An Automated Micro Aneurysm Detection Algorithms – Review

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Abstract: **Diabetic retinopathy is the commonest cause of vision loss in most of the cases. The occurrence of small areas of balloon-like swelling in the retina's tiny blood vessels called as micro aneurysms indicates the first stage of diabetic retinopathy. Many researchers have actively involved in detecting the micro aneurysms in order to diagnose the disease as early as possible to prevent vision loss. This will further assist the ophthalmologists in investigating and treating the disease more efficiently. This review focuses on automatic detection of micro aneurysm. The standard database such as STARE, DRIVE, DIARETDB1, DIARETDB2, Retinopathy on line challenge(ROC) data base and private database such as Messidor, Moorefield's, Mashhad were used by the researchers for testing the algorithm. The performance parameters like Sensitivity, Specificity, Precision, Accuracy, Area under Curve, Competition Performance Measure were used to measure the performance of various algorithms.**

INTRODUCTION:

Presently in India, diseases related to food habits and life style are being increasing day by day and this is the reason for diabetes also. If the problems related to diabetes increases its harms nerves and give rise to heart problems. The dangerous affect of diabetes is seen on eyes. The National Eye Institute (NEI) is conducting and supporting research that seeks better ways to detect, treat, and prevent vision loss in people with diabetes. Diabetic eye disease refers to a group of eye problems that people with diabetes may face as a complication of diabetes. If the patient's blood sugar level is not maintained it may lead to severe vision loss or even blindness. Fig -1 represents the scene viewed by person with normal Vision and by a person with diabetic retinopathy. It is therefore more essential to diagnose as early as possible before it turns out to be dangerous.

Diabetes affects the walls of blood veins and weakens the veins carrying oxygen to the Retina. The retina is the back part of the eye and is made up of cells, which are sensitive to light. The retina is fed by a network of blood vessels and it is changes in these which cause the difficulties with vision. The walls of the blood vessels become fragile and then start to break, leaking blood around them. Sometimes, before the walls actually break, the weakened area can be seen, by the person who examines the eye, to have ballooned out. These are called micro-aneurysms. If these break, the amount of blood which leaks out is fairly small, and the only symptoms may be a few areas of blurring or floating spots in front of the eyes. These may well disappear without treatment. Later the blood vessels may stop carrying blood permanently, and the cells in the retina will die from lack of nourishment. This kind of loss of sight is gradual but at the present time, it is permanent. When old blood vessels close down, new but abnormal ones will grow to take their place. They are unable to nourish the retina properly, and may grow into the transparent inner part of the eye, and further affect vision.

Fig -1 Normal Vision and the same scene viewed by a person with diabetic retinopathy.

Diabetic retinopathy is detected during an eye examination that includes:

- **Visual acuity test**: This test uses an eye chart to measure how well a person sees at various distances (i.e., visual acuity).
- **Pupil dilation**: The eye care professional places drops into the eye to widen the pupil. This allows him or her to see more of the retina and look for signs of diabetic retinopathy. After the examination, close-up vision may remain blurred for several hours.
- **Ophthalmoscopy or fundus photography**: Ophthalmoscopy is an examination of the retina in which the eye care professional: (1) looks through a slit lamp biomicroscope with a special magnifying lens that provides a narrow view of the retina, or (2) wearing a headset (indirect ophthalmoscope) with a bright light, looks through a special magnifying glass and gains a wide view of the retina. Hand-held ophthalmoscopy is insufficient to rule out significant and treatable diabetic retinopathy. Fundus photography generally recreate considerably larger areas of the fundus, and has the advantage of photo documentation for future reference, as well as availing the image to be examined by a specialist at another location and/or time.
- **Fundus Fluorescein angiography (FFA)**: This is an imaging technique which relies on the circulation of Fluorescein dye to show staining, leakage, or non-perfusion of the retinal and choroidal vasculature.
- **Optical coherence tomography (OCT)**: This is an optical imaging modality based upon interference, and analogous to ultrasound. It produces cross-sectional images of the retina (B-scans) which can be used to measure the thickness of the retina and to resolve its major layers, allowing the observation of swelling.
- **Digital Retinal Screening Programs**: Systematic programs for the early detection of eye disease including diabetic retinopathy are becoming more common, such as in the UK, where all people with diabetes are offered retinal screening at least annually. This involves digital image capture and transmission of the images to a digital reading center for evaluation and treatment referral..
- **Computer Vision Approach**: It is a System developed by Researchers at IIT Kharagpur in collaboration with IBM India. It uses data analytics capabilities to automatically compare and analyse retina images of the patient. It can tell if the patient has DR and also provides risk categorization ranging from low to medium and high.
- **Slit Lamp Biomicroscopy** Retinal Screening Programs: Systematic programs for the early detection of diabetic retinopathy using slit-lamp biomicroscopy. These exist either as a standalone scheme or as part of the Digital program (above) where the digital photograph was considered to lack enough clarity for detection and/or diagnosis of any retinal abnormality.

