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Computerized Approaches for Retinal Microaneurysm Detection

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Abstract— The number of diabetic patients throughout the world is increasing with a very high rate. The patients suffering from long term diabetes have a very high risk of generating retinal disorder called Diabetic Retinopathy(DR). The disease is a complication of diabetes and may results in irreversible blindness to the patient. Early diagnosis and routine checkups by expert ophthalmologist possibly prevent the vision loss. But the number of people to be screen exceeds the number of experts, especially in rural areas. Thus the computerized screening systems are needed which will accurately screen the large amount of population and identify healthy and diseased people. Thus the workload on experts is reduced significantly. Microaneurysms(MA) are first recognizable signs of DR. Thus early detection of DR requires accurate detection of Microaneurysms. Computerized diagnosis insures reliable and accurate detection of MA's. The paper overviews the approaches for computerized detection of retinal Microaneurysms.

Keywords- *Coputerized Approaches, Retinal Microaneurysms, Diabetic Retinopathy.*

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I. Introduction

The Diabetes is becoming an important public health issue and world leaders have targeted it as one of the noncommunicable disease (NCD) of prime concern. The glucose level in the blood increases because of diabetes. The disease occurs because insufficient insulin production by pancreas of the body (Type 1 diabetes) or improper utilization of the produced insulin by beta cells in body (Type 2 diabetes). The disease prevalence has been increasing with a steady rate since last few decades. Global prevalence has been doubled since the year 1980 which was 4.7% to 8.5% in the year 2014 in the working age adults[1]. 422 million adults were estimated to be suffering with diabetes in the year 2014 in comparison to 108 millions in the year 1980. It is seen that the rise is rapid in developing economical countries than developed ones.

Diabetic retinopathy (DR) is one of the complications of diabetes in which the blood vessels in retina get damaged because of excess sugar level and may gradually result in visual impairment. The complication occurs when a person has sustained 10 or more years of diabetes. The disease thrives in two stages - 1) Non-proliferative DR 2) Proliferative DR. The early stages of DR usually do not show any recognizable symptoms unless checked by an expert.

As discussed earlier, the number of patients with diabetes is huge as compared to the small number of experts. Hence computerized screening algorithms should be developed for screening large population with same accuracy and reliability. Apart from the above fact, DR shows number of recognizable lesions throughout the progression of disease. Each of these lesions have explicit appearance which can be detected by a computerized algorithm also detecting the particular lesion may give useful information about growth of DR. Thus automated algorithms can detect the disease at early stage as well as tells information about progression of the disease.

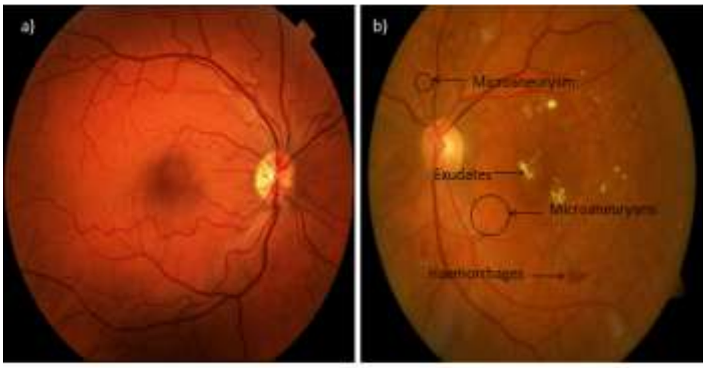

Fig 1: a)Normal Retina, b) DR lesions

Microaneurysms (MA) are the first evident symptoms of DR. These are the tiny swelling occurring on the walls of capillaries of the retina. The swelling may burst out and leaks blood in retina giving birth to other DR lesions. Since capillaries of retina are very small they can't be seen in fundus images, though MA's appear as dark red round objects in fundus images and Bright fluorescent objects in angiogram images. The Diameter of MA is expected to be between 10 to 125 microns. Since MAs are the first change that can be observed in retinal image of DR infected person they can be used for early detection of DR. Computerized algorithms are developed for detection of these small red dots from retinal images. Figure1 shows healthy and DR infected retinal image. Microaneurysms along with other retinopathy lesions are shown.

