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An Ensemble based System for Detection of Retinal Microaneurysms and Diabetic Retinopathy

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***Abstract* – Diabetic retinopathy is a serious complication of diabetes and major cause of blindness. Therefore early detection through regular screening will be highly beneficial in effectively controlling the progress of the disease. Microaneurysms are the early signs of Diabetic retinopathy and appear as mall red dots. The number of microaneurysms gives the severity of the disease. Early microaneurysm detection can help to reduce the incidence of blindness. We propose an ensemble-based system to improve microaneurysm detection. We propose a system that combine the internal components of microaneurysm detectors, namely preprocessing methods and candidate extractors.**

***Keywords* – Diabetic Retinopathy, Ensemble-Based System, Microaneurysms.**

I. INTRODUCTION

Diabetes is a disease that occurs when the pancreas does not secrete enough insulin or the body is unable to process it. Insulin is the hormone that regulates the level of sugar in the blood. Diabetes can affect children and adults. Patients with diabetes are likely to develop eye problems such as cataracts and glaucoma, but the disease's affect on the retina is the main threat to vision. Most patients develop diabetic changes in retina after approximately 20 years. The effect of diabetes on the eye is called diabetic retinopathy. Diabetes affects the circulatory system of the retina. Vessel growth and scar tissue may cause serious problems such as retinal detachment and glaucoma. The effect of diabetic retinopathy on vision is varies widely, depending on the stage of the disease. Some common symptoms of diabetic retinopathy are given below. Diabetes may cause other eye symptoms also.

- Blurred vision (this is often linked to blood sugar levels)
- Floaters and flashes
- Sudden loss of vision

Diabetic patients require routine eye check up, so related eye problems can be detected and treated as early as possible. Diabetic retinopathy results when diabetes affects blood vessels in the eyes, producing abnormalities such as microaneurysms, hemorrhages, exudates and new blood vessels as shown in Fig.1.This can cause loss of vision and even blindness. These abnormalities are divided into two stages non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR). Non-proliferative diabetic retinopathy can be further classified as Mild NPDR, Moderate NPDR and Severe NPDR. Mild NPDR is characterized by the presence of at least one micro aneurysm. Moderate NPDR is characterized by the presence of hemorrhages, more micro aneurysms, soft exudates and venous beading. Severe NPDR has more hemorrhages, more microaneurysms and micro vascular abnormalities. PDR is an advanced stage. In PDR the signals sent by the retina for nourishment trigger the growth of new blood vessels. This may in turn cause neovascularisation of disc and it may result in severe vision loss and even blindness.

Laser surgery called pan retinal photocoagulation (PRP) is usually used as a treatment for this problem. For PRP, the surgeon uses laser to destroy oxygen-deprived retinal tissue outside of the patient's central vision. Because the process of analyzing all retinal fundus images is time consuming and repititive. Many of these images may not have any abnormalities. Thus the requirement of the automating grading process by which more patients can be screened and if require can be sent to ophthalmologist for further examination. Several automated techniques are designed for diabetic retinopathy screening.

The presence of microaneurysms is considered as early stage of diabetic retinopathy. As shown in the Fig.2. microaneurysms on the retina appear as small red dots of maximum diameter to be less than the diameter of the major optic veins. The recognition of microaneurysms is essential in the process of diabetic retinopathy grading, since it forms the basis of deciding whether an image of a patient's eye should be considered healthy or not. A key feature to recognize the Diabetic retinopathy is to detect microaneurysms (MAs) in the fundus of the eye.

