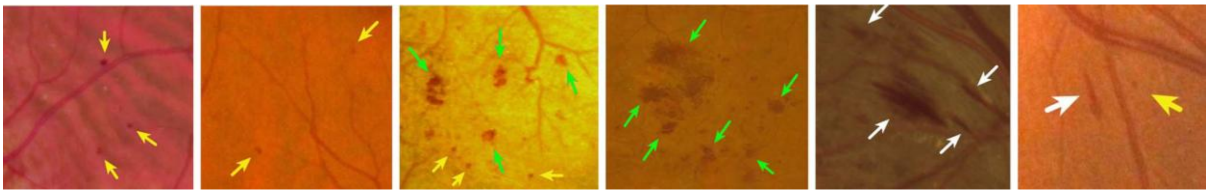

Fig. 1.Portions of different fundus images with red lesions. The yellow, green and white arrows point respectively to MAs/dot HEs, blot HEs and flame HEs.

Therefore, there is a need of an automated computational system that accurately assesses the severity of the Diabetic Retinopathy and this becomes the aim of this proposed system.

The Organization of the paper is as follows. Section II describes the overview of state of art approach. The details of the proposed method are discussed in section III. Section IV reports the methodology of performance evaluation and the experimental results. Finally the main points are summarized and the conclusion is given in section V.

II. OVERVIEW OF STATE OF ART

Several techniques have been proposed for the automatic detection of other symptoms in fundus images with DR, but only few methods have been done to detect and grade the severity of the disease by detecting microaneurysms and hemorrhages.

AlirezaOsareh et al [9], developed a method for automatic identification of DR. The color retinal images were preprocessed and it is segmented using FCM clustering algorithm. The feature vectors were calculated and classified using multi-layer neural network. The classification performance for this stage was only 96% sensitivity and 94.6% specificity.

Syed Ayaz et al [10] proposed an automated microaneurysm detection system based on curvelet transform. Blood vessels are removed and a local entropy thresholding technique is used to select the microaneurysmcandidates. Image background is estimated using statistical features. The results are allowed to identify the microaneurysm candidates which are also present in the image foreground. A collection of three set of features, namely color based, hessian matrix based and curvelet coefficients based are fed to a rule based classifier to divide the candidate as microaneurysms and non microaneurysms.

The bright lesions like exudates, cotton wool spots and drusen were distinguished by Niemeijer et al in [11]. The clusters are formed based on the probability map. Based on the probability, the clusters were classified as exudates, cotton wool spots or drusen. Sensitivities and specificities were used as the performance parameter.

Sinthanayothin et al in [12] proposed the automatic detection of DR using Recursive Region Growing techniques. The authors reported 88.5% of sensitivity and 99.7% of specificity as their performance on a dataset of 21 abnormal and 9 normal fundus images.

In Akarasopharak et al [13], conducted a series of experiments for Lesion classification using Naïve Bayes (NB) and Support Vector Machine (SVM) classifiers. They compared the obtained result with nearest neighbor (NN) classifier and proved that Naive Bayes (NB) and SVM classifier produces better result than
the NN classifier.

III. PROPOSED METHODOLOGY

The aim of this approach is to introduce a novel efficient methodology for the grading of Diabetic Retinopathy by detecting exudates. The schematic overflow of the proposed method is shown in figure 2 for the better understanding.