The paper overviews some methods for MA detection. Earlier attempts made for the lesion detection are described in II. After some efforts a standard approach is developed for detection process which is adopted and advanced by many researchers in the field. In III , these extended approaches along with additional attempts are analysed.

II. Prior Approaches

A. Early Morphological Methods

Previously angiograms were used as digitized images for the detection of retinal MAs. A fluorescent dye was injected in patients' blood which highlighted the blood vessels at the back of the eye so that they can be photographed easily and checked for disorders.

Year 1996, T. Spencer et al. [2] put forward a strategy that discriminated the binary objects obtained after morphological shape analysis into true lesion objects and spurious objects. This method was the first one to add classification step in detection process. Input images are shade corrected and binary top-hat transformed is used for vessel removal. A matched filter of 11 X 11 with Gaussian cross section of ($\sigma = 1$pixel) is used for highlighting MAs. After thresholding the image region growing procedure applied for segmentation of candidates. The classification gave true MA candidate at the output.

Year 1997, Michel Cree et al. [3] developed a fully automated method based on the Spencer's method which selects the same ROI for every image as well as counts the number of MAs without human intervention. Cree et al. made use of 68 images with 394 true MAs for training his MA detector and 20 images with 297 true MAs for testing purpose. The specified detector achieved a sensitivity of 82% with 5.7 false positives per image against the training set and 82% sensitivity and 5.7 False positives per image against test set. The classifier used the features described by the Spencer plus the additional four features which are scaled version of Spencer's intensity features and matched filtered responses.

Many other authors used Spencer's method as a base with different pre-process and classification approaches. Some are - A. J. Frame et al. (Year 1998) [4] , A.D. Fleming et al. (Year 2006) [5].

B. Genralized Flow For detection Process

General flow of microaneurysm detection process is described in figure 2. The input image is pre-processed for noise removal and illumination correction. Most of the shade correction techniques estimates the background of retinal images and then subtract it from original image. Thus highlighting the vessels and MA's in the image.

Then unwanted features such as blood vessels are then removed from shade corrected image to reduce false candidate detection. The vascular structure and MA's both appear darker in retinal images. Vessel removal will help to locate the MA's more clearly. Then candidate lesions are segmented from vessel removed image. A feature set is formed based on the characteristics of MA's and used to train a classifier for a set of images. This trained classifier when tested on other images gives true microaneurysms present in image. Many of the researchers have extended this approach for the further research work. Depending on true and falsely detected candidates the performance of algorithm is evaluated in the form of sensitivity and specificity.

The sensitivity is the condition when abnormal or diseased retinal image is given as an input to the algorithm and found abnormal or diseased after processing it. Similarly, specificity is the condition when a normal or healthy retinal image is given as input to the algorithm and obtained as normal or healthy after processing. They are also called as true positive rate and false positive rate respectively.