Table-1 Diabetic Retinopathy Disease Severity Scales

Disease Severity Level	**Findings Observable upon Dilated Ophthalmoscopy**
No apparent retinopathy -**NORMAL**	No abnormalities
Mild non proliferative diabetic retinopathy-**Mild NPDR**	Micro aneurysms only
Moderate non proliferative diabetic retinopathy - **Moderate NPDR**	More than just micro aneurysms but less than severe NPDR
Severe non proliferative diabetic retinopathy- **Severe NPDR**	Any of the following: • More than 20 intra retinal hemorrhages in each of four quadrants • Definite venous beading in two or more quadrants • Prominent IRMA in one or more quadrants and no signs of proliferative retinopathy.
Proliferative diabetic retinopathy -**PDR**	One or both of the following: • Neovascularization • Vitreous/preretinal hemorrhage

At the courtesy of International clinical diabetic retinopathy and diabetic macular edema disease severity scales Ophthalmology Volume 110, Number 9, September 2003

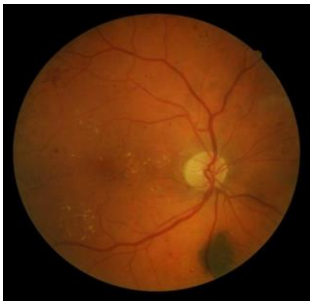
Diabetic retinopathy has four stages:

1. **Mild Non proliferative Retinopathy.** At this earliest stage, micro aneurysms occur. They are small areas of balloon-like swelling in the retina's tiny blood vessels.
2. **Moderate Non proliferative Retinopathy.** As the disease progresses, some blood vessels that nourish the retina are blocked.
3. **Severe Non proliferative Retinopathy.** Many more blood vessels are blocked, depriving several areas of the retina with their blood supply. These areas of the retina send signals to the body to grow new blood vessels for nourishment.
4. **Proliferative Retinopathy.** At this advanced stage, the signals sent by the retina for nourishment trigger the growth of new blood vessels. This condition is called proliferative retinopathy. These new blood vessels are abnormal and fragile. However, they have thin, fragile walls. If they leak blood, severe vision loss and even blindness can result.

The eye care professional will look at the retina for early signs of the disease, such as:

1. leaking blood vessels,
2. retinal swelling, such as macular edema,
3. pale, fatty deposits on the retina (exudates) – signs of leaking blood vessels,
4. damaged nerve tissue (neuropathy), and
5. Any changes in the blood vessels.

NORMAL FUNDUS IMAGE

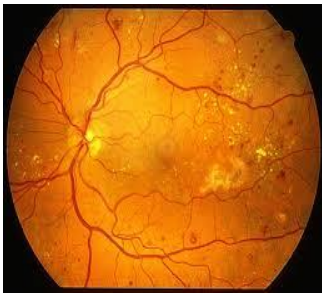


MILD NPDR

Micro aneurysms only

MODERATE NPDR

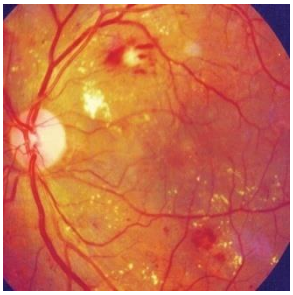
More than just micro aneurysms but less than severe NPDR



SEVERE NPDR

Any of the following:

- More than 20 intra retinal hemorrhages
- Definite venous beading.
- Prominent IRMA



PDR

- Neovascularization
- Vitreous/preretinal hemorrhage

Fig-2 Stages of Diabetic Retinopathy and their symptoms

Survey on Detection of Micro aneurysms

Micro aneurysms in Retinal image are the first symptom for the prevalence of the Diabetic retinopathy. Micro aneurysms are focal dilatations of retinal capillaries and they appear as small round dark red dots on the retinal surface.

MAs are characterized by Intensity, size and shape. Intensity: They have luminous isolated peaks, i.e. they are much brighter than the background and they are disconnected from the network of blood vessels. Size: The diameter of a MA lies between 10 and 100 µm, and to the maximum of 125 µm. Shape: They are almost circular in shape.Fig-2 represents the fundus image of a patient with DR at different stages with their symptoms.

Sopharak, B. et al [1] in their work proposed a system with pre processing stage that includes noise removal, contrast enhancement and shade correction followed by detection and removal of Vessels, exudates and optic disc to have an effective detection of Micro aneurysms. The candidate MAs are detected by using a set of optimally adjusted mathematical morphology. The best features from a feature set of 18 features are proposed to distinguish MA pixels from non-MA pixels. Finally Classification is done using Naive Bayes Classifier. The overall sensitivity, specificity, precision, and accuracy of the proposed system are 84.82%, 99.99%, 89.01%, and 99.99%, respectively.