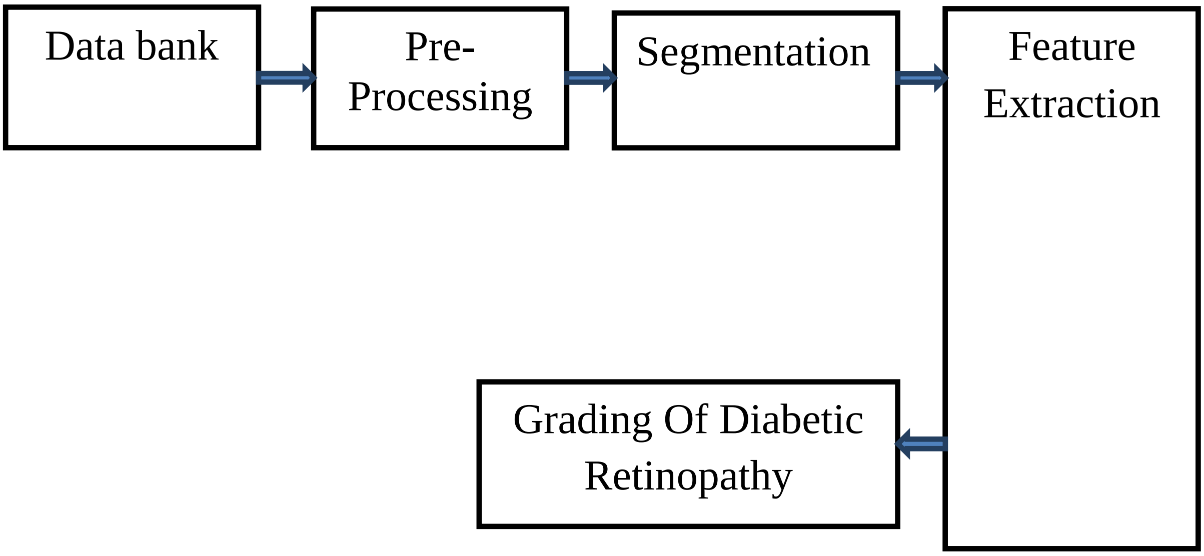

Figure 2: Schematic overflow of the proposed method.

3.1. Databank

To achieve an efficient grading of the disease, the primary thing is to obtain an effective database. The color fundus images required for simulation are collected from four different publicly available databank- diaretdb1, Messidor, Erlangen and STARE.

3.1.1. Diaretdb1 Databank

This databank consists of 60 images for testing and 28 images for training along with the manual segmentations of exudates. This databank is publicly available in PNG format [14].

3.1.2. Messidor Databank

Messidor databank is one of the widely used dataset in the research work. It consists of 546 normal images, 654 abnormal images which are captured with a field of view (FOV) of 45[15].

3.1.3. Erlangen Databank

This databank comprises of 15 normal and 30 affected images which are acquired with a field of view (FOV) of 60and are publicly available as JPEG file format [16].

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3.1.4. STARE Databank

This databank of 81 color fundus images were captured by TRV-50 camera with a 45 field of view. Out of 81 images, 50 images are abnormal images and 31 are healthy images[17].

3.2. Image Pre-processing

The proposed method takes as input a color fundus image. Generally, the color fundus images are pre-processed to overcome the problem of non-uniform illumination, poor contrast and noise. In this approach, the images are first preprocessed by

3.2.1 Grey scale imaging,

3.2.2 Denoising,

3.2.3 Contrast Enhancement.

3.2.1 ***.Gray Scale Image***

All MAs appear as tiny red dots on retinal fundus image. Therefore the red component of the RGB image are used to identify the MAs. Initially extracted red channel image is converted into gray scale image and then preprocessed for uniformity. Then the illuminationequalization is applied to this extracted M-channel.

Gray scale or gray scale digital image is an image in which the value of each pixel is a single sample, that is, it carries only intensity information.

Each pixel in the M-channel is adjusted using the following equation as

$$Geq(x, y) = G(x, y) + \mu - Gw(x, y)$$

whereGeq(x, y) = Illumination Equalized Image, G(x, y) = Red channel extracted from the RGB image.

μ = desired mean intensity and Gw(x, y) = average intensity value of the pixels within a running window of size 40 x 40.

3.2.2. *Denoising*

Noise is any undesirable signal. at each pixel in an image we have a neighborhood around that particular point, evaluate the values of all the pixels in the neighborhood according to the steps and then replace the original pixel's value with one based on the analysis performed on the pixels in the neighborhood.

The neighborhood, moves successively over every pixel in the image, repeating the process. A median filter does a very good job at reducing the noise in image.

3.2.3 Contrast Enhancement

Contrast is an important factor in any subjective evaluation of image quality.

Firstly, HE transforms the histogram of the input image into a uniform histogram by distributing the entire range of gray levels uniformly over the histogram of an image, with a mean value that is in the middle of gray level range.

Secondly, histogram equalization performs the enhancement based on the global content of the image.

