Comparative Study of methodologies used to identify microaneurysms in RETINA

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ABSTRACT

Diabetes mellitus, commonly known as diabetes has become a huge problem in recent days throughout the world. If the patient's sugar levels in blood are not maintained properly, it may lead to deformities in the retina over a long period of time. These deformities are diagnosed as Diabetic Retinopathy (DR). Some major problems associated with it are Hard Exudates, Cottonwool spots, hemorrhages & Microaneurysms. The topic of study relates to early detection of such microaneurysms in the retina of the patient diagnosed with Diabetic Retinopathy. Microaneurysms are capillary dilatations that are circular and appear as red dots in the retina. If not treated within time, these lesions may result in loss of vision since it is directly associated with the macula of the eye. These lesions are generally present in inner nuclear layer i.e., the 4th layer of retina. Many methodologies have been proposed for detection of microaneurysms. However, each of them is lacking one thing or the other such as inadequate database, poor pre-processing, false identification etc., In this study, a comparative study between different methodologies that have been implemented and various characteristics that are associated with them is carried out. Comparison of these methods along with evaluating their performance would help in identifying the problems faced by each of these methods. That would give an insight on how to proceed with if the implementation is picked up after this comparative study. Relative differences present in them can be sorted out and used for the advantage of the method that is selected from the pool of methodologies available.

Keywords: *Fundus images, Fluorescein Angiograms, Microaneurysms, Automated Detection.*

1. INTRODUCTION

Identifying and comparing various methodologies used for early detection of microaneurysms from retinal images of patients diagnosed with Diabetic Retinopathy. Diabetes has become a global phenomenon in recent times. If the sugar levels are not maintained properly by these patients, over time it may result in forming lesions in the retina such as Hard Exudates, Cottonwool spots, Hemorrhages, Micro aneurysms etc., Early detection of one of the lesions called Microaneurysms will help the doctors in treating the patients well within time. There are several methods of edge detection available to identify and detect the edges of certain objects. However, the methodologies vary in accuracy and consistency with respect to the type of the object/image they are trying to detect. The goal is to identify various methodologies and their characteristics and compare them that might help in detecting the edges of retinal images of the patient.

In this comparative research, understanding how the inputs are taken in the first place i.e., the type of retinal image used as input is the first and foremost step. Some of the most common images constitute fluorescein angiograms and fundus images.

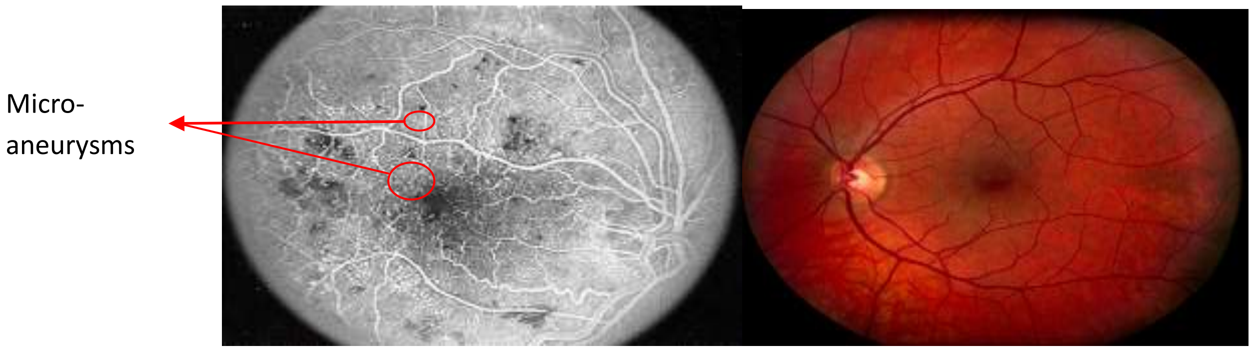

Fig 1: Fluorescein & color Fundus images of retina

Fluorescein angiograms are the images obtained by injecting fluorescein dye into patients' blood vessels and scanning it after the dye fills the eye completely. This will give an easy target for the machine to capture all the highs and lows in contrast and brightness. Fundus imaging is nothing but taking the picture of the rear part of the eye i.e., the fundus. Structures of the retina like optic disc, blood vessels and macula are visible through this image