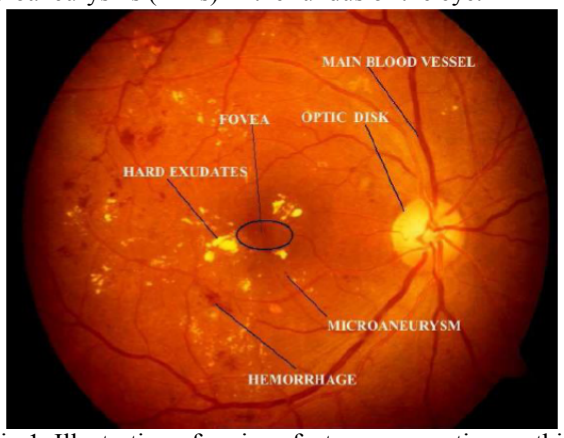

Fig.1. Illustration of various features on a retionopathic image

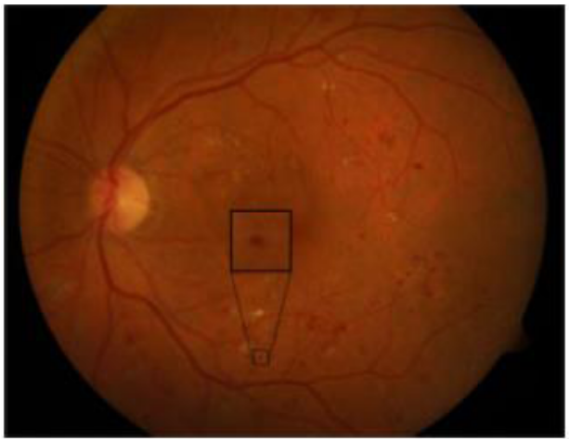

Fig.2. Retinal image with microaneurysm marked

II. Related Work

Image analysis tools can be used for the automated detection of the various features and stages of Diabetic Retinopathy [1], and can be referred to the specialist accordingly for intervention, thus making it a very effective tool for effective screening of Diabetic Retinopathy patients. DR patients require frequent, at least six monthly screening of vast number of patients and automating the process will go a long way in relieving the burden on the specialist and reducing the most common cause of preventing blindness.

Automated detection of lesions in retinal images can help in early diagnosis and screening of a common disease: Diabetic Retinopathy. A robust and computationally efficient approach for the localization of the different features and lesions in a fundus retinal image is presented in [11]. Since many features have common intensity properties, geometric features and correlations are used to distinguish them. The new constraint for optic disk detection is used to detect the major blood vessels first and then use the intersection of these to find the approximate location of the optic disk. This is further localized by using color properties. Also many of the features such as the blood vessels, exudates, microaneurysms and hemorrhages can be detected quite accurately using different morphological operations applied appropriately. These compare very favorably with existing systems and assure real deployment of these systems.

An approach to improve microaneurysm detection in digital color fundus images is presented in [7]. Instead of following the standard process which consist preprocessing, candidate extraction and classification, they propose a novel approach that combines several preprocessing methods and candidate extractors before the classification step. They ensure high flexibility by using a modular model and a simulated annealing-based search algorithm to find the optimal combination. Experimental results show that the proposed method outperforms the current state-of-the-art individual microaneurysm candidate extractors.

In this paper, we propose an effective MA detector based on the combination of preprocessing methods and candidate extractors. We use an ensemble based framework to select the best combination. The rest of the paper is organized as follows: the preprocessing methods and candidate extractors are presented in section III and IV respectively. The details of the proposed ensemble based framework are discussed in section V. M.A detection is given in VI. We summarize our experimental result in section VII and draw a conclusion in section VIII.

III. Preprocessing Methods

In this section, we present the selected preprocessing methods, which are applied before executing candidate extraction. The selection of the preprocessing method and candidate extractor is a challenging task. The pre-processing method is been selected to remove the noisy images so that the MA detection is done easily. We have to select algorithms that can be used before any candidate extractor and do not change the characteristics of the original images. The best methods is been selected from image processing that will have all the characteristics needed to detect diabetic retinopathy. These preprocessing methods used can be modified for future purpose. A summary on the differences of the algorithms is given in Table I.

A. Walter -Klein Contrast Enhancement [9]

This method is used to improve the contrast. This is been done by using the gray level transformation, which is applied to the retinal image that is been used as input image.