M. U. Akram et al [2] have proposed a three stage system with candidate region extraction, feature vector formation and classification as their stages for the automatic and accurate detection of MAs in colored retinal images. The candidate region extraction phase includes mathematical morphology, contrast enhancement technique and Gabor filter bank. Elimination of blood vessel pixels is also performed to enhance the MA regions present in fundus image. Four types of features such as gray level, color, shape and statistical based features are included in feature vector formation. The feature space formed for each region is enhanced by applying a supervised local Fisher discriminant analysis (LFDA). A hybrid classifier is formed by combining LFDA-GMM and SVM classifiers in a weighted probabilistic framework to obtain better decision in the classification. The overall sensitivity, specificity and accuracy of the proposed system are 98.64%, 99.69% and 99.40% respectively.

Kedir M. Adal et al [3] proposed an automated Detection of Micro aneurysms using Scale-Adapted Blob Analysis and Semi-Supervised Learning .The singular value based contrast enhancement technique is used as a pre processing step .In Feature extraction stage ,the features such as Scale-Space Features, Speeded Up Robust Features (SURF), Radon-Transform Features were calculated .The classifier stage includes K-Nearest Neighbor (KNN), Nave Bayes, Random Forest, and Support Vector Machines (SVM) classifiers. In order to increase performance efficiency optimal classifier-feature pair was tried out. Experimentation is done in Retinopathy Online Challenge (ROC) and the University of Tennessee Health Science Center (UTHSC) private database. The performance evaluation results show that Radon and SURF features coupled with SVM and KNN classifiers outperform the other classifier-feature pairing.

Balint Antal [4] proposed an effective ensemble based micro aneurysm detector. They have considered several preprocessing methods such as gray level transformation, local histogram equalization, Vessel Removal and in painting, vignette correction. For candidate extractions the algorithms such as diameter closing, top-hat transformation, circular Hough-transformation, matching multiple Gaussian masks cross-section profile analysis were considered. In the proposed work they first apply the preprocessing method to the input image and then the candidate extractor is applied to the result. An ensemble E is a set of ⟨preprocessing method, candidate extractor⟩ or shortly ⟨PP;CE⟩ pairs. In the proposed Ensemble creation process all ensembles E from an ensemble pool E is evaluated and the best performing one $E_{best} \epsilon E$ is selected based on the Euclidean distance d from c which is smaller than a predefined constant. Best performance of the proposed method 76% sensitivity and 88% specificity is achieved at the threshold of 0.9.

B Zhang et al [5] proposed a two stage algorithm in which the first step is detection of micro aneurysms in coarse level and confirming the presence of true micro aneurysms as fine tuning in the second stage. Correlation coefficient for each pixel is calculated in coarse level candidate detection by applying a sliding neighborhood filter with multi-scale Gaussian kernels to the fundus image. Gaussian kernel is preferred since micro aneurysms are circular in nature and expected to produce maximum correlation. The regions having a higher coefficient are more likely to be true micro aneurysms. The range of the coefficient is from 0 to 1.In the fine level micro aneurysms classification, the author has used features based on shape, grayscale pixel intensity, color intensity, responses of Gaussian filter-banks, and correlation coefficient values. Totally 31 features are calculated for each candidate. A discrimination table is created with minimum and maximum value for each feature of true micro aneurysms. Using this table candidate whose feature values are greater than maximum or less than minimum can be eliminated. The MSCF

algorithm performs better in DIARETDB1 with that of ROC Database.

B Antal et al [6] proposed an Simulated annealing-based search algorithm to select the optimal combination of preprocessing method, candidate extractor pair. Various preprocessing techniques such as Walter– Klein contrast enhancement, Contrast limited (CL) adaptive histogram equalization, and vessel removal and extrapolation were used. Five different techniques were considered for candidate extraction. Then simulated annealing is used to select an optimal combination of preprocessing and candidate extraction pair. A pair that has minimum number of false positives is considered to be an optimal combination. The success of simulated annealing lies in the selection of energy function. Centroids of micro aneurysms are selected manually by clinical experts to find the ground truth. Then if the Euclidean distance of the centroid of a candidate is lesser than the manual value, it is regarded as a true positive (TP), otherwise it is a false positive (FP).Sensitivities obtained for Retinopathy Online challenge,DIARETDB1 and Moore fields databases are 74.47%,98.2% and 95.6% respectively