2. METHODOLOGIES

All the papers through which various methodologies have been implemented, have shown the usage of majorly two types of images i.e., fluorescein angiograms and color fundus images. The pre-processing steps were carried out and explained in an elaborate way enough to get hold on the meaning for why each operation has been used with a specific operator, filter etc., Quality of the image has turned out to be one of the most important factors which will make further implementation easier without much difficulties. The methodologies themselves are numerous in number, each focusing on a specific agenda. Some have concentrated on pre-processing while some have concentrated on reducing computational and time complexity. Some papers have focused mainly on the accuracy rate at which the methodology was able to detect microaneurysms positively out of all the images. While majority of them are significant in their own ways, none has been able to nail all the basics all the time i.e., time complexity, computational complexity while balancing sensitivity and specificity. This has provided the motivation to carry out this comparative study to understand the behaviors of various methodologies and find a balance between all the basics aforementioned. The general process in which microaneurysm detection is carried out is as follows. It need not be in the same order or the sa

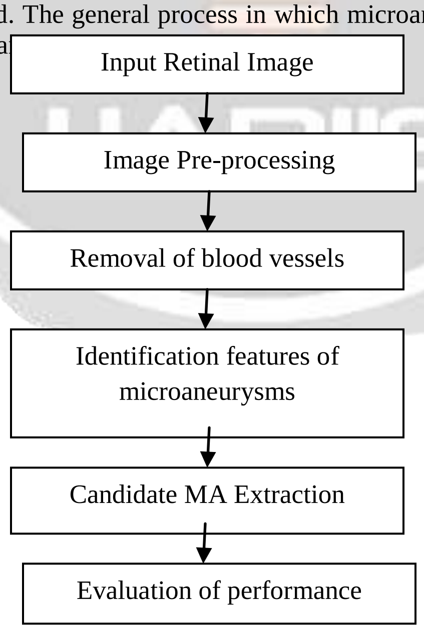

Fig 2: Generalized Sequence of Operations

2.1 Literature Survey

One of the proposed papers suggests the use of fluorescein angiograms and detecting the microaneurysms by adaptive edge technique. The framework first makes use of canny operator with linear filtering using gaussian kernels to smooth out the edges. Since the lesion's typical size ranges between 15 microns to 135 microns, any object larger than that will be removed. Then sobel edge operator is used to build the edges of incomplete structures. The resultant objects are then marked as candidate MA's. The framework is successful enough to provide some major improvements over existing Hough transform in falsely detecting microaneurysms.[1]

In this paper, Lee & Michael propose detection of microaneurysms using color fundus images. It uses green channel to obtain the foreground and background variation from shade corrections. Then the intensity correction is made on the whole image to pop the microaneurysms out. Further step involved use of a series of typical morphological operations as mentioned in 1.4. Feature extraction is done by using various classification methods by inducing a threshold value to remove other objects. The methodology is able to have 1:1 ratio of detecting positives along. [2]

Fluorescein angiograms are used in this methodology and microaneurysms are detected by implementing circular Hough transform. Since a general Hough transform can find any arbitrary curve, vessel removal is NOT DONE using Hough transform to save time and reduce computational complexity. A 5*5 average filter is used for pre-processing image noise removal. Sobel or canny is used to remove blood vessels. Central parts of MA's are approximately identified by Hough transform. Region growing process is applied to find the scope of MA's. High speed detection of microaneurysms has become the major advantage of applying this methodology. [3]

A new approach called multi-scale correlation filtering and dynamic thresholding has been taken up in this paper. A 25*25 median filter is applied to the image and subtracted from the original one to get shade corrected image. Using the green channel from the fundus images, gaussian function is used and the values are taken up for correlation coefficient of the grayscale distributions. Then candidate detection is done by applying a sliding neighborhood filter with multi-scale gaussian kernels. In this hierarchical approach-based paper, intensity based microaneurysm classification and detection has been achieved. [4]

An automated microaneurysm screening system is proposed along with a Decision Support System (DSS). The contrast of the color fundus image is done by using local contrast enhancement technique. Dynamic thresholding is used for feature extraction. Neural networks help in finally classifying the microaneurysms present in the retina. This paper indicates significant improvement over all the previous works carried out by others with respect to sensitivity and specificity. [5]