B. Contrast Limited Adaptive Histogram Equalization [10]

This is the popular technique that is been used in image processing technique which increases the clarity of the salient part of the image making it visible and clear. First image is split into disjoint regions, and in each region local histogram equalization is applied. Then, the boundaries between the regions are eliminated by using bilinear interpolation.

C. Vessel Removal and Extrapolation [12]

In this method the unwanted vessels is been removed from the input image [11] and extrapolate the missing parts to fill in the holes caused by the removal using the inpainting algorithm presented in [12]. MAs appearing near the vessels become more easily detectable in this way.

D. Illumination Equalization [8]

This preprocessing method is used to reduce the vignetting effect caused by uneven illumination of retinal images and each pixel intensity is been set according to the following formula:

$f\_ = f + \mu d - \mu l$

where f , $f\_$ are the original pixel intensity and the new pixel intensity values, μd is the desired average intensity, and μl is the local average intensity. MAs appearing on the border of the retina are enhanced by using this step.

E. No Preprocessing

We also consider the results of the candidate extractors obtained for the original images without applying any preprocessing. That is why we formally consider a "no preprocessing" operation, as well.

IV. Candidate Extractors

Candidate extraction is a process that uses to spot any objects in the image showing MA-like characteristics. The individual MA detectors consider different principles to extract MA candidates. In this section, we provide a brief overview of the candidate extractors which are involved in our analysis. Again, just like for preprocessing methods, adding new MA candidate extractors may lead to further improvement in the future.

A. Walter et al. [14]

Candidate extraction is accomplished by using grayscale diameter closing. This method aims to find all sufficiently small dark patterns on the green channel. Finally, a double threshold is applied.

B. Spencer et al. [15]

From the input fundus image, first the vascular map is extracted by applying 12 morphological top-hat transformations with 12 rotated linear structuring elements (with a radial resolution 15◦). Then, the vascular map is subtracted from the input image, which is followed by the application of a Gaussian matched filter. Then the resulting image is then binarized with a fixed threshold. Since the extracted candidates are not gives the precise representations of the actual lesions a region growing step is applied to them.

Table I: Summary of the Differences of the Preprocessing Methods

Algorithm	Aim	Method
Walter – Klein	Contrast enhancement	gray level transformation
CLAHE	salient object enhancement	local histogram equalization
Vessel removal	MA enhancement near Vessels	vessel removal and inpainting
Illumination eq.	MA enhancement at the border of ROI	Vignette correction

While the original paper [15] is written to detect MAs on fluorescein angiographic images, our implementation is based on the modified version which is published by Fleming *et al.* [16].

C. Circular Hough-Transformation [17]

As the idea presented in [17], we established an approach that was based on the detection of small circular spots in the image. Candidates are obtained by detecting circles on the images using circular Hough transformation method. With this technique, a set of circular objects can be extracted from the image.

D. Zhang et al. [18]

For the candidate extraction, this method constructs a maximal correlation response image for the input retinal image. This is accomplished by taking the maximal correlation coefficient with five Gaussian masks with different standard deviations for each pixel. The maximal correlation response image is threshold with a fixed threshold value to obtain the candidates. Vessel detection is applied to reduce the number of candidates, and region growing is to determine their precise size, respectively.

E. Lazar et al. [19]

Pixel-wise cross-sectional profiles with multiple orientations are used in this method to construct a multidirectional height map. This map assigns a set of height values which describe the distinction of the pixel from its surroundings in a particular direction. In a modified multilevel attribute opening step, we are constructing a scoremap, from which the MAs are extracted by thresholding.

V. Ensemble Creation

In this section, we describe our ensemble creation approach for M.A. detection. In our framework, an ensemble E is a set of (preprocessing method, candidate extractor) or shortly pair of (PP, CE). The meaning of a (preprocessing method, candidate extractor) is that first we apply the preprocessing method to the input image and then we apply the candidate extractor to this result. Such a pair will extract a set of candidates HE from the original image. The process of ensemble creation is also shown in Fig.3.