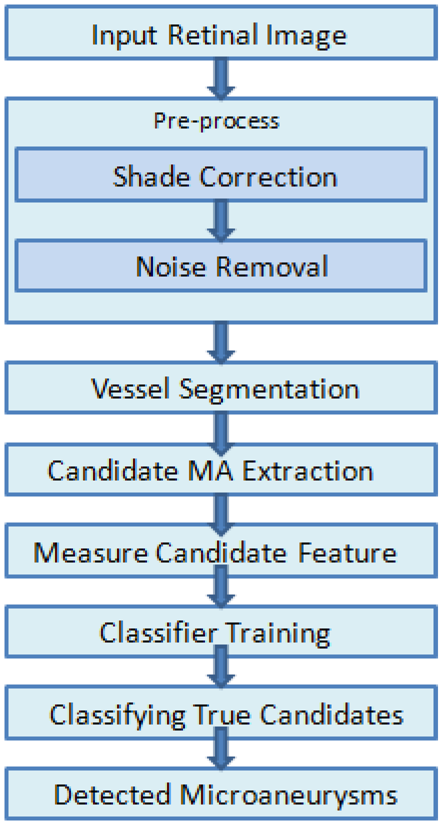

Fig 2: General method for MA Detection

III. Other Approaches

Year 2005, M. Niemeijer et al. [6] gave a method for detection of red lesions (MA and haemorrhages) by using hybrid approach based on Spencer (1997) and Frame (1998). Two contributions are added in previous approach. First is detection of candidates based on pixel classification. The candidate extraction process is same as the one used by Spencer and frame based on morphology. Then pixel classification is done by training a kNN classifier with set of 40 images containing red lesions, vessels and background pixels. After thresholding the probability map obtained from classifier stage, the objects are region grown to their original size. These objects are hole filled and final set of candidates is obtained. Second contribution is in terms of features used to classify the candidate lesions. Another set of 100 images used to train classifier and testing purpose. The sensitivity and specificity achieved was 100% and 87% respectively.

Year 2007, Thomas Walter et al. [7] used contrast enhancement and shade correction for pre-processing an image. Then for candidate extraction diameter closing was performed on pre-processed image which removes all dark objects with diameter specified. the top hat transform of diameter closed image gives binary object which are double thresholded to get candidate objects. in total 15 features were used to train classifier. The method tested against 94 images and achieved the sensitivity of 88.5% with2.13 false positives per image.

Year 2008, Gwenole Quellec et al. [8] detected MA's by optimizing the wavelet transform. The method was tested against 120 images of three different modalities 1)35 intermediate time angiograms, 2)35 color images, 3)50 green filtered color photographs. A lesion template is formed and matched to the sub-bands of wavelet transformed images. The wavelet adaptation is done in lifting scheme framework. Optimization procedure involves genetic algorithms along with direction set descent algorithm given by Powell. The sensitivity for color photographs is 89.62%, for angiographs 93.74% and for green filtered photographs is 90.24%. The positive predictive value for the same sequence are 89.50%, 91.67% and 89.75% respectively.

Year 2008, Abhir bhalerao et al. [9] proposed novel method for MA detection. firstly the input image is contrast normalized with median filter. Later Laplacian of Gaussian(LoG) filters are used to highlight the MA's in contrast normalized image. A complex valued circular symmetry operator is correlated with orientation map of pre-processed image for shape filtering. Combination of LoG filters with circular symmetry operator followed by thresholding gives candidate object set. For separating true and false candidates from each other Eigen-image analysis is used. The method shows the sensitivity of 82.6% and specificity of 80.2%.

Year 2008, Maria Gracia et al. [10] presented a technique for red lesion detection using multilayer perceptron model. The pre-processing involves luminosity and contrast normalization. For segmentation of candidate objects, pixel intensity is checked for a value lower than fraction of mean intensity value in a particular window size. Total 29 features were selected and used to train a multilayer perceptron model. The database used of 100 images out of which 50 are used for training and 50 for testing purpose. For lesion based classification achieved sensitivity and positive predictive value is 86.1% and 71.4% respectively, Similarly for image based classification specificity, sensitivity and accuracy was found to be 60%, 100% and 80% respectively.

Year 2009, Saiprasad Ravishankar et al.[11], used morphological processing techniques for detecting lesions of diabetic retinopathy. In the technique proposed MAs are treated as holes being the dark lesion in appearance. These holes are filled and hole filled image subtracted from original one. The thresholding gives the candidate MAs. The threshold depends upon the mean intensity value of red channel input image of retina. The method also detects optic disk and exudates, segments blood vessels with morphological techniques. the method achieves sensitivity of 95.1% and 90.5% for MA/Haemorrhages detection.

Year 2009, A. Mizutani et al.[12] used double ring filter for initial MA candidate detection. The pre-processing method includes brightness and gamma corrections, contrast enhancement, resizing the images. Then double ring filter with inner circle having 5 pixel and outer ring of 13 pixels in radius is used to detect candidate MA objects. After that blood vessel are removed. Then candidates are reshaped again to their original size. A set of 12 features were used to train Artificial Neural Network. ANN classifies the true and false candidates with sensitivity 65% with 27 false positives per image.