3.3 Image Segmentation :

Image segmentation is the process of partition the input image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation which used to find objects and margins (lines, curves, etc.) in an images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

There are two steps involved in segmentation of medical image in digital image processing. They are

A. Morphological Operation

B. Thresholding Method

In this paper morphological operations are used in post processing mainly as a filter. Its fundamental operations are Boundary pixels and low frequency pixels are eliminated from image. Then difference image was generated. There are two operations performed in morphological process.

They are

1. Erosion

2. Dilation.

Erosion: It was originally defined for binary images, later being extended to gray scale images, and subsequently to complete lattices.

Dilation: The dilation is applied to binary images, but it can work on grayscale images also. The basic effect of the operator on a binary image is to gradually enlarge the boundaries of regions of foreground pixels.

Morphological closing consists of dilation followed by erosion. Morphological closingoperation is carried out to remove the blood vessels.

Canny edge detector is an edge detecting operator that uses multistage algorithm to detect wide range ofedges in images. Strong and weak fine blood vessels can be detected using this canny edge detector.Finally segmentation is completed to make the red lesions visible.

3.4 Feature Extraction:

To discriminate the lesion and the non-lesion region from the segmented image, different features based on dynamic shape [18], are extracted.

These attributes are computed as follows.

i) Circularity (f1)

The ratio of area of basin over its squared perimeter multiplied by 4□.

ii) Rectangularity (f2)

The ratio of area of basin over the area of its bounding box.

iii) Solidity (f3)

The ratio of area of basin over the area of exudates.

iv) Eccentricity (f4)

$$f_4 = \sqrt{\frac{L^2 - W^2}{L^2}}$$

where W and L are the width and length of the bounding box.

v) Relative area (f5)

The number of pixels in the basin area divided by total number of pixels in the region of interest(ROI).

These features are all combined and it is formed as a feature vector.

3.5. Grading of Diabetic Retinopathy

To grade the severity of the disease as mild, moderate and severe, Random Forest (RF) classifier [19] isused. The main reason for selecting this RF classifier is that it incorporates feature selection algorithm.Therefore it overcomes over fitting problem and suitable for non-linear high dimensional data classification.Based on theextracted features, the RF classifier classifies the image as normal, medium and severe.

The RF implementation provided in [20] and the MATLAB interface provided in [21] are used. Finally,the MATLAB App. is generated by combining all the above step. The MATLAB App. generation providedin [22] is used.

VI. RESULTS AND DISCUSSION

The proposed MATLAB App. has been tested with normal and abnormal images in the four different databanks like Diaetdb1, Messidor, Erlangen and STARE. Results are compared with the already existing methods. This App. is developed on a 2.8 GHz Intel Core i5 Personal computer with a 64-bit Operating Systems and RAM memory of 6 GB. The proposed algorithm takes a computational time of about 12 sec for each retinal image. Sensitivity, specificity and area under receiving operating curve (AUC) are used to evaluate the performance of the method as follows:

$$\text{Sensitivity} = \frac{TP}{(TP+FN)}$$

$$\text{Specificity} = \frac{TN}{(TN+FP)}$$

where TP, TN, FP and FN are true positive, true negative, false positive and false negatives respectively.

Table I depicts the overall sensitivity and specificity for the detection of exudates in four different databanks.

Table 1Performance Measure of the Proposed Method

Performance Parameter	*Diaretdb1*	*Messidor*	*Erlangen*	*STARE*
Sensitivity	95.36%	96.89%	97.1%	95.53%
Specificity	92.12%	93.75%	94.0%	91.25%

The proposed method achieves an sensitivity of 96.3% and a specificity of 93.3%. , and area under the ROC curve of 0.899,

V. CONCLUSION

Existing approaches for the screening of diabetic retinopathy are expensive, more time consuming and requires an expert ophthalmologists. An Efficient MATLAB App. for the grading of Diabetic Retinopathy was presented and validated on four different databanks. The performance of the proposed App. Outperforms several existing approaches. For classification and grading of disease, RF classifier is used which itself have a feature selection algorithm. However, further development can be made by focusing on the detection of cotton wool spot and neo-vessels in the retina.

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