This paper mainly concentrates on removing blood vessels and optic disc from the retinal image which will make it easy for identifying MA's. Segmented regions are identified from the image by using pixel's intensity. The image is smoothened out to remove noise. Top hat transformation is applied at 12 directions on structuring elements to strengthen the blood vessels and remove background. Iterative clustering method is used within sum of squared errors for vessel extraction. Then, threshold value is applied to remove the optic disc and classification is done for candidate microaneurysms. [6]

One of the papers suggests the use of mathematical morphology to identify microaneurysms. Three steps are involved viz., pre-processing, detecting MA's & post-processing. Pre-processing involves balancing out the contrast levels of the image using green channels by using Adaptive-Histogram equalization technique. Canny edge detector is used to separate the edges and iterative subtraction of preliminary images is done with current image to obtain candidate MA's and hard exudates. Optic disc is removed in post processing and contrast levels are checked from original image to get brightness of locations of MA's. Threshold values of the operators and typical shape of microaneurysms have been found to be the benefits of this implementation. [7]

Sparse Representation Classifier is used for blood vessel extraction and multi-scale correlation coefficient filtering applied for identifying candidate MA's. However, two dictionaries are maintained with Dictionary Learning by SRC to classify MA from non-MA images. Double thresholding and center-line calculations made this implementation more reliable in classifying vessels and MA's separately. [8]

Feature analysis of retinal fundus images has been carried out in this paper by 3 steps. The first one being pre-processing, involves brightness normalization, gamma correction and histogram expansion for each image. A double ring filter that compares the pixel intensity values of neighboring pixels is applied to identify microaneurysms. Removal of false positives by extracting blood vessels is carried out. The proposed method has proven to be mediocre in identifying the candidate MA's. [9]

A complementary method had been proposed to identify microaneurysms from fundus images. An x-ray computed tomography is used (Radon Transform: RT) along with multi-overlap window methodology to segregate the image into sub-partitions. Optic Nerve Head (ONH) is masked and vessel extraction is done. This leaves us with microaneurysms. However pre-processing steps mentioned in various papers have been followed before identification of MA's. This method helps the ophthalmologist to separate fundus images into normal parts and lesions. [10]

A simple hybrid method has been proposed to identify candidate microaneurysms from digital retinal images. Pre-processing included noise removal, contrast enhancement and shade correction for the images. Then, exudates and blood vessels are eliminated by having a threshold value operator. An optimal mathematical morphology is used for microaneurysm segmentation and feature extraction. Fine segmentation is done using Naive-Bayes classifier. The system proved to be efficient even on low resource computers. [11]

Images from fluorescence oscilloscope are used in this paper. Contrast Limited Adaptive Histogram Equalization (CLAHE) is used to make the region more visible by adjusting contrast and dynamic range. Isodata technique is used for automatic thresholding for segmentation of retinal blood vessels. Fractal analysis is used to distinguish between normal and abnormal images. Finally, canny edge detection is applied and box counting method with the help of retinal vascular tree is used to identify the MA's. The implementation has showed satisfactory results in detecting candidate MA's. [12]

In this paper, Usman, Shehzad & Shoab have suggested the diagnosis be divided into two classes i.e., screening and monitoring of DR. Contrast and vessel enhancement is done in pre-processing. Dark regions are detected, and vessels are segmented based on the size. From the texture representation, Gabor filters are applied for microaneurysm detection. A feature vector is formed with pixel intensity values. The specificity of this implementation has shown significant improvements over other papers. [13]

In order to reduce the false positives detected, an implementation of detecting microaneurysms using eigen value analysis with a Hessian matrix. A hessian matrix is a square matrix of second order partial differentiation derived functions. Pre-processing is a standard procedure followed by extraction of blood vessels. Then the eigen values of the first two values in hessian matrix are used for detecting the candidate MA's. This methodology has improved ability to identify dark lesions in the retinal fundus images. [14]