Year 2010, Bob Zhang et al.[13] suggested to use multi-scale correlation coefficients for detection of MA. The proposed method is divided in two steps. At coarse level candidate objects are detected. A correlation coefficient is defined for measuring the similarity between the Gaussian function and gray scale distribution of MA. If the resemblance is high, the correlation coefficient value will be high otherwise it is low. Since MA's appear in different sizes multiple scales are used for different sigma values of Gaussian kernels. Five scales are chosen for Gaussian kernels with sigma values ranging from 1.1 to 1.5. The maximum coefficients from each five scales are merged to form final response. The candidates are segmented from output by thresholding. in second level candidates are classified. 31 features are selected and feature vector is divided in two groups as true MA and non-MA. The candidates are selected by comparing the minimum and maximum feature values of candidate and true MA.

Year 2010, M. Niemeijer et al.[14] organized an online competition for studying different aspects of DR. In the paper described five methods were compared developed by different researchers but working on same data. 50 training images with the reference present and 50 test images without standard reference was used as data set. The results submitted online by different researchers were evaluated for performance by computerized algorithm. Also a human expert is involved for comparison of the computerized systems. It was found that the best performing system does not match the expert findings yet. For betterment of computerized approaches the dataset is made publically available and the website for result submission will continue onwards.

Year 2011, Keerthi Ram [15] proposed a method which emphasizes on rejecting the false objects (called clutters) than selecting the good candidates from retinal images. The candidates are extracted by simple thresholding operation after pre-processing. Pre-processing involves shade correction by median filter, bottom hat transformation and final pre-processing is obtained by morphological reconstruction. Then a two step clutter rejection stage of supervised learning is applied. In first rejection stage known clutters, in particular clutters introduced by vessels and their cross points, haemorrhages etc are rejected by training classifier 1 by their features. in second rejection stage clutters occurring due to noise, improper illumination i.e. objects inconsistent with the true candidates are rejected. Finally the objects passed by second stage are again classified by SVM based on similarity features and score computation. The results evaluated on three datasets. Maximum sensitivity obtained for DIRETDB1 as 88.46%. at 18.02 false positives per image at lesion level.

Year 2011, L. Giancardo [16] used the radon transform based classification for MA detection. The method requires minimum pre-processing and doesn't need any knowledge about retinal morphological features for lesion identification. The inverted green channelled image is used for pre-processing. Candidates are selected by thresholding at t= 0.58.The Radon transform is analysed for the image. Then classifier used to distinguish between True MA and false ones. The method tested on ROC database.

Year 2011, Balint Antal, Andras Hajdu [17] proposed an improvement in MA detection process by combining pre-processing strategies. Three pre-processing strategies are concerned Walter-kein method, Contrast adaptive histogram equalization method (CLAHE) and vessel removal. The pre-processing strategies are tested for optimal combination which will increase the detection of true MA in candidate detection phase itself. The results of candidate extractors of Four Pre-processing methods are considered individually. also the results of candidate extractors with combined pre-processing strategies are evaluated. Then optimal combination is searched by simulated annealing. It was seen that the candidate extraction with combined pre-processing strategies was successfully extracting true MA than the individual ones. The ensemble formed based on the methods gave sensitivity of 99%.

Year 2012, B. Antal [18], provides an ensemble based system for MA detection. An ensemble is basically a set of two methods PP i.e. pre-processing technique and CE i.e. candidate extractor. An ensemble containing more pairs of PP and CE will apply each pair on input images individually and extract candidates. The results of multiple pairs of ensemble are fused together. The best performing ensemble is selected based on the training data. This selected best ensemble is used to detect MAs from test images. Final MA candidates are obtained by fusion of candidates extracted from each ensemble pair constituting best ensemble. The method was ranked first in ROC online competition. On Messidor database for DR/Non-DR classification, AUC achieved by proposed algorithm is 0.9±0.1 based on presence of MA.