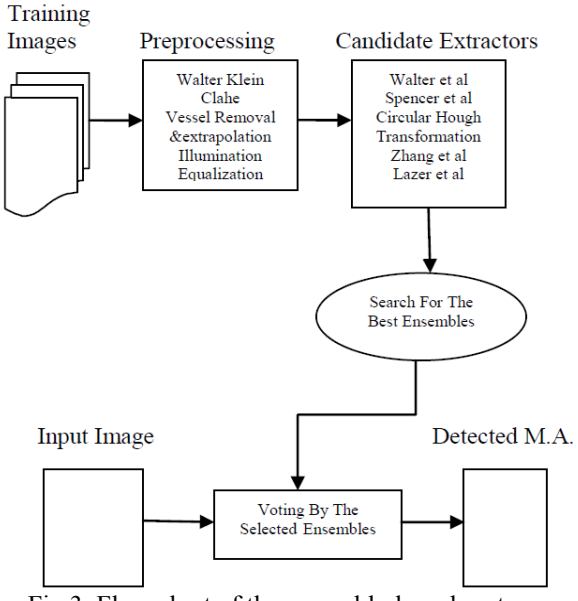

Fig.3. Flow chart of the ensemble-based system

If an ensemble E contains more (preprocessing method, candidate extractor) pairs, their outputs are determined in the following way:

Take 10 training images which are already disease affected images. Then we use the selected preprocessing methods, which we consider to be applied before executing MA candidate extraction. There may be around 5 methods present in preprocessing method. Candidate extraction is present next to preprocessing method. Similar to preprocessing there are 5 techniques are present in Candidate extractors.

For a single image, 25 combinations are available. Since there are 5 methods available in both preprocessing and candidate extraction, for each method in preprocessing there are 5 candidate extraction methods are processed. Likewise it repeated for 5 methods in preprocessing. So there are 25 methods are proceeded for a single image. Then we should have to calculate the entropy for all 25 results. Then after calculating the entropy for the 25 methods, we can predict the best technique or method, considering whose entropy is highest. For ex., if third method's entropy is highest means we determine that third one is the best technique.

Likewise, we should calculate for a set of 10 training images, by following the procedure mentioned above we can determine best techniques for 10 images. For ex. the best techniques of 10 images are like this format given as: [3 2 4 3 6 3 8 3 4 3]. After analyzing the best techniques whose entropies are highest for 10 images, mentioned above, we can see that third technique is repeated many times than other. So we can conclude that the third technique is the best technique.

VI. M. A. Detection

We have evaluated the MA detection capabilities of the proposed method in the ROC competition for MA detectors [13]. ROC is the competition dedicated to measure the accuracy of MA detectors. The ROC database consists of 50 training and 50 test images in it, With different resolutions (768 × 576, 1058 × 1061 and 1389 × 1383), 45◦ FOV and JPEG compression. The average MAs for the training and test sets are 6.72 and 6.86, respectively. There are total 13 and 10 images of the training and test sets, where no MAs are marked by the experts.

VII. Result

We are using different preprocessing methods and candidate extractors. Thus, use of different preprocessing methods with candidate extractors creates diversity among the members of the ensemble. This diversity ensures the suppression of false detections. The proposed ensemble based framework provide high flexibility for given dataset

VIII. Conclusion

We have proposed an ensemble-based MA detector that has proved its high efficiency in grading the diabetic retinopathy to detect M.A. compared with the present techniques. Our novel framework relies on a set of preprocessing method, candidate extractor pairs, from which a search algorithm selects an optimal combination of preprocessing and candidate extractor. Since our approach is modular, we can expect further improvements by adding more preprocessing methods and candidate extractors in our system. However, a proper screening system should contain other components, which is expected to increase the performance of this approach.

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