The major problem in any retinal fundus image is the quality. One paper suggested the improvement of the quality in the first place to ease out the detection of microaneurysms. Green plane is selected from RGB images as red lesions have highest contrast in this plane. Median filtering is applied along with CLAHE for contrast adjustment. Canny edge detector along with dilation & erosion operations are performed on the image. "AND" logic is used to remove large objects like exudates. Blood vessels are detected and subtracted from the resultant image using a threshold value. After removing optic disc, the brightest pixels are calculated and located as candidate MA's. Preserving the quality of the image had been the main emphasis of this paper which in turn reduces extra work for the eye specialist with such screening system. [15]

Use of multi-agent system approach has been identified in one of the papers for detection of MA's. Multi-agent paradigm refers to finding the methods that build cascading systems with self-entities acting as agents acting upon only the local changes. Median filter is applied for noise. Two types of agents, Explore Agents (EA) & Region Agents (RA) are identified. RA detects the region contour size with the help of thresholding. RA performs region growing, filling & validation operations thereby completing the MA detection. This model has been able to detect lesions close to blood vessels to a satisfactory level. [16]

3. CONCLUSIONS

The sustainability of the topic mainly depends on two things i.e., accuracy and consistency of the methodology followed. The major points related to such sustainable model are

Sensitivity: It can be stated as the number of microaneurysms detected **truly** out of all the microaneurysms. It is also known as True Positive Rate (TPR). It is given as

$$\text{Sensitivity (TPR)} = \frac{\text{True Positives}}{\text{Positives}}$$

Specificity: Specificity refers to the number of microaneurysms that are said to be negative truly out of the total number of negatives i.e., true negatives AND false positives. Here, false positives refer to microaneurysms that are detected as true but are not. It is known as the True Negative Rate (TNR), given as

$$\text{Specificity (TNR)} = \frac{\text{True Negatives}}{\text{True Negatives} + \text{False Positives}}$$

As there is a need for seeing the results of various methodologies and how they perform, the quantification of the same is given in the graph below. It is to be noted that the percentages of values given are proportionate to the number of images they have taken for the study derived from the results. So, that would generate optimal results within their own computing environment with the number of images in the respective databases showing the values with respect to the same.

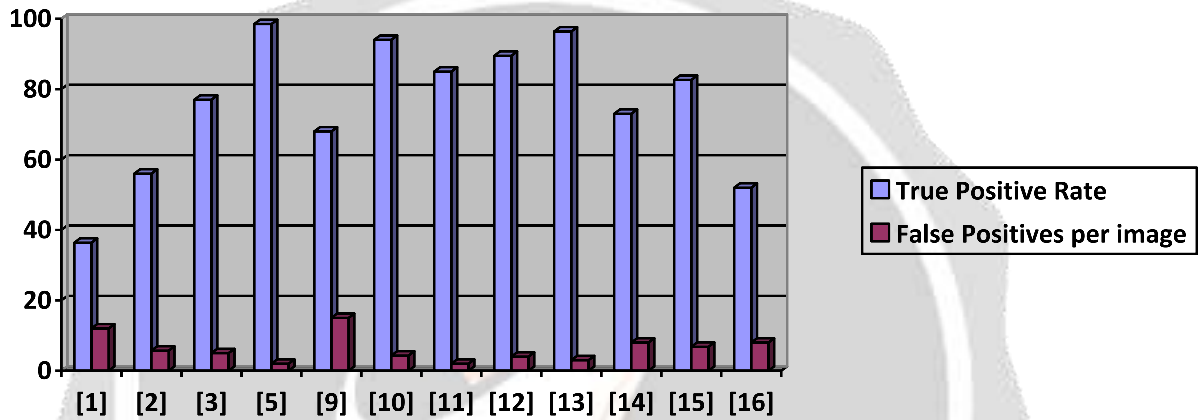

Chart 1: Performance Measures (TPR & FP) based on various approaches

Various methodologies have produced results that have drastic difference in between with respect to the accuracy and consistency of the models. However just the quantification given will not give the whole picture as the conditions they have been implemented are entirely different from one another. But by understanding the operational hierarchy and reliability of the model, Eigen vectors along with dynamic thresholding might be a possible solution for increasing the sensitivity and decreasing the false positive rate per image. The main backing for this selection would be the shape identification method available in eigen vectors which will be benefited significantly if multiple iterations of dynamic thresholding is performed on the same image. Thus, comparing various methodologies through which microaneurysms can be detected in retinal images and provide a probable solution for the issues that current implementations have faced, has been carried out successfully.