Year 2012, Brigitta Nagy et al.[19] proposed database clustering for MA detection improvement. An algorithm with particular parameters set for a certain database may not work with same efficiency for other database. The author tries to overcome this limitation by clustering images taken from different sources. To extract individual image characteristics, 19 similarity measures are computed and clusters are obtained by k-means clustering. ROC database is used for creation and training of clusters. The unknown images are tested by assigning the nearest cluster to them and then are proceeded to the selected MA detector (here an ensemble based detector is used). The performance with and without clustering is evaluated and found to be greater if proposed method is used.

Year 2013, V. Saravanan et al.[20] presented a method for DR red lesion detection. Pre-processing starts with green channel extraction followed by normalization and thresholding stage. Then features are extracted and GMM classifier is used for classifying the DR candidate lesions.

Year 2013, Lazar and Hajdu [21] came up with new theory to detect MA based on intensity profiles. The inverted green channelled is pre-processed with Gaussian filter of variance selected as 1. Then image is scanned for finding local regional maxima. These regional maxima objects are considered to be possible MAs. Then every candidate is subjected to cross sectional scanning. At this step the intensity profiles surrounding the candidates are observed in every directions. A peak detector algorithm identifies if the peak is present at the center of every profile. The features of the peak are computed and used as a feature set to train a naive Bayes classifier. The proposed method ranked second in ROC competition.

Year 2013, Tsuyoshi Inoue et al. [22] used Eigen values and hessian matrix for detection. Pre-processing has contrast enhancement brightness correction steps. Black top hat transform and double ring filter combined to remove vascular structures. Eigen values are computed from Hessian matrix. A shape index is defined based on these values. Smaller the value of shape index more the possibility of MA.

Year 2013, Jorge Oliveira [23], used method of slant stacking of radon transform. The pre-processing is done by shade correction and normalization. The normalized image is thresholded with 0.68 value. Then binary image is divided in a window of size 5X5.The window is place on pixel having max intensity in normalized image. The slant stacking of radon transform is computed at each candidate. Supervised learning is used for classification with SVM classifier. Algorithm tested on DIRETDB1 with accuracy and specificity being 84.16%, and sensitivity of 89.46%

Year 2013, Rukhmini Roy [24] used Fractal analysis for MA detection. Algorithm works in two stages. first stage contains green channel extraction and contrast adaptive histogram equalization followed by blood vessel extraction. Blood vessels are extracted by background subtraction and entropy thresholding. A fractal analysis checks whether the retina is normal or abnormal. If the retina is abnormal, the second step applies canny edge detection and morphological reconstruction. The two images are subtracted to get candidate objects. The sensitivity and specificity 89.5% and 82.1% respectively.

Year 2013, M.U Usman et al. [25], proposed the use of hybrid classifier by assembling the Gaussian Mixture Model and Support Vector Machine together. The pre-processing is done on HSI color space. Then morphological opening is used to smooth the optic disc. Then smoothened image is subjected to contrast enhancement. The Gabor filter Bank enhances the MA regions and after that blood vessel segmenting is carried out. Thresholding gives the candidate MA. Seven features are computed to classify MAs from non-MA candidates. The algorithm is worked out DIRETDB1 database to give 100% and 97.6% accuracy at image level and pixel level comparison.

Year 2013, Hussain F. Jaafar [26] presented a method for detection of red lesions. The pre-processing includes green channel extraction and shade correction. Morphological flood filling is applied on the pre-processed image. Candidate MA's are segmented using morphological technique. Multi scale technique is used for vessel segmentation. A rule based classifier is trained with some features so as to discriminate between true and false lesions. The method gave sensitivity and specificity as 89.7% , 98.6% respectively.

Year 2014, The method of Shan Ding and Wenyi Ma [27] uses sum of errors and correlation coefficients for matching degree measurement of dynamic multi-parameter template matching (DMPT). The pre-processing involves inverted green channel, and top hat transformation. To enhance MA region Gaussian enhancement filtering is used. The DPMT parameters are computed and applied to the pre-processed image. Vessels are segmented are removed from DPMT image. Remaining objects are supposed to be the MA candidates. Author has used 48 features and computed two scores namely distribution character based score (DCS) and adaptive weighted summing scheme score (AWS). The two scores are used to compute metrics that classifies MAs from non-MAs.