M. Tavakoli et al [7], proposes a complementary method for automated detection of micro aneurysms detection .The algorithm first involves in detection of the optic nerve head and vascular tree. Top-hat transformation and averaging filter were applied to remove the back ground in preprocessing step. In the main stage the whole preprocessed image is divided into sub-images, and then the vascular tree is segmented and masked by applying Radon Transform (RT) in each sub-image. RT is integral of an image over straight lines in specified angle. The proposed algorithm is more powerful and less sensitive to noise than other algorithms because the process of integration omits the intensity variations due to noise. A multi overlapping sliding window is applied to find objects on border of sub-images. The window size (n) has a direct effect on the extraction accuracy. Optimum value of n results in good lesion detection. Maximum diameter of the biggest MA in pixel decides the size of n. n=18, n=10 were selected for MUMS-DB and 2nd-DB respectively. Three different retinal images databases, the Mashhad Database with 120 Fluorescein Angiography (FA)fundus images, Second Local Database from Tehran with 50 FA retinal images and a part of Retinopathy Online Challenge (ROC) database with 22 images are selected for testing the algorithm. Automated DR detection demonstrated sensitivity and specificity of94% and 75% for Mashhad database and 100% and70% for the Second Local Database respectively.

I.Lazar et al [8] proposed a micro aneurysm detection method in which the inverted green channel of a fundus image is considered as the input image to highlight MAs, hemorrhages and the vasculature as bright structures in the image. The method for the detection of MAs on retinal images is based on the principle of analyzing directional cross-section profiles centered on the candidate pixels of the preprocessed image. The local maxima of the preprocessed image are considered to reduce the number of pixels to be processed. Peak detection was applied on each profile and a set of values that describe the size; height and shape of the central peak are calculated. The statistical measures of these values as the orientation of the cross-section changes constitute the feature set used in a classification step to eliminate false candidates. A formula to calculate the final score of the remaining candidates was proposed based on the obtained feature values. Various classifiers, such as k-nearest neighbor (kNN), and support vector machines (SVMs) with different kernel functions and naïve Bayes (NB) classifier have been used .Naïve Bayes (NB) classifier seems to produce better results.

Table-2 Image processing techniques adapted by various researchers in detecting Microaneurysms with their results

S.No	Author	Year	Image processing techniques adapted	Database	Results %			
					Se	Sp	P	A
1.	Sopharak et al	2013	optimally adjusted mathematical morphology + Naive Bayes Classifier	45 Real time images	84.82	99.99	89.01	99.99
2.	M. U.Akram et al	2012	Filter banks+ hybrid classifier	DIARETDB0 & DIARETDB1	98.64	99.69	-	99.40
3.	K M. Adal et al	2014	Scale-Adapted Blob Analysis and Semi-Supervised Learning	ROC & UTHSC private database	56	CPM- 0.364		
4.	B Antal et al	2010	Ensemble based micro aneurysm detector	Messidor database	76	88	AUC 0.90_0.01	
5.	B Zhang et al	2010	MSCF& dynamic thresholding	ROC & DIARETDB1	71.3	-	-	-
6.	B Antal et al	2012	Simulated annealing-based search algorithm	ROC	74.47	-	-	-
				DIARETDB1	98.2			
				Moorefields	95.6			
7.	M. Tavakoli et al	2013	Radon Transform and multi overlapping window.	Mashhad	94	75		
				Local Database from Tehran	100	70		
8.	I.Lazar et al	2013	Local Rotating Cross-Section Profile Analysis+ Naive Bayes Classifier	ROC & Moorefields	-	-	-	-

Se = Sensitivity Sp = Specificity
P = Precision A = Accuracy
AUC = Area Under Curve CPM = Competition Performance Measure

CONCLUSION:

Occurrence of Micro aneurysms is the first sign of presence of diabetic retinopathy. The main objective of detecting Micro aneurysms is to diagnose the diabetic retinopathy at an earlier stage, which will prevent many diabetic patients from severe vision loss. Automatic detection system will be of great help to the ophthalmologist to concentrate on those patients who really have the threat of the disease. Table-2 shows the results of various Image processing techniques adapted by researchers in detecting Micro aneurysms. The algorithm considered for review mostly work on fluorescein angiography or colour images taken on patients with dilated pupils, in which the MA and other retinal features are clearly visible. Efforts are to be taken to work with non dilated pupils, so that examination time and effect on patients will reduced. However, the quality of these images will be a challenge for the researchers for detecting MA. Detection of micro aneurysms that are in smaller in dimensions is difficult as they are removed during preprocessing step. The standard database such as STARE, DRIVE, DIARETDB1, DIARETDB2, Retinopathy on line challenge(ROC) data base and private database such as Messidor, Moorefield's, Mashhad were used by the researchers for testing the algorithm. The performance parameters like Sensitivity, Specificity, Precision, Accuracy, Area under Curve, Competition Performance Measure were used to measure the performance of various algorithms. A direct comparison on the performance of the methods is not possible because of authors have tested their algorithm with different databases.

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