4. REFERENCES

[1] Mohammed Hafez, Sherif Abdel Azeem," Using Adaptive Edge Technique for Detecting Microaneurysms in Fluorescein Angiograms of the Ocular Fundus", IEEE MELECON 2002, May 7-9,2002, Cain, EGYPT

[2] Lee Streeter and Michael J. Cree," Microaneurysm Detection in Colour Fundus Images", Image and Vision Computing NZ

[3] P M D S Pallawala, Wynne Hsu, Mong Li Lee, Say Song Goh," Automated Microaneurysm Segmentation and Detection using Generalized Eigenvectors", Proceedings of the Seventh IEEE Workshop on Applications of Computer Vision (WACV/MOTION'05) 0-7695-2271-8/05 $ 20.00 IEEE

[4] Bob Zhang, Xiangqian Wu, Jane You, QinLi, Fakhri Karray," Detection of microaneurysms using multi-scale correlation coefficients", Pattern Recognition43(2010)2237–2248

[5] Ali Shaeidi," An algorithm for identification of retinal microaneurysms", Journal of the Serbian Society for Computational Mechanics / Vol. 4 / No. 1, 2010 / pp. 43-51

[6] Neera Singh, Ramesh Chandra Tripathi, "Automated Early Detection of Diabetic Retinopathy Using Image Analysis Techniques", International Journal of Computer Applications (0975 – 8887) Volume 8– No.2, October 2010

[7] Ardimas Andi Purwita, Kresno Adityowibowo, Ashlih Dameitry, Made Widhi Surya Atman," Automated Microaneurysm Detection Using Mathematical Morphology", 2011 International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering 8-9 November 2011, Bandung, Indonesia

[8] Bob Zhang, Fakhri Karray, Qin Li, Lei Zhang," Sparse Representation Classifier for microaneurysm detection and retinal blood vessel extraction", Information Sciences 200 (2012) 78–90

[9] Yuji Hatanaka, Tsuyoshi Inoue, Susumu Okumura, Chisako Muramatsu and Hiroshi Fujita," Automated microaneurysm detection method based on double-ring filter and feature analysis in retinal fundus images",2012, IEEE

[10] Meysam Tavakoli, Reza Pourreza Shahri," A complementary method for automated detection of microaneurysms in fluoresce in angiography fundus images to assess diabetic retinopathy", Pattern Recognition46(2013)2740–2753

[11] Akara Sopharaka, Bunyarit Uyyanonvarab, Sarah Barmanc, "Simple hybrid method for fine microaneurysm detection from non-dilated diabetic retinopathy retinal images, Computerized Medical Imaging and Graphics (2013)

[12] Rukhmini Roy, Srinivasan Aruchamy, Partha Bhattacharjee," Detection of Retinal Microaneurysms using Fractal Analysis and Feature Extraction Technique", International conference on Communication and Signal Processing, April 3-5, 2013, India

[13] M. Usman Akram, Shehzad Khalid, Shoab A. Khan," Identification and classification of microaneurysms for early detection of Diabetic retinopathy", Pattern Recognition 46 (2013) 107–116

[14] Tsuyoshi Inoue, Yuji Hatanaka, Member, IEEE, Susumu Okumura, Chisako Muramatsu, and Hiroshi Fujita," Automated Microaneurysm Detection Method Based on Eigenvalue Analysis Using Hessian Matrix in Retinal Fundus Images", 35th Annual International Conference of the IEEE EMBS Osaka, Japan, 3 - 7 July, 2013

[15] Niladri Sekhar Datta, Himadri Sekhar Dutta, Mallika De, Saurajeet Mondal," An Effective Approach: Image Quality Enhancement for Microaneurysms Detection of Non-Dilated Retinal Fundus Image", International Conference on Computational Intelligence: Modelling Techniques and Applications (CIMTA) 2013

[16] Carla Pereiraa, Diana Veigaa, Jason Mahdjou, Zahia Guessoum, Luís Gonvesd, Manuel Ferreiraa," Using a multi-agent system approach for microaneurysm detection in fundus images", Artificial Intelligence in Medicine (2014)