Year 2014, Kedir M. Adala et al. [28] applied semi supervised learning for MA detection. The contrast enhancement is done by singular value decomposition technique. To detect the MA region, hessian matrix is used along with its derivative. Candidate MAs are obtained by thresholding. The local scale for each candidate is selected. scale-shape features, surf features and radon transform features are extracted. Classification is done in two stages. In one stage the classifier is trained by few available labelled images. In second stage multiple classifier training is done among themselves forming different hypothesis of classification. The method achieved a competitive score in ROC as 0.364.

Year 2014, Sharath Kumar [29] developed a technique that detects the red lesions from image accurately. the candidates are extracted using mathematical morphology based techniques. Vessel and bright lesions are removed from the image. The false positives reduction is employed based on average intensity value, rate of intensity change with respect to background.

Year 2014, Ms. J. Kalaivaani [30] segmented red lesions from retinal image. Input images are pre-processed by morphological techniques for contrast normalisation. Entropy filters Gabor filters and matched filters are used for segmentation of red lesions from retinal images. The paper evaluated the performance using Gabor filter and matched filter separately.

Year 2014, Petra Varsanyi [31] proposed the method to detect MA which are visible based on shape and size parameter. Pre-processing is done on green channel. Contrast enhancement and stretching gives the pre-processed image. Morphological region growing and closing are employed in order to segment the MS's from retinal images. Classification method involves checking largest cross sections and circular shape analysis. The method achieved the 50% detection performance.

Year 2014, Shah Syed Ayaz Ali [32], used local thresholding and edge detection technique to increase sensitivity of MA's. Pre-processed image is generated by applying shade correction technique. For extracting candidate MA's local thresholding of image by considering a small window is employed. Threshold depends upon the image features. Blood vessels detected by Gabor wavelet and removed for reduction of false detections. Then canny edge detector is used for detecting the edges of MA's depending upon the local maxima image gradient. For DIRETDB1 the algorithm achieved the sensitivity of 93.65%

Year 2015, Ruchir Srivastava [33], used frangi based filters for robust detection of red lesions MA's and haemorrhages from retinal images. The image is divided in small NxN blocks and each block is pre-processed by contrast enhancement on inverted green channel. Every sub image given to filters for detection of lesion. Eigen values are used for detection of lesion from a sub image. An SVM classifier is trained to classify true lesions.

Year 2016, Lama Seoud [34] contributed in finding a set of dynamic shape features. The method ranks fourth in ROC online competition with score 0.420. The method has six working stages. In first stage in order to compensate for different image resolutions, a spatial calibration step is added. The diameter of ROI of a fundus image is considered invariant and is used for setting kernel size of filters used in proposed method. The Pre-processing is carried out in four stages namely illumination normalization, noise removal, adaptive contrast equalization, color normalization. After that, the optic disk masking is employed. The lesion candidates are extracted by finding regional minima from an image by taking into account the contrast values. Candidates are selected based on the suitable threshold. Six shape features and four intensity based features is computed for each candidate. Random Forest classifier is used for classification. For DR/non-DR classification, the algorithm achieves the AUC of 0.899 on Messidore database.

For MA detection, we are proposing a simple approach based on mathematical morphological operators. The pre-processing color retinal image is proposed in two steps. First step is the noise removal by basic filtering and second step is shade correction for enhancing contrast. In our approach we are using morphological extended minima transforms for lesion detection. The method employs noise removal using median filters. The proposed approach is used to distinguish between normal and abnormal fundus images. The approach is useful for ophthalmologists as a basic screening tool for diseased and healthy patients.

IV. Conclusion

The paper briefly summarizes the efforts made by different authors in the field of microaneurysm detection and diabetic retinopathy. The content gives a general overview of the recent and early trend in development of computerized algorithms for Microaneurysms detection. Earlier only morphology was used for MA detection but as the time proceeded, other features of MA's also taken into account for accurate detection. Though ample of work is done in this field, there is still a room of improvement remained. The robustness of methods need to be increased. The paper presents a detailed analysis on recent methodologies employed for computer methodologies adapted for MA